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THE NASTRAN PROGRAMMER'S MANUAL

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PREFACE TO THE NASTRAN PROGRAMMER'S MANUAL

The Programmer's Manual is one of four manuals that constitute the documentation for NASTRAN, the other three being the Theoretical Manual, the User's Manual and the Demonstration Problem Manual. The Programmer's Manual is divided into seven major sections: Section 1, NASTRAN Programming Fundamentals; Section 2, Data Block and Table Descriptions; Section 3, Subroutine Descriptions; Section 4, Module Functional Descriptions; Section 5, NASTRAN - Operating System Interfaces; Section 6, Modifications and Additions to NASTRAN; and Section 7, NASTRAN Support Programs.

Section 1 is a general overview of the program, and as such it should be read as background material for all sections which follow.

Section 2 contains descriptions of the data blocks, which are the principal means of data communication between the program's functional modules (a module is defined to be a group of subroutines which perform a specific function) and the NASTRAN Executive System. Two indexes for the data block descriptions, one sorted alphabetically on data block names and the other sorted alphabetically on the names of the modules from which the data blocks are output, are given in Sections 2.2.1 and 2.2.2 respectively. Section 2 also contains a) descriptions of tables, both core and noncore resident, maintained by the NASTRAN Executive System and b) descriptions of miscellaneous tables which are accessed by a class of modules. Alphabetical indexes for these tables are given at the beginning of Sections 2.4 and 2.5 respectively.

Sections 3 and 4 contain descriptions of the (utility or general purpose) subroutines and modules of NASTRAN respectively. The reader is directed to the alphabetical indexes, sorted on entry point names, in Sections 3.2 and 4.1.3 respectively for these sections. An index to the Module Functional Descriptions, sorted alphabetically on module names, is given in Section 4.1.2. The reader is urged to read the introductory material to Sections 3 and 4 before using these sections.

Section 5 treats computer and operating system dependent matters such as operating system control cards and generation of the absolute (executable) NASTRAN system.

Section 6 describes the means by which modifications and additions to NASTRAN are implemented.

Section 7 describes several auxiliary programs used to maintain or interface with NASTRAN.

The learning of any new system, whether it be an operating system or a large applications system like NASTRAN, is made more difficult than it ought to be because of the use by the designers of the system of new mnemonics, acronyms, phrases and "buzz" words. In order to aid the reader in

learning such commonly used NASTRAN terms, a single source reference, Section 7, the NASTRAN Dictionary, of the User's Manual is provided. The programmer is adivsed to secure a copy of at least this section of the User's Manual for his day-to-day reference.

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1.1 PROGRAM OVERVIEW

1.1.1 Objectives

The NASTRAN program has been designed according to two classes of criteria. The first class relates to functional requirements for the solution of an extremely wide range of large and complex problems in structural analysis with high accuracy and computational efficiency. These criteria are achieved by developing and incorporating the most advanced mathematical models and computational algorithms that have been proven in practice. In particular, they are achieved by providing such features as the bandwidth-with-active-column technique in matrix decomposition; packing routines to take maximum advantage of matrix sparsity so as to conserve input/output time; highly stable and efficient algorithms for the solution of problems in eigenvalue analysis and transient response; and an elegant approach to modeling the effects of control systems and other nonstructural components.

The second class of criteria relates to the operational and organizational aspects of the program. These aspects are somewhat divorced from structural analysis itself; yet they are of equal importance in determining the usefulness and quality of the program. Chief among these criteria are:

1. Simplicity of problem input deck preparation.
2. Minimization of chances for human error in problem preparation.
3. Minimization of need for manual intervention during program execution.
4. Ease of program modification and extension to new functional capability.
5. Ease of program extension to new computer configurations and operating systems, and generality in ability to operate efficiently under a wide set of configuration capabilities.
6. Capability for step by step problem solution, without penalty of repeated problem set up.
7. Capability for problem restart following unplanned interruptions or problem preparation error.
8. Minimization of system overhead, in the three vital areas:
    a. Diversion of core storage from functional use in problem solution.

b. Diversion of auxiliary storage units from functional to system usage.

c. System housekeeping time for performing executive functions that do not directly further problem solution.

These criteria are achieved in NASTRAN through modular separation of functional capabilities, organized under an efficient, problem-independent Executive System.

This approach is absolutely essential for any complex multi-operation, multi-file application program such as NASTRAN. To see this, one must examine the implications of modularity in program organization.

Any application computer program provides a selection of computational sequences. These are controlled by the user through externally provided options and parameter values. Since no user will wish to observe the result of each calculation, these options also provide for the selection of the data to be output.

In addition to externally set options, internal switches whose setting depend upon tests performed during the calculations will control the computation sequences. There is, therefore, a natural separation of computations into functional blocks. The principal blocks are called functional modules; modules themselves of course may, and usually must, be further organized on a sub-modular basis.

Despite this separation, however, it is clear that modules cannot be completely independent, since they are all directed toward solution of the same general problem. In particular, they must intercommunicate data among themselves. The principal problem in organizing any application program, large or small, is designing the data interfaces between modules.

For small programs, the standard techniques are to communicate data via subroutine calling sequences and common data regions in core. For programs that handle larger amounts of data, auxiliary storage is used; however, strict specifications of the devices used and of the data record formats are usually imposed.

The penalty paid is that of "side effects". A change in a minor subroutine initiates a modification of the data interfaces that propagates through the entire program. When the program is small, these effects may not be serious. For a complex program like NASTRAN, however, they would be disastrous.

This problem has been solved in NASTRAN by a separation of system functions, performed by an Executive System, from problem solution functions, accomplished by modules separated strictly along functional lines. Each module is independent of all other modules in the sense that modification of a module, or addition of a new module, will not in general require modification of other modules. Even so, programming constraints on module development do exist but are minor. The essential restrictions are:

1. Modules may interface with other modules only through auxiliary storage files, as opposed to passing information between each other while in core.

2. Since the availability and allocation of auxiliary files for module execution interact with the execution of other modules, no module can specify or allocate files for its input or output data. All auxiliary storage allocation is reserved as an Executive function.

3. Modules operate as independent subprograms, and may not call, or be called by, other modules. They may be entered only from the Executive System.

4. Modules may interface with the Executive System through a parameter table that is maintained by the Executive System. User-specified options and parameters are communicated to modules in this way. The major line of communication is one-way, from user to Executive routine to module. However, in addition, an appreciable two way communication, from module back to executive routine (and therefore to other modules) is permitted via the parameter table.

5. Intra-module parameter communication is format-free in the sense that each module defines and orders its own local parameter set internally. Thus each module is independent of common data formatting by any other module.

No other constraints, except those imposed by the resident compilers and operating systems, are required for functional modules.

1.1.2 Program Organization

Because of the very large size of the NASTRAN program (more than 750 decks and 300 individual overlay segments), execution as one physical program was not possible. However, to meet the stated design objectives, it was required that NASTRAN appear to the resident operating system as one program.

A program structure evolved which is basically computer independent, although the way in which the code structure is supported varies across the computers.

The NASTRAN program is divided into a series of logical pieces called links. Each link contains its own root segment (the set of subprograms which is always core resident for that link) and its own complete overlay structure. Each link is capable of performing a predefined subset of NASTRAN operations. Communication between links occurs through computer files. Control of the sequence of execution of the links is performed entirely by the NASTRAN program and requires no operator intervention. As a result of this approach, a NASTRAN program execution appears to the resident operating system as a normal batch job to be processed in the batch stream. Detailed descriptions of the way in which the link structure is implemented on each computer are given in section 5.

1.2 NASTRAN EXECUTIVE SYSTEM

1.2.1 Introduction

The essential functions of the Executive System are:

1. Establish and control the sequence of module executions according to options specified by the user.

2. Establish, protect, and communicate values of parameters for each module.

3. Allocate system files to all data blocks (a data block designates a set of data, matrix or table, occupying a file) generated during program execution. A file is "allocated" to a data block, and a data block is "assigned" to a file. The general data block I/Ø routine (GINØ) and the data card conversion routines (XRCARD and RCARD) are considered Input/Output utilities and are discussed separately in section 1.6.

4. Maintain a full restart capability for restoring a program execution after either a scheduled or unscheduled interruption.

The Executive System is open-ended in the sense that it can accommodate an essentially unlimited number of functional modules, files, and parameters. Modification of the Executive System necessary for change, addition, or extension of functional modules is restricted to changes in entries in control tables stored within the Executive routines.

Program execution is divided into two phases: 1) the Preface, in which modules XCSA, IFP1, XSØRT, IFP and XGPI are executed to: a) process the NASTRAN input data deck and b) perform general problem initialization; and 2) the program body itself, in which the sequence of program operations is controlled by the Operation Sequence Control Array (ØSCAR) Executive table, which was developed in the XGPI module of the Preface. A diagram of a sample NASTRAN input data deck is shown in Figure 1. Note that a NASTRAN input data deck consists of 3 separate decks: 1) the Executive Control Deck, 2) the Case Control Deck and 3) the Bulk Data Deck. A detailed description of the contents of the NASTRAN data deck is given in section 2 of the User's Manual. The flow of operations during the Preface is presented in Figure 2. The numbers in the blocks in Figure 2 refer to section numbers where more detailed explanations of the subroutines and modules can be found.

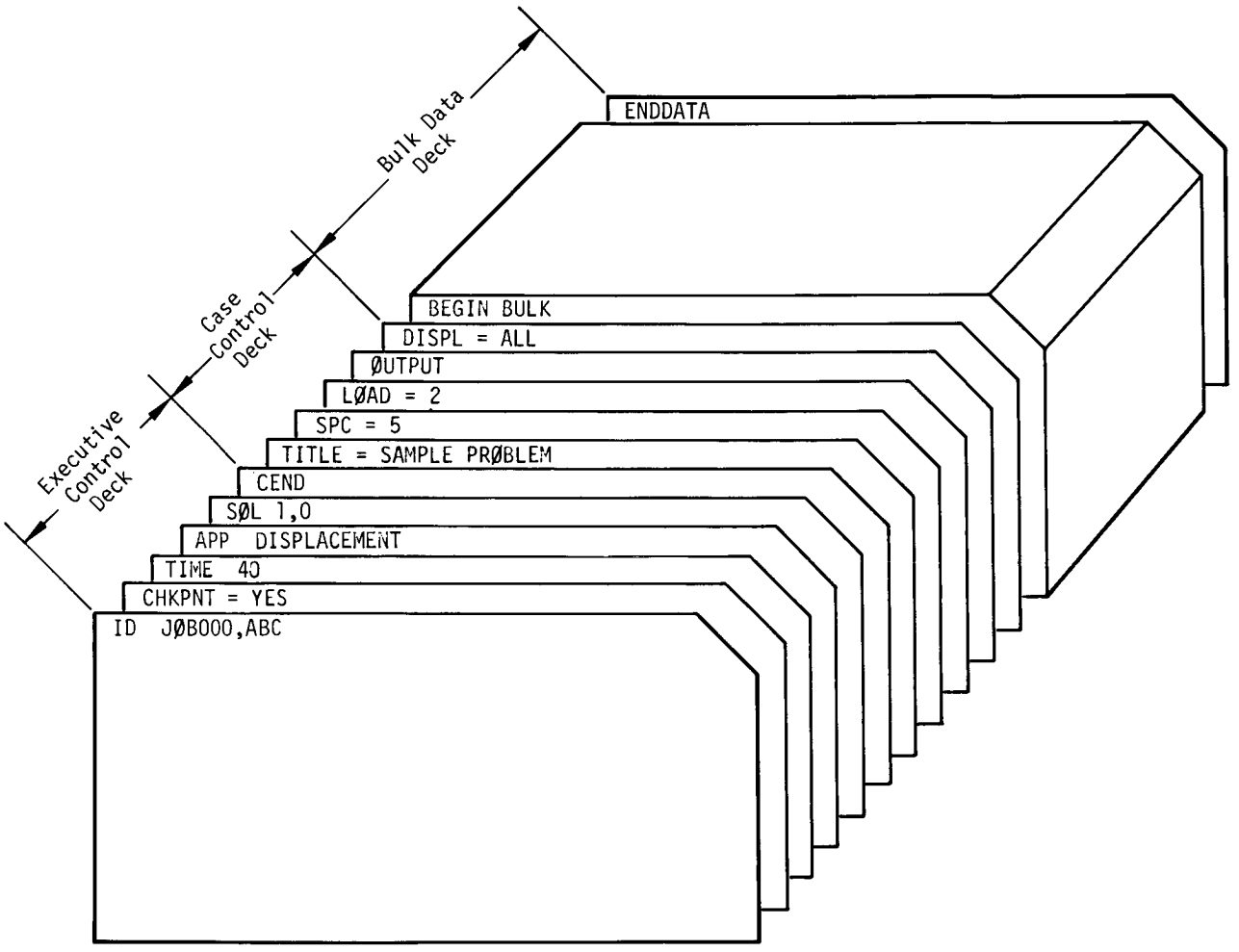


Figure 1. Sample NASTRAN input data deck.

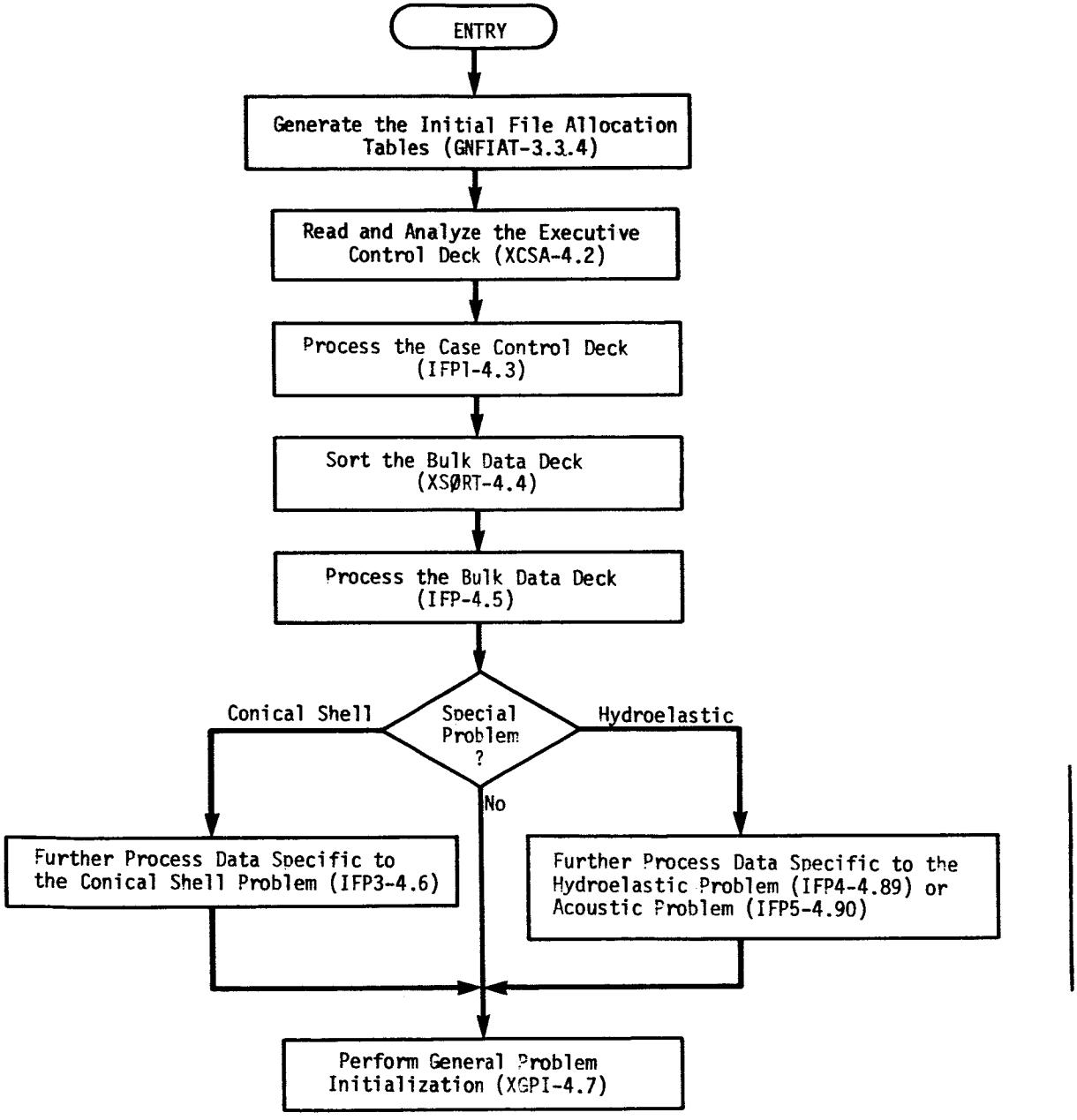


Figure 2. Flow of operations during the Perface.

1.2.2 Executive Operations During the Preface

The sequence of Preface operations shown in Figure 2 is controlled by the Sequence Monitor Initialization subroutine, SEMINT (see section 3.3.3). Each routine called by SEMINT is discussed in the following sections. The numbers in the section headings refer to section numbers where more detailed information on the subroutine or module can be found.

1.2.2.1 Generation of the Initial File Allocation Tables (GNFIAT section 3.3.4)

Two file allocation tables are maintained by the NASTRAN Executive System. One table, FIAT, (see section 2.4) defines the files to which data blocks generated during solution of the problem will be allocated. The second table, XFIAT, (see section 2.4) includes files to which permanent Executive data blocks, such as the New Problem Tape, the Old Problem Tape, plot tapes, and the User's Master File are assigned.

The New Problem Tape will contain those data blocks generated during the solution that are necessary for restarting the problem at any point. The Old Problem Tape contains the data blocks saved from some previous execution that may serve to bypass steps in the solution of the new problem. The User's Master File is a permanent collection of useful information, such as material properties, that may be used to generate input data.

The generation of the XFIAT and FIAT tables is a computer dependent operation since direct interface with the operating system of the computer must be made. The GNFIAT routine, which accomplishes this function, interrogates file tables in the nucleus of the operating system. Files which are available for use by the NASTRAN program are reserved, and the unit numbers for these files are stored in the NASTRAN file allocation tables. An indication of which units are physical tapes is also stored. If the number of files available is insufficient to run the problem, an error message is generated, and the run is aborted.

1.2.2.2 Analysis of the Executive Control Deck (XCSA Section 4.2)

The Executive Control Deck is processed and analyzed by the XCSA Executive Preface module. The Executive Control Deck includes cards which describe the nature and type of solution to be performed. This includes an identification of the problem, an estimated time for solution of the problem, the approach, a selection of the Rigid Format to be executed or an alternative sequence of NASTRAN operations (DMAP) to control the solution, a restart deck from a previous run if the

solution is to be restarted, an indication of any diagnostic printout to be made, a specification of whether the problem is to be checkpointed or not, and, if a Rigid Format is selected, any desired alterations to that format. Section 2 of the User's Manual should be consulted for the formats of, and restrictions on, each of the cards in the Executive Control Deck. The approach (APP) card, and the solution (SØL) card, which selects a particular solution (Rigid Format) to be executed, are worthy of special note. However, first some introductory definitions are required.

The sequence of operations to be executed during the program body is written in a data block oriented language called DMAP, an acronym for "Direct Matrix Abstraction Program". A DMAP instruction is a statement in the DMAP language, a DMAP sequence is a set of DMAP instructions, and a DMAP loop is a DMAP sequence to be repeated. A DMAP module is one which is "called" by means of a DMAP instruction.

A Rigid Format consists of: a) a fixed pre-stored DMAP sequence and b) its associated restart tables. A Rigid Format performs a specific (structural) problem solution. Section 3 of the User's Manual presents the DMAP sequence and the associated restart tables for each Rigid Format.

The APP card of the Executive Control Deck defines the problem solution approach. The APP card is required, and there are two options on the APP card: DISPLACEMENT or DMAP. The SØL card has the form

SØL n,m

where n = Rigid Format number, and m = a subset of the Rigid Format. The SØL card is required if the DISPLACEMENT option is chosen on the APP card. The SØL card must not be present in the deck if the DMAP option is chosen.

In addition to using the Rigid Formats provided automatically by NASTRAN, the user may wish either to execute a series of modules in a manner different from that provided by the Rigid Format, or to perform a series of matrix operations which are not contained in any existing Rigid Format. If the modifications to an existing Rigid Format are minor, the ALTER feature described in Section 2 of the User's Manual may be employed. Otherwise, a user-written Direct Matrix Abstraction Program (DMAP) should be used, in which case the card

APP DMAP

must be used. Chapter 5 of the User's Manual discusses DMAP.

Each of the cards comprising the Executive Control Deck is read via XRCARD (3.4.19) and analyzed. Depending on the card, information is either stored in various Executive tables maintained in core storage or written in the Executive Control Table (2.4.2.5) on the New Problem Tape for further processing during the general problem initialization phase (XGPI-4.7) of the Preface. Figure 3 presents the format of the Problem Tape. The formats of the New and the Old Problem Tapes are identical; only chronology defines their separate functions.

1.2.2.3 Processing of the Case Control Deck (IFP1 Section 4.3)

The Case Control Deck includes the following classes of cards: selection of specific sets of data from the Bulk Data Deck, selection of printed or punched output, definition of subcases, definition of structural plots to be made, and definition of XY plots to be made. Section 2 of the User's Manual discusses in detail all cards of the Case Control Deck.

This deck is read via XRCARD (3.4.19) and processed. Information defining set selection, output selection and subcase definition is written into the Case Control data block, CASECC. Information defining plot requests is written in the Plot Control (PCDB) and XY Control (XYCDB) data blocks.

If the problem is a restart, a comparison with the Case Control Deck from the previous run is made. Differences are noted in an Executive restart table, which is used in the general problem initialization phase (XGPI-4.7) of the Preface.

1.2.2.4 Sorting of the Bulk Data Deck (XSØRT Section 4.4)

The function of the XSØRT routine is to prepare a file on the New Problem Tape (see section 1.2.2.1) which contains the sorted Bulk Data Deck (bulk data). Operation of the routine is influenced by the type of run. If the run is a cold start, the bulk data is read from the system input file (e.g. card reader) or the User's Master File, sorted, and written on the New Problem Tape. If the run is an unmodified restart, (restarts are discussed in section 1.10), the bulk data is copied from the Old Problem Tape (see section 1.2.2.1) to the New Problem Tape. If the run is a modified restart, the bulk data is read from the Old Problem Tape, and cards are deleted and/or added in accordance with cards in the system input stream. The modified bulk data is sorted and written on the New Problem Tape. Additionally, any changes in the data are noted in the Executive restart table.

A printed list of the unsorted bulk data is given if requested by an ECHØ card in the Case Control Deck. Similarly, the sorted bulk data is echoed on request.

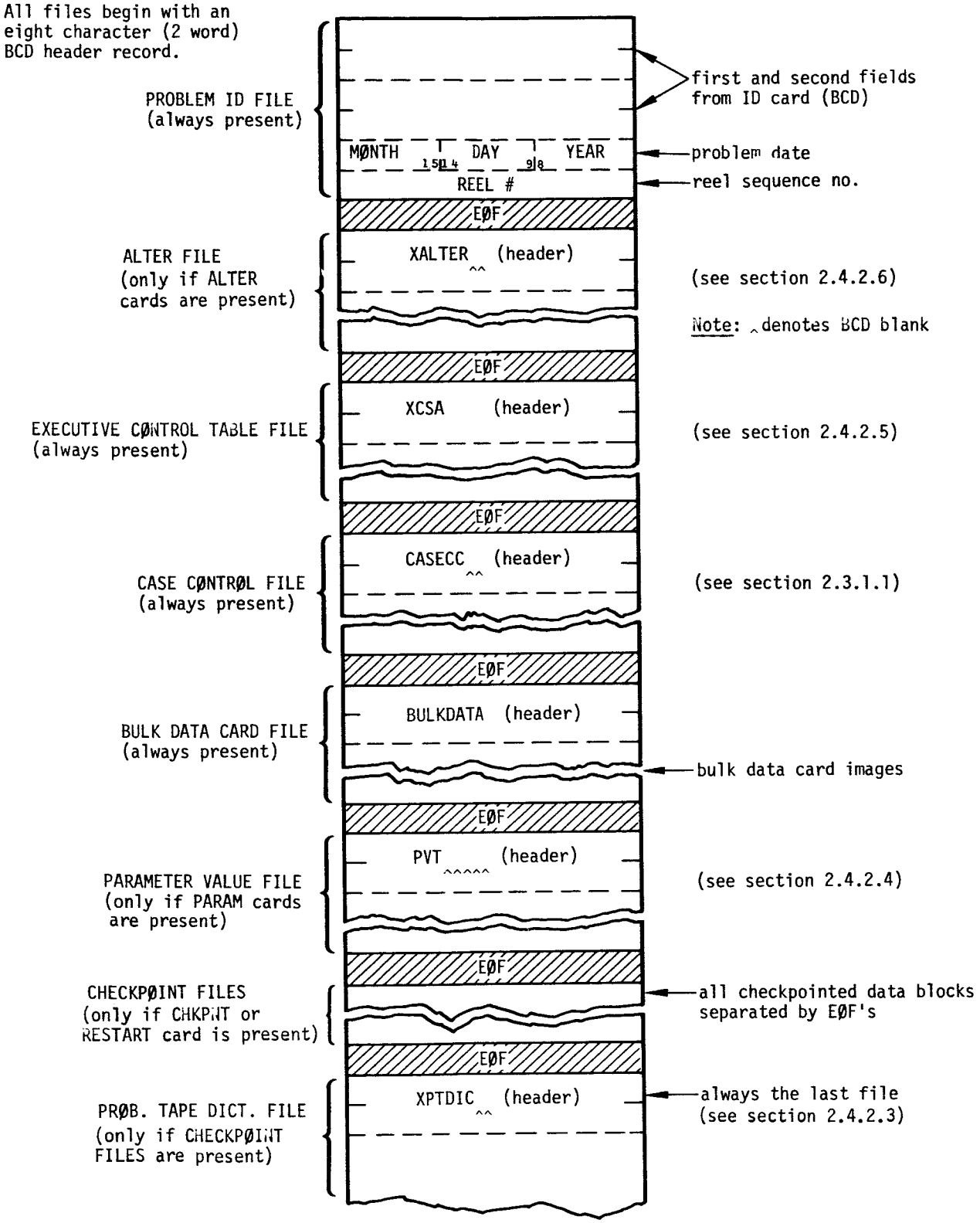


Figure 3. Problem tape format (same format for New Problem Tape and Old Problem Tape).

Since the collating sequence of alphanumeric characters varies from computer to computer, the sort routine converts all characters to an internal code prior to sorting. Following the sort, the characters are reconverted. In this way, the collating sequence is computer independent.

The algorithm used by the sort routine is biased toward the case where the data in sort or nearly in sort. Consequently, Bulk Data Decks which are nearly in sort will be processed efficiently by the routine.

1.2.2.5 Processing of the Bulk Data Deck (IFP Section 4.5)

The sorted Bulk Data Deck is read card-by-card from the New Problem Tape by the Input File Processor (IFP) and converted to internal binary form by RCARD (3.4.20). Each of the cards is checked for correctness of format. If any data errors are detected, a message is written, and a switch is set to terminate the run at the conclusion of the Preface. Section 2 of the User's Manual presents a detailed description of all cards of the Bulk Data Deck.

Processing of each bulk data card depends on the type of card. All bulk data cards of the same type are written into the logical record to which the card type has been assigned. These records are organized into data blocks classified according to general categories of use and written on prescribed preallocated files.

1.2.2.6 Processing of Conical Shell Data (IFP3 Section 4.6)

If the problem is a conical shell problem, further processing of the bulk data specific to the conical shell problem is accomplished. The nature of this processing is to convert data for the conical shell model into formats of a conventional statics problem. The result is that the conical shell problem can be described in a format convenient to the analyst and processed by NASTRAN in a format convenient to the program.

1.2.2.7 Processing of Hydroelastic Data (IFP4 Section 4.89)

If hydroelastic analysis data exists, this data must be converted to the data block formats and merged with existing data output from IFP. This module creates grid point, scalar point, element connection, and constraint data as well as producing a section in the MATPØØL data block.

1.2.2.8 Processing of Acoustic Data (IFP5 Section 4.91)

If acoustic analysis data exists, the IFP5 module generates and merges grid points, scalar elements, and plotting elements with the existing data blocks.

1.2.2.9 General Problem Initialization (XGPI Section 4.7)

The Executive General Problem Initialization (XGPI) module is the heart of the Preface. Its principal function is to generate the Operation Sequence Control Array (ØSCAR-2.4.2.1), which defines the problem solution sequence. The ØSCAR consists of a sequence of entries, with each entry containing all of the information needed to execute one step of the problem solution. The ØSCAR is generated from information supplied by the user through his entries in the Executive Control Deck. This information is supplied by the SØL card, which points to a Rigid Format, or by a user supplied DMAP sequence.

The initial sequence of instructions was written in the Executive Control Table (2.4.2.5) on the New Problem Tape by the XCSA Preface module. This table is read to initiate assembly of the ØSCAR.

If the problem is a restart, the restart dictionary (contained in the Executive Control Table) and the Executive restart table are analyzed to determine which data blocks are needed to restart the solution and which operations in the ØSCAR need to be executed to complete the solution. Entries in the ØSCAR for operations not required for the current solution are flagged for no operation.

To aid in efficient assignment of data blocks to files, two attributes are computed and included with each data block in each entry of the ØSCAR. These attributes are: a) the ØSCAR sequence number when the data block is next used (NTU) and b) the ØSCAR sequence number when the data block is last used (LTU). Details of the file allocation are discussed in section 1.2.3.3.

When generation of the ØSCAR is complete, it is written on the Data Pool File (PØØL). If the problem is restart, data blocks needed for the current solution are copied from the Old Problem Tape to the Data Pool File.

1.2.3 Executive Operations During Problem Solution

1.2.3.1 Sequence Monitor (XSEMi Section 3.3.7)

When the Preface has been completed, solution of the problem is initiated. This solution is controlled by the sequence monitor. Figure 4 shows the flow for the sequence monitor. Note that there are i copies of XSEMi within NASTRAN, one controlling each link's operation. Section 1.1.2 defined the necessity for these divisions.

The sequence monitor reads an entry from the ØSCAR (2.4.2.1) which defines one step in the problem solution in terms of: the operation to be performed, data blocks required for input, data blocks to be output, scratch files required and parameters used. The File Status Table (FIST-2.4.1.3), which relates the internal data block reference numbers (see Section 1.6.4) to the file position in the File Allocation Table (FIAT-2.4.1.2), is created by the FIST generator, subroutine GNFIST. When the status table is complete, XSEMi moves the parameters required for the operation into blank common and calls the requested module (if within the current link) to begin the operation. If the requested module is not within the current link, ENDSYS (see Section 3.3.5) is called and the Sequence Monitor within the new link is executed.

With the exception of XSFA, the seven routines described in the following subsections are Executive modules called directly by XSEMi to perform their specified functions.

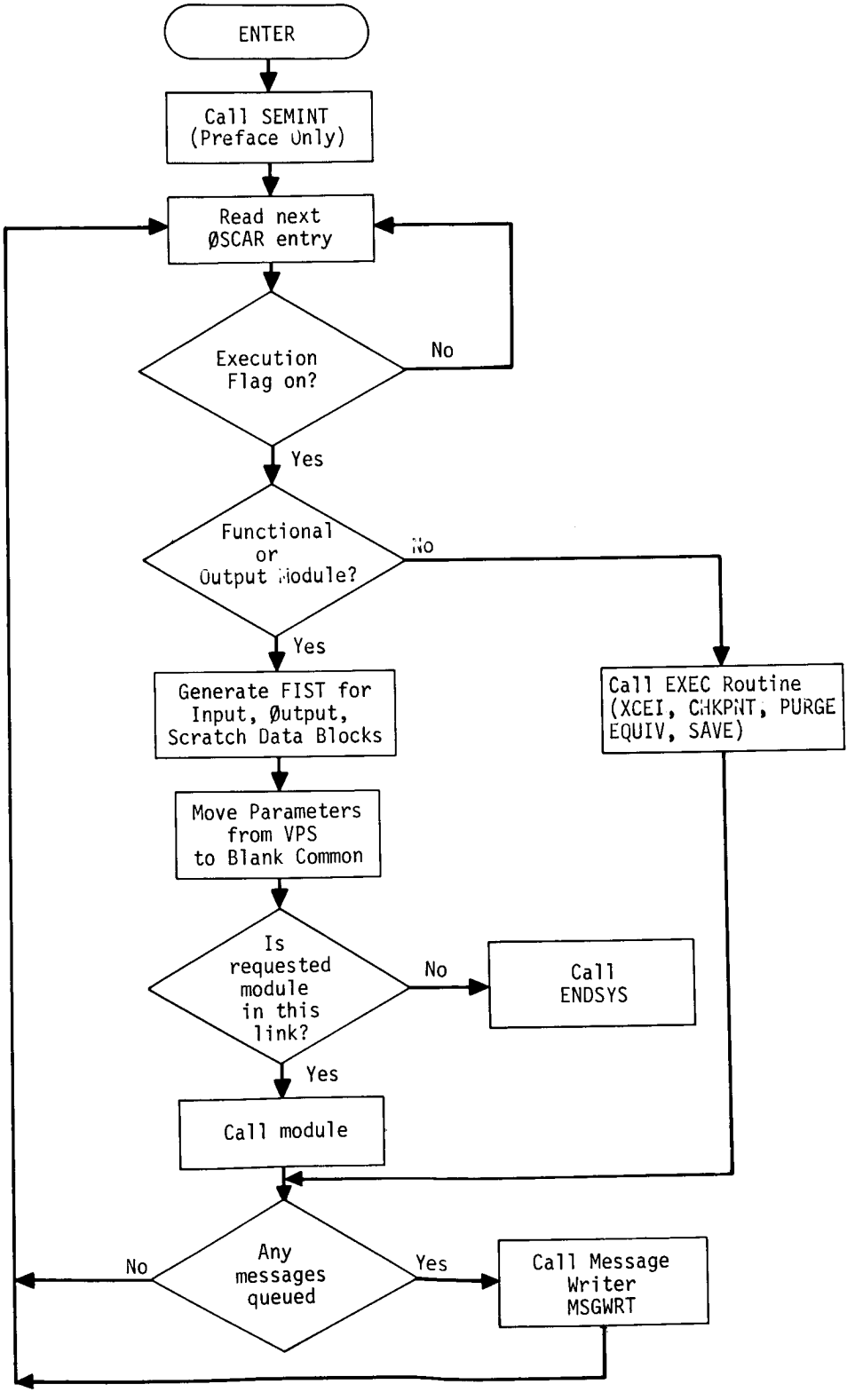


Figure 4. Flow diagram for the sequence monitor, XSEMi.

1.2.3.2 FIST Generator (GNFIST Section 3.3.9)

The FIST generator, subroutine GNFIST, creates the File Status Table (FIST), which contains the linkage between the internal data block reference numbers and the actual system files listed in the File Allocation Table (FIAT). Each input, output and scratch data block required by the forthcoming module is assigned an internal reference number if found to be active in FIAT. A data block found to be inactive, that is purged or not generated, will not be assigned a reference number. This missing reference number will cause the accessing module to be signaled regarding the inactive status. If, during the generation of the FIST, a data block is not found in the FIAT, active or inactive, the Executive Segment File Allocator (XSFA) module is called by GNFIST to make a file available to the subject data block.

1.2.3.3 Segment File Allocator (XSFA Section 4.9)

The Executive Segment File Allocator (XSFA) module, which is called exclusively by GNFIST, is the administrative manager of data blocks for NASTRAN. Since, in general, the number of data blocks required for solution of a problem far exceeds the number of files available, assignment of data blocks to files is a critical operation for efficient execution of NASTRAN.

The Executive Segment File Allocator module is called whenever a data block is required for execution of an operation but is not currently assigned to a file (i.e., does not appear in the FIAT). When the Segment File Allocator is called, it attempts to allocate not just for the data block initiating the call, but for as much of the remaining problem solution as possible. This allocation depends on the type of problem, the number of files available, and the range of use of the remaining data blocks.

The Segment File Allocator reads entries from the ØSCAR from the point of current operation to the end of the problem solution. The FIAT table entries are created in which attributes of the data blocks, including their next use (NTU) and last use (LTU), are stored. Data blocks which are currently assigned to files but are no longer required for problem solution are released. In certain cases, when the range of use of a data block is large, it may not be possible to allocate a file to the data block throughout its range of use. In this case, pooling of the data block is required so that the file to which the data block was assigned may be freed for another allocation. The next time used (NTU) attribute for a data block is used to efficiently pool data blocks. In general, the data block whose next use is the furthest from the current point is pooled, that is, copied onto the Data Pool File (PØØL). The format of the Data Pool File is shown in Figure 5.

One additional check is made with regard to pooling. The operation of the Segment File Allocator itself is less expensive than a pooling operation. Therefore, pooling occurs only when the module for which the allocation was required cannot be allocated without pooling.

When the Segment File Allocator is complete, a new File Allocation Table (FIAT) has been generated. This table is used until the solution again reaches a point where a data block is required to execute an operation but is not assigned to a file.

1.2.3.4 Interpretation of Executive Control Entries (XCEI Sections 4.11, 4.12, 4.13, 4.14)

Executive control entries include the DMAP instructions: REPT, JUMP, CØND and EXIT. Executive control entries in the ØSCAR are processed by the Executive Control Entry Interpretor (XCEI). When such an entry is encountered in the ØSCAR, the Control Entry Interpretor is called by XSEMi. If the operation is a jump, conditional jump or repeat, the ØSCAR is repositioned accordingly. If the operation is an exit, the NASTRAN termination routine PEXIT (3.4.22) is called.

1.2.3.5 Checkpointing Data Blocks (CHKPNT Section 4.10)

The checkpoint module (DMAP name: CHKPNT; entry point name: XCHK) copies specified data blocks required for problem restart onto the New Problem Tape and makes appropriate entries in the restart dictionary. This dictionary is also punched onto cards as each new entry is made. Thus, in the event of any unscheduled problem interruption, a restart from the last checkpoint

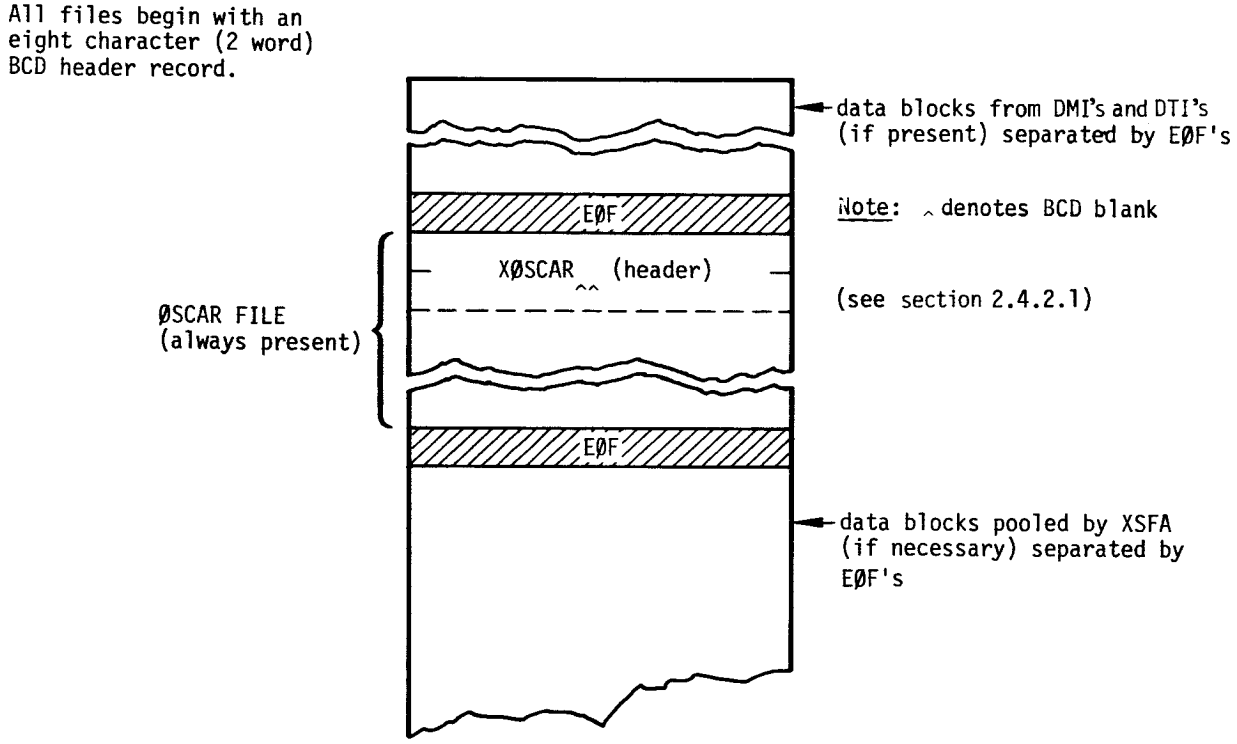


Figure 5. Format of the Data Pool File.

can be made using the Problem Tape and the restart dictionary from the interrupted run.

1.2.3.6 Purging a Data Block (PURGE Section 4.16)

The purge routine (DMAP name: PURGE; entry point name: XPURGE) flags data blocks so that they will not be assigned to physical files. This special status provides a means for logically suppressing a segment of processing steps requiring the data block. Thus, if the function of a module is to multiply two matrices and add a third matrix to the product, the addition step might be deleted by purging the data block corresponding to the third matrix.

1.2.3.7 Equivalencing Data Blocks (EQUIV Section 4.17)

The equivalence routine (DMAP name: EQUIV; entry point name: XEQUIV) attaches one or more equivalent data block names to an existing data block. This special status provides a means of logically removing a module function by making a data block input to the module equivalent to a data block output from the module. Thus an entire module could be skipped, and an input data block "copied" to an output data block without physically moving the data from one file to another.

1.2.3.8 Saving Parameters (SAVE Section 4.15)

The save routine (DMAP name: SAVE; entry point name: XSAVE) provides a protection feature for the parameters communicated between, and used by, the functional modules. All variable parameters are stored within the VPS Executive table (see section 2.4). Prior to each module's operation, the subset of parameters required by the module is moved to blank common. The module may use or modify this subset of parameters as desired. When the module terminates operation, only those parameters within the subset designated to be saved are restored to the Executive table.

1.3 WORD SIZE AND COMPUTER HARDWARE CONSIDERATIONS

1.3.1 Introduction

Although NASTRAN is a FØRTRAN oriented system, considerable effort was required to develop programming and word handling techniques applicable to four separate computer configurations. These computers exhibit wide differences in their binary word sizes and integer representation method. The current computer configurations considered and their significant differences follow:

1. Computer - IBM 7094/7040 DCS

Word Size - 36 Bits

Character Capacity - 6 bits/character and 6 characters/word

Integer Representation - Sign and Magnitude

2. Computer - IBM System/360 series

Word Size - 32 Bits

Character Capacity - 8 bits/character and 4 characters/word (character ≡ byte)

Integer Representation - Twos complement for negative integers

3. Computer - UNIVAC 1108

Word Size - 36 Bits

Character Capacity - 6 bits/character and 6 characters/word

Integer Representation - Ones complement for negative integers

4. Computer - CDC 6600

Word Size - 60 Bits

Character Capacity - 6 bits/character and 10 characters/word.

Integer Representation - Ones complement for negative integers

Various Executive routines (e.g., XSØRT (4.4), XRCARD (3.4.19)) that deal directly with character strings from the input stream require some method of obtaining the above computer dependent information. Within the NASTRAN Preface, subroutine BTSTRP (3.3.2) solves an algorithm that determines which of the four computers is currently operating. This algorithm functions by inspecting the word length (by means of shifting and testing) and by checking the negative integer representation method. As a result of these tests, a word (MACH) within the SYSTEM Executive table (see section 2.4) is set to indicate the computer type. Since data within BTSTRP defines the number of bits-per-word (NBPW), the number of characters-per-word (NCPW), and the number of

bits-per-character (NBPC) for each computer type, the correct values for these parameters are also stored into the SYSTEM table. This table resides within the NASTRAN root segment and is thus accessable to any module or subroutine.

1.3.2 Alphanumeric Data

Data stored within a computer as binary-coded-decimal (BCD) characters must be represented by the proper hardware defined bit codes. These character codes (and in the case of the IBM System/360, the number of bits representing the code) vary among the NASTRAN computer types. Although the number of characters-per-word could have been obtained from the SYSTEM table, various data blocks and buffers within NASTRAN required firm entry sizes, regardless of computer type, to facilitate indexing. For these reasons, the minimum number of characters-per-word (4) among the four computer types was chosen as a program design standard. Computer types with a word capacity of greater than four characters will have the unused low order character positions filled with BCD blanks.

1.3.3 Word Packing

Standard FØRTRAN compilers do not provide the capability for storing or retrieving data that occupies less than a full computer word. Through the Machine Word Functions (MAPFNS, 3.4.1) routine some limited word packing (not to be confused with matrix packing) is performed within the Executive System and a few utility subroutines. Packing provides an efficient use of memory space at the expense of the additional operating time needed to combine or separate the elements of the packed words. The Machine Word Function ØRF is generally used for combining elements, while ANDF with a suitable mask is used for separating them.

1.3.3.1 Examples of Machine Word Functions (MAPFNS) Usage

Assume three 10-bit items of data occupy the low order 10 bits of three separate 30-bit computer words (A, B, and C). To pack these three items into a single 30-bit word (X), perform the following steps using the individual functions available within MAPFNS:

a) Left shift (LSHIFT) word A, twenty bits

b) Left shift (LSHIFT) word B, ten bits

c) Logically add (ØRF) words A and B; store into X

d) Logically add (ØRF) words X and C; store into X.

Assume two 8-bit items of data are packed into the left and right halves of a 16-bit word (X). To unpack these two items into the low order 8 bits of two separate 16-bit words (A and B), perform the following steps using the individual functions available within MAPFNS:

a) Create MASK containing 8 low order bits equal to 1 and the 8 high order bits equal to 0

b) Right shift (RSHIFT) word X, eight bits; store into A

c) Logically multiply (ANDF) word X by MASK; store into B.

In the preceding example, the word X remains unchanged since the functions return the requested modified result in a computer register.

1.4 SYSTEM BLOCK DATA SUBPROGRAM (SEMDBD)

NASTRAN contains a master block data program (SEMDBD) which is responsible for defining and initializing (root segment) common blocks. The common blocks referenced in SEMDBD are either Executive common blocks (XFIAT, XXFIAT, XFIST, etc.) which require initial values, or general information common blocks (SYSTEM, NAMES, TYPE, etc.) which are referenced by many modules. The source listing for SEMDBD identifies the common blocks, and it documents the data which are initialized, via comments. In addition, the Executive common blocks are documented in section 2.4 and the non-Executive common blocks in section 2.5. Certain parameters in these common blocks contain machine dependent values such as word size, number of BCD characters per word, etc. These values are set by subroutine BTSTRP (section 3.3.2) by identifying the machine on which the NASTRAN program is currently operating and setting the values accordingly.

1.5 THE OPEN CORE CONCEPT

1.5.1 Introduction

The design philosophy of the NASTRAN system dictated a completely open ended design whenever possible. NASTRAN was to have the flexibility to operate on a second generation machine with a 32K core (the IBM 7094/7040 DCS) as well as the largest of the IBM S/360 series of computers, and take complete advantage of the additional core storage without major program changes. The use of a fixed dimension for large arrays was outlawed since this automatically restricted the size of a problem that could be solved. Instead, modules were to be programmed to allocate space as required and to use spill logic to transfer data to scratch files if complete core allocation was impossible. In this manner, a problem might cause spill logic to be used on a computer with limited core storage, but not on a computer with a larger core storage capacity.

1.5.2 Definition of Open Core

The definition of open core is: a contiguous block of working storage defined by a labeled common block whose length is a variable determined by the NASTRAN Executive function CØRSZ. The implementation of this definition by the module writer consists of the origining of a labeled common block at the end of his overlay segment. This labeled common block contains a dimensioned variable of length 1. CØRSZ returns the number of words of core available between his open core origin and the end of core. The module writer can now write his program as if he had dimensioned his array by that number. In actuality, he is extending beyond the area reserved for the array into an area reserved for the job but not currently used by the segment. When implementing this concept, care must be taken to assure that the system does not use this area.

1.5.3 Example of an Application of Open Core

Figure 1 demonstrates the use of open core by two subroutines, A and B. By some means, which are machine dependent and are discussed in section 5, an end point is established for open core. The length of open core is then the difference between this end point and the labeled common block. In the example shown, subroutine A will have more open core available to it than B does.

```
      SUBRØUTINE A
      CØMMØN // XX
      CØMMØN /AX/ Z(1)
      INTEGER CØRSZ
      NZ = CØRSZ(Z(1),XX)
      DØ 10 I = 1, NZ
   10 Z(I) = I
      RETURN
      END
```

```
      SUBRØUTINE B
      CØMMØN // XX
      CØMMØN /BX/ Z(1)
      INTEGER CØRSZ
      NZ = CØRSZ(Z(1),XX)
      DØ 10 I = 1,NZ
   10 Z(I) = I
      •
      •
      •
      RETURN
      END
```

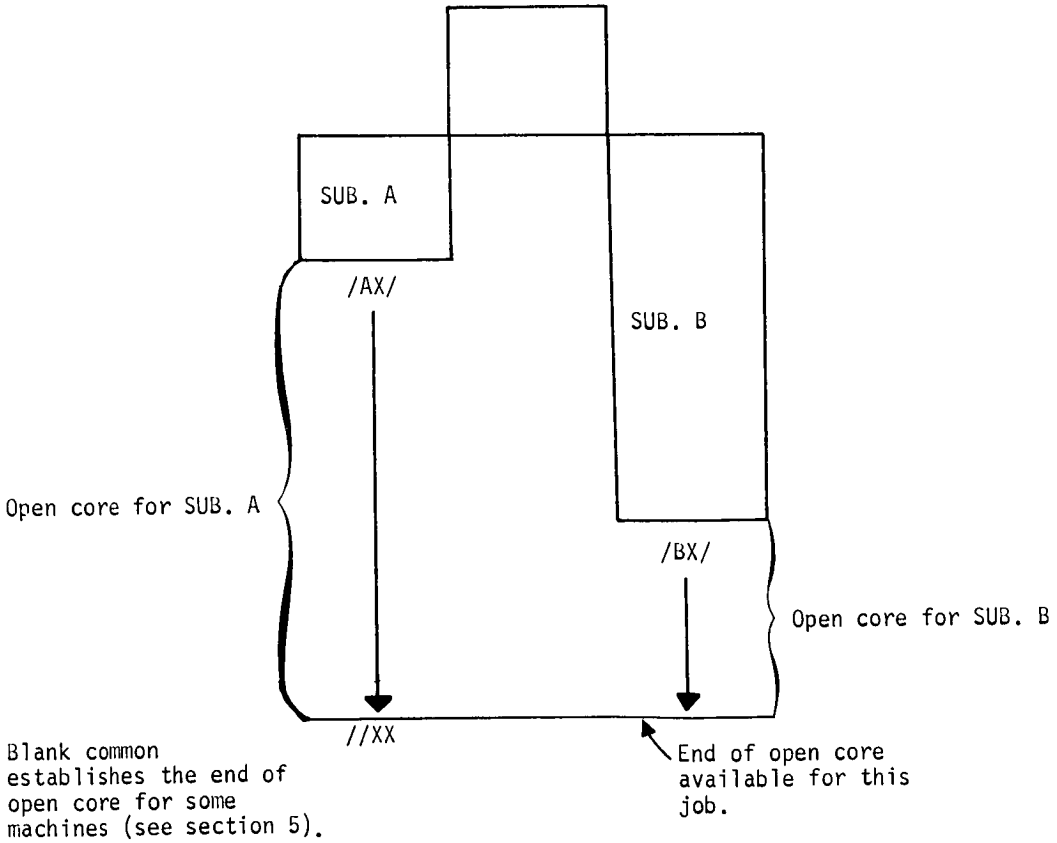


Figure 1. A example of the use of open core.

1.6 NASTRAN INPUT/OUTPUT

1.6.1 Introduction

The particular (IBM 7094, IBM S/360, Univac 1108, CDC 6600) operating system input and output files provide the required data connection between NASTRAN, the input data decks and the printed output. Utility subroutines XRCARD (section 3.4.19) and RCARD (section 3.4.20) convert special NASTRAN input card formats to standard FØRTRAN data words easily handled by all NASTRAN input processors. Printed output is generated through FØRTRAN formatted write statements. All internal data block input/output is handled by GINØ, the system of NASTRAN general purpose input/output routines. GINØ provides the required manipulation to tailor the variable length logical data records needed by most NASTRAN modules to fixed length records available on all direct access mass storage hardware.

1.6.2 Use of the Operating System Input File

The system input file is read only by the following routines within the NASTRAN Preface:

1. SEMINT (see section 3.3.3) reads the first card and processes it using utility XRCARD if it is the NASTRAN card (see section 6.3.1).

2. The Executive Control Deck containing free-field cards is read and processed by XCSA (section 4.2) using the XRCARD utility.

3. The Case Control Deck containing free-field cards is read and processed by IFP1 (section 4.3) using the XRCARD utility.

4. The Bulk Data Deck containing fixed-field cards is read by XSØRT (section 4.4). This data is subsequently processed by IFP (section 4.5) using the RCARD utility.

These card conversion utilities (XRCARD and RCARD) provide respectively all the free-field and fixed-field data card processing required by NASTRAN.

1.6.2.1 Use of the Subroutine XRCARD (See Section 3.4.19)

XRCARD interprets NASTRAN free-field data cards and processes the fields into a sequential buffer that can be easily handled by subsequent modules. Free-field data consist of series of data items separated by suitable delimiters and punched in non-specific card columns. Data items may include alphanumeric, integer, and various types of real variables. Field delimiters

may include the comma, slash, parenthesis, and blanks. For details regarding data and delimiter usage and the format of the sequential output buffer, see the XRCARD subroutine description in section 3.4.19.

1.6.2.2 Use of the Subroutine RCARD (See Section 3.4.20)

RCARD interprets NASTRAN fixed-field data cards and processes the fields into a sequential buffer that can be easily handled by subsequent modules. Fixed-field data consist of data items punched within specific card fields. Each eighty-column card is divided into an eight-column ID field (for the card mnemonic) followed by either eight eight-column data fields or four sixteen-column data fields. A special character (asterisk or plus) within the ID field determines when the card is to be interpreted as containing sixteen-column fields. The last eight columns of the card are for continuation mnemonics used by XSØRT and are not processed by RCARD. The data item within the ID field must be alphanumeric. The data items within all other fields may include alphanumeric, integer, and various types of real variables. For details regarding data and the format of the sequential output buffer, see the RCARD subroutine description in section 3.4.20.

1.6.3 Use of the Operating System Output File

Although NASTRAN printed output is formed and placed onto the system output file through use of standard FØRTRAN formatted write statements, two basic NASTRAN design concepts prohibit every operating module from generating printed output. Firstly, since the FØRTRAN I/Ø package for output generation occupies a sizable block of computer memory, this package is generally positioned by loader directives within specific output oriented segments, rather than within the root segment of the overlay, to reduce the total memory requirement. Secondly, because many functional modules generate the same or similar diagnostic and information messages, a NASTRAN message writer (MSGWRT) was developed to centralize message text and thus prevent duplications within many separate modules.

For the reasons previously discussed, NASTRAN output generation is restricted to a specific class of modules which can reside within an output oriented segment below the link root segment. These segments will contain the output producing modules such as the Output File Processor (ØFP- section 4.70), the Message Writer (MSGWRT - section 3.4.26), and the various table and matrix printers (TABPT - section 3.4.29, MATPRT - section 4.71, etc.) along with the output titling (PAGE - section 3.4.24) and necessary FØRTRAN I/Ø packages.

1.6.4 GINØ

GINØ is a collection of subroutines which provide for all input and output operations within NASTRAN except reading data from the resident system input file and writing data on the resident system output and punch files. These latter operations are accomplished through FØRTRAN formatted read/write statements. NASTRAN programs perform input/output operations by making the following calls to GINØ entry points:

1. ØPEN (see section 3.4.2)

   ØPEN initiates activity for a file (unless the data block assigned to the file is purged, in which case an alternate return is given). A working storage area (GINØ buffer), for use by GINØ, is assigned (allocated) by the calling program thus providing optimum allocation of storage by the calling program. This working storage area is reserved for use by GINØ until activity on the file is terminated by a call to CLØSE (see paragraph 4 below). On each of the NASTRAN computers, the working storage area allocated by the calling program is separate from the actual physical I/Ø buffer.

2. WRITE (see section 3.4.3)

   WRITE writes a specified (by the calling program) number of words on a file. The block of words to be written may comprise an entire logical record or portion of a logical record.

3. READ (see section 3.4.5)

   READ returns to the calling program a specified (by the calling program) number of words from the logical record at which the file is currently positioned. READ may be used to transmit an entire logical record or portion of a logical record.

4. CLØSE (see section 3.4.4)

   CLØSE terminates activity for a file. The working storage area assigned at ØPEN is released. The file is repositioned to the load point if requested.

5. REWIND (see section 3.4.8)

   REWIND repositions the requested file tc the load point. The file must be "open", i.e. a REWIND operation is requested subsequent to a call to ØPEN and prior to a call to CLØSE.

6. FWDREC (see section 3.4.6)

   FWDREC repositions the requested file one logical record forward.

7. BCKREC (see section 3.4.7)

BCKREC repositions the requested file one logical record backwards.

8. SKPFIL (see section 3.4.10)

SKPFIL repositions the requested file forward or backward N logical files where N is specified by the calling program.

9. EØF (see section 3.4.9)

EØF writes a logical end-of-file on the requested file.

The basic unit of I/Ø in NASTRAN is a logical record. The length of a logical record is completely variable and may range from one word to an arbitrarily large number of words. For NASTRAN matrix data blocks, the convention was adopted that each column of the matrix would comprise one logical record. For NASTRAN data blocks containing tables, no rigid convention exists. Typically each logical record contains one table of a specific type.

The logical record concept provides greatest ease in programming. However, since these records must be stored on a physical device such as a drum, disk or tape, the characteristics of the device must be taken into consideration. The bulk of NASTRAN data is stored on drums or disks. For both these devices the common unit of organization is a track, which stores a fixed number of words. Thus, there is a conflict between the variable length GINØ records and the fixed length tracks.

This conflict is resolved by blocking. GINØ acts as the interface between the device and the NASTRAN program. Using this technique, the program itself need not be concerned with device considerations (which would create machine dependent code). GINØ has been parameterized so that different devices may be easily accommodated.

Basically, blocking provides for the reading and writing of fixed-length blocks. The length of a block is a function of the device. It may be one track, one-half track or other integral division of a track (but never more than one track). Because of the relatively large time to access a given position on a track (due to the rotational speed of the device and/or mechanical movement of the head to the track), a block size equal to one full track is the most desirable. However, limitations in the amount of storage available to hold the blocks in core is a second consideration.

Since logical record lengths are variable but the length of records physically read or written is fixed, logic must be provided to accommodate this situation. This logic is provided in the GINØ routine, which allows for the following cases:

1. Multiple logical records per block
2. Multiple blocks per logical record

The method by which physical input and output of blocks is accomplished by GINØ is machine dependent. On the IBM 7094, IØEX is used. On the IBM S/360, FØRTRAN binary read/write statements are used. On the Univac 1108, NTRAN is used. On the CDC 6600, SCØPE macros are used. These implementation differences are transparent to the NASTRAN applications programmer (functional module writer). The systems programmer who is interested in implementation details on the various machines is referred to section 5.

1.6.4.1 GINØ File Names

The names of files input as arguments to the GINØ routines listed above may be alphabetic (BCD, of the form 4HXXXX) or integer.

A GINØ file name is BCD if the file contains permanent Executive tables or data blocks. A list of these files for a particular NASTRAN run resides in the permanent portion of the FIST Executive table. The following list presents all current Executive files with their BCD file names:

File	BCD File Name
Data Pool File	PØØL
New Problem Tape	NPTP
Old Problem Tape	ØPTP
BCD Plot Tape	PLT1
Binary Plot Tape	PLT2
User's Master File	UMF
New User's Master File	NUMF
User Input File	INPT .

Functional modules should not access these permanent Executive files. Functional modules access the files on which their input, output and scratch data blocks reside by internal integer GINØ file names. Prior to calling a functional module, the link driver routine, XSEMi, calls subroutine GNFIST (GNFIST is called exclusively by XSEMi) to generate the FIST Executive table. For each input, output or scratch data block required for operation of a module (this information being contained in the ØSCAR entry), GNFIST searches the FIAT to find the data block. If the data block is in the FIAT and a file has been assigned to it, an internal GINØ file number denoting the data block and a pointer (index) to the entry in the FIAT is placed in the FIST. The following convention is used for internal GINØ file numbers: input data blocks -- 100 + position in the ØSCAR entry; output data blocks -- 200 + position in the ØSCAR entry; scratch data blocks -- 301 through 300 + n where n = number of scratch data blocks as defined in the MPL. (The position in the ØSCAR entry is the position in the DMAP instruction). If the data block is in the FIAT and is purged, no entry is placed in the FIST. For example, consider the following DMAP calling sequence for functional module XYZ:

```
XYZ      A,B,C/D,E,F,G/V,N,PARM1/V,N,PARM2 $
```

The data blocks input to the module are A, B and C; the data blocks output from the module are D, E, F and G; the module's parameters are PARM1 and PARM2. Note that internal scratch files are not mentioned in the DMAP calling sequence. The number of scratch files for a module is defined in the Module Property List (MPL) Executive table (see section 2.4) and is communicated to the Executive System via the ØSCAR. Details on the syntactical rules of DMAP are given in section 5 of the User's Manual.

In order to read the input data block B, the GINØ file number internal to XYZ is 102; in order to write data block D, the GINØ file number is 201. The third of, say, five scratch data blocks is referenced by XYZ through the GINØ file number 303.

1.7 NASTRAN MATRIX ROUTINES

1.7.1 Introduction

The requirement that NASTRAN handle large structural analysis problems implies that NASTRAN should be able to manipulate and store large matrices efficiently and effectively. In general, the matrices generated in the displacement approach tend to be sparse (i.e., the number of non-zero terms in any column of a matrix is small compared to the order of the matrix). The NASTRAN matrix routines, ADD, MPYAD, DECØMP, etc., which are described in section 3.5, are optimized as much as possible to take advantage of matrix sparsity and thus eliminate many unnecessary operation on zero elements. In order to aid in these operations and to make effective use of auxiliary storage, a packing scheme was devised to store only the non-zero terms in a column.

1.7.2 Matrix Packing and Unpacking

The need for a matrix packing routine can be seen by computing the auxiliary storage required to hold a 10,000 order matrix which is 1% dense (i.e., the average number of non-zero terms in a column is 100). With no packing technique, 10^8 words of storage are required to hold the matrix. Using the NASTRAN packing routines, a maximum of 2×10^6 words of storage are required if the terms are scattered, and 10^6 words are required if the terms occur in a band.

The subroutines BLDPK, INTPK, PACK, and UNPACK, along with their additional entry points, provide the matrix packing/unpacking capability of NASTRAN. The user should refer to the descriptions of these subroutines in sections 3.5.1 through 3.5.4 for a detailed description of the packing logic.

Matrices are stored by columns, and subroutines PACK/UNPACK provide the ability to pack/unpack a complete column. The capability is also provided to pack/unpack a column from the first non-zero element to the last.

An added feature of the packing routines is that subroutines BLDPK and INTPK provide the capability of packing/unpacking one element at a time. By use of INTPK, a matrix can be read element-by-element, such that an entire matrix can be processed without any appreciable core storage requirements. Likewise, by using BLDPK, a matrix can be built one element at a time. This is an extremely important feature to routines that must process matrices when storage is limited.

1.7.3 The Nested Vector Set Concept Used to Represent Components of Displacement

In constructing the matrices used in the Displacement Approach, each row and/or column of a matrix is associated closely with a grid point, a scalar point or an extra point. Every grid point has 6 degrees of freedom associated with it, and hence 6 rows and/or columns of the matrix. Scalar and extra points only have one degree of freedom. At each point (grid, scalar, extra) these degrees of freedom can be further classified into subsets, depending on the constraints or handling required for particular degrees of freedom. (For example in a two-dimensional problem all "z" degrees of freedom are constrained and hence belongs to the s (single-point constraint) set). Each degree of freedom can be considered as a "point", and the entire model is the collection of these one-dimensional points.

Nearly all of the matrix operations in displacement analysis are concerned with partitioning, merging, and transforming matrix arrays from one subset of displacement components to another. All the components of displacement of a given type (such as all points constrained by single-point constraints) form a vector set that is distinguished by a subscript from other sets. A given component of displacement can belong to several vector sets. The mutually exclusive vector sets, the sum of whose members are the set of all physical components of displacements, are as follows:

u_m points eliminated by multipoint constraints,

u_s points eliminated by single-point constraints,

u_o points omitted by structural matrix partitioning,

u_r points to which determinate reactions are applied in static analysis,

u_ℓ the remaining structural points used in static analysis (points left over),

u_e extra degrees of freedom introduced in dynamic analysis to describe control systems etc.

The vector sets obtained by combining two or more of the above sets are (+ sign indicates the union of two sets):

$u_a = u_r + u_\ell$, the set used in real eigenvalue analysis,

$u_d = u_a + u_e$, the set used in dynamic analysis by the direct method,

$u_f = u_a + u_o$, unconstrained (free) structural points,

$u_n = u_f + u_s$, all structural points not constrained by multipoint constraints,

$u_g = u_n + u_m$, all structural (grid) points including scalar points,

$u_p = u_g + u_e$, all physical points.

In dynamic analysis, additional vector sets are obtained by a modal transformation derived from real eigenvalue analysis of the set u_a. These are:

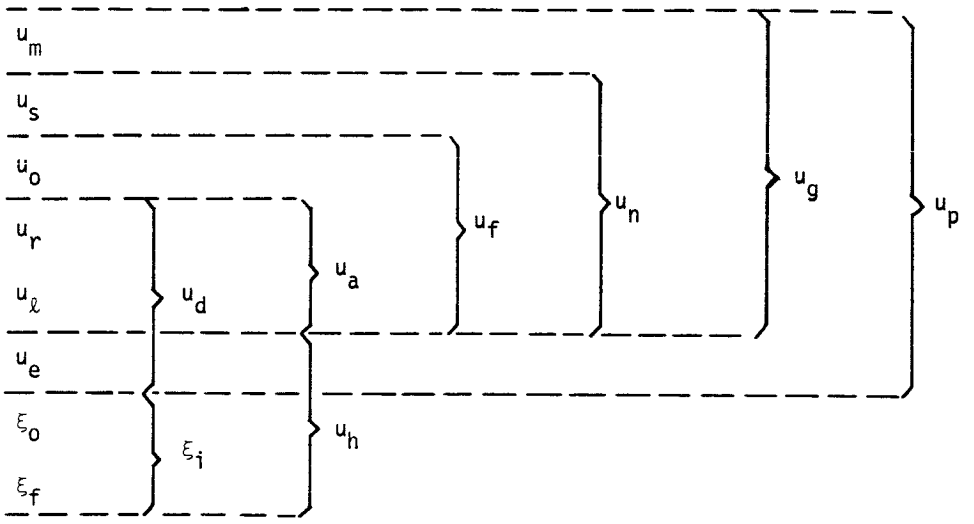
ξ_o rigid body (zero frequency) modal coordinates,

ξ_f finite frequency modal coordinates,

$\xi_i = \xi_o + \xi_f$, the set of all modal coordinates.

One vector set is defined that combines physical and modal coordinates. That set is $u_h = \xi_i + u_e$, the set used in dynamic analysis by the modal method.

The nesting of vector sets is depicted by the following diagram:



The data block USET (USETD in dynamics) is central to this set classification. Each word of USET corresponds to a degree of freedom in the problem. Each set is assigned a bit in the word. If a degree of freedom belongs to a given set, the corresponding bit is on. Every degree of freedom can then be classified by analysis of USET. The common block /BITPØS/ relates the sets to bit numbers.

Two types of operations occur repeatedly. The first is the partitioning or sort operation. Examples are:

$$\{u_g\} \Longrightarrow \begin{Bmatrix} u_n \\ \hline u_m \end{Bmatrix} \quad ; \tag{1}$$

and

$$\left[K_{nn}\right] \Longrightarrow \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] . \tag{2}$$

The second is the recombining (or merge) operation:

$$\{u_g\} \Longleftarrow \begin{Bmatrix} u_n \\ \hline u_m \end{Bmatrix} . \tag{3}$$

These operations can be completely described by a "partitioning" vector whose length corresponds to the length of the major set (the u_g set in Equation 1) and whose elements are zeros or ones depending on whether a degree of freedom belongs to the upper (the u_n set in Equation 1) subset or the lower (the u_m set in Equation 1) subset. Such a partitioning vector can be constructed by subroutine CALCV, which is described in section 3.5.5. This operation is described throughout the documentation by the notation USET (UG,UN,UM) where UG (u_g) is the major set, UN (u_n) is the zero set, and UM (u_m) is the one set. The partitioning vector generated by subroutine CALCV is input to the matrix routine PARTN (section 3.5.6) to perform operations similar to those in Equations 1 and 2 and is input to the matrix routine MERGE (section 3.5.6) to perform operations similar to that in Equation 3.

1.7.4 Processing of Matrices

Matrices in NASTRAN can be divided in two general types: core held matrices such as the 6x6's generated by the element routines and data block held matrices such as those output by functional modules. There are many routines to assist the programmer in the processing of both types of matrices. Incore matrices can be processed by GMMATD (Section 3.4.32), GMMATS (Section 3.4.33), INVERD (Section 3.4.34) and INVERS (Section 3.4.35). Data block held matrices can be processed at several levels. The most general is through the matrix packing and unpacking

routines (BLDPK, PACK, INTPK and UNPACK). The next level of generality is provided by the matrix subroutines such as ADD, PARTN, MERGE, TRNSP, MPYAD, SDCØMP, DECØMP, CDCØMP, FBS, GFBS, and INVTR. The functions provided by these routines can also be activated by a simple subroutine call through such routines as SSG2A, SDR1B, SSG2C, SSG2B, SSG3A, SØLVER, FACTØR and TRANP1. This third form is by far the most convenient and error free method for the novice NASTRAN applications programmer.

1.8 GENERATION OF MATRICES

The Structural Matrix Assembler (SMA) modules generate the stiffness, structural damping, mass and damping matrices for the structural model. SMA1 generates the stiffness matrix exclusive of general elements, $[K^{x}_{gg}]$, and the structural damping matrix, $[K^{4}_{gg}]$; SMA2 generates the mass matrix, $[M_{gg}]$, and the damping matrix, $[B_{gg}]$; and SMA3 generates the final stiffness matrix, $[K_{gg}]$, by generating a matrix for each general element in the model, and successively adding these matrices to $[K^{x}_{gg}]$. Other matrix generation modules are: 1) DSMG1, which generates the differential stiffness matrix, $[K^{d}_{gg}]$, for use in the Static Analysis with Differential Stiffness Rigid Format and in the Buckling Analysis Rigid Format; 2) PLA1, which generates the stiffness matrix for linear elements, $[K^{\ell}_{gg}]$, for use in the Piecewise Linear Analysis Rigid Format; 3) PLA4, which generates the stiffness matrix for nonlinear elements, $[K^{n\ell}_{gg}]$, for use in the Piecewise Linear Analysis Rigid Format; 4) MTRXIN, which provides a two-fold capability: a) to provide for direct input matrices such as control systems in the dynamics Rigid Formats, and b) to provide the DMAP user a capability of converting matrices input on DMIG bulk data cards to NASTRAN matrix format; and 5) the IFP module which provides the user the capability of converting matrices input on DMI bulk data cards to NASTRAN matrix format. Detailed information on each of these modules can be found in section 4, Module Functional Descriptions. The central role that the ECPT data block plays in the formation of the structural matrices generated in modules SMA1, SMA2, DSMG1, PLA1 and PLA4 is explained in the following subsections.

1.8.1 The ECPT Data Block

NASTRAN embodies a lumped element approach, i.e., the distributed physical properties of a structure are represented by a model consisting of a finite number of idealized substructures or elements that are interconnected at a finite number of points. An element will affect terms in the matrices only in rows and columns related to its interconnected points. Hence each column of these matrices may be formed using only elements connected to the grid or scalar point associated with that column.

The Table Assembler (TA1) module constructs the Element Connection and Properties Table (ECPT) data block for use in the generation of these structural matrices. Each record of the ECPT corresponds to a grid point or a scalar point of the model, and, conversely, every grid point or scalar point of the model corresponds to a record of the ECPT. The point to which a

record of the ECPT corresponds is called the pivot point of the record. Each record contains the connection and properties data for all elements connected to the pivot point. Hence data for an element will appear n times, where n is the number of points defining the element.

1.8.2 Structural Elements

The basis for the structural matrices in NASTRAN are the finite structural and scalar elements. Each element generates matrix terms connecting and connected to the grid and scalar points given on its input connection card (e.g., CRØD). A structural element generates 6 by 6 matrix partitions related to the six degrees of freedom of each connecting grid point. A scalar element generates one term for each connection.

The stiffness matrix, [K], for a structural element consists of a 6 by 6 partition for each combination of the connected grid points. For example, a BAR or RØD element is connected to two grid points, "a" and "b". The stiffness matrix partitions are: $[K_{aa}]$, $[K_{ab}]$, $[K_{ba}]$ and $[K_{bb}]$. A triangular element (e.g., TRMEM) is connected to three points. It will generate nine partitions: $[K_{aa}]$, $[K_{ab}]$, $[K_{ac}]$, $[K_{ba}]$, $[K_{bb}]$, $[K_{bc}]$, $[K_{ca}]$, $[K_{cb}]$ and $[K_{cc}]$.

Although the actual equations for the element stiffness, mass and damping matrices are different for each element, the solutions follow a definite pattern. The element connection, orientation and property data are given in the ECPT data block. The coordinate system data for orienting the global coordinates at each grid point are given in the CSTM data block. The material properties are given in the MPT and DIT data blocks. A utility routine, PRETRD, is available to fetch coordinate system data, and a utility routine, PREMAT, is available to fetch material properties.

1. An element coordinate system is calculated using the locations of the grid points. Using these data a matrix, [E], is formed, which transforms displacements from element coordinates to basic coordinates.

2. The stiffness matrix may be formed in element coordinates using many methods. For the simple elements (e.g., RØD) the terms are direct functions of the geometry, properties and material coefficients of the element. For some elements the matrix is first formulated in terms of generalized coordinates, {q}, usually the coefficients of a power series. In general coordinates, the matrix is $[K_q]$. Transformation matrices, $[H_i]$, are generated to

transform the displacements at the grid points in element coordinates {u}, to the general coordinates {q}.

3. The global coordinate system orientation matrix, [T], for each grid point is calculated.

4. The stiffness matrix partition for the columns related to point j and the rows related to point i is $[K_{ij}]$. In general it is formed by the equation

$$[K_{ij}] = [T_i]^T[E][H_i]^T[K_q][H_j][E]^T[T_j]. \quad (1)$$

In order to generate a particular partition, $[K_{ij}]$, it is often necessary to generate [K]. Only those partitions $[K_{ij}]$, where i is the pivot point and j = 1,2,...,n (n being the number of grid points associated with the element), are useful for the current ECPT record being processed. The unused partitions are recalculated and used when $j \neq i$ appears as a pivot point in a subsequent ECPT record. An alternate procedure for matrix generation, which is not used, would be to calculate all of the element matrices once and store them on an auxiliary file for future use when needed. The alternate procedure is less efficient for large problems, where efficiency really counts, because the recalculation time is less than the time required to recover element matrices from the auxiliary file.

1.9 TERMINATION PHILOSOPHY AND DIAGNOSTIC MESSAGES

Certain restrictions are placed upon the functional module writer with regard to run termination and error diagnostics. This is necessary in order to complete certain functions upon terminating and to maintain uniformity with regard to diagnostic messages.

A functional module writer is required to utilize a message writer (MSGWRT, section 3.4.26) to print all of his messages. In this manner similar message formats do not have to be duplicated in each module. Also, in order to avoid placing the I/Ø conversion routines and the lengthy format statements in the root segment, the message writer is restricted to its own overlay segment, Communication between the module and the message writer is via a queued message concept. Subroutine MESAGE (section 3.4.25) is called to store the message parameters. In the case of a fatal message, a dump is taken if a DIAG 1 card is present in the Executive Control Deck, and PEXIT (section 3.4.22) is called. For non-fatal messages, the message is queued and control given back to the user. The message queue is printed after each module is executed.

In order for any routine to terminate the current execution, a call to PEXIT must be made. PEXIT handles all the functions necessary to wrap up the run: flushing output buffers, printing queued messages, and punching the last card of the checkpoint dictionary.

1.10 RESTARTS IN NASTRAN

NASTRAN is designed to run large problems with long running times. Even with the best of computer systems, a hardware, operator, or system failure is not uncommon for long running jobs. At the same time, the large volumes of data and the complexity of the structures that can be modeled and analyzed using NASTRAN make it highly likely that user input data errors will occur. Many of these errors are of a subtle type, meaning that they cannot be immediately detected in the NASTRAN Preface by the modules which process the data decks. To deal with these problems, and to save machine time on runs which abort because of data or system errors, NASTRAN has a sophisticated checkpoint and restart capability (see section 3 of the User's Manual for a discussion of restarts from the user point of view). The overall design philosophy for restart is twofold. A restart selectively executes only the modules necessary to accomplish a user-input data change. The user is able to change any part of his problem including structural model changes, additional cases, or more output requests. At the same time restarts are automatic as far as user interference is concerned. The user need only checkpoint (see section 1.2.3.5) his original run and submit changes to the original run on subsequent runs. The user does not have to analyze the effect of his changes. In addition the selective nature of restart allows the program to proceed with implicit errors (errors present in the data but not yet identified) until no further valid progress can be made. The work accomplished to this point is not lost, but rather only the table or matrix data block in error must be corrected to allow the program to proceed. Much error checking can be deferred until the actual module using the data is in control. The remainder of this section will explain the program mechanics by which restart is accomplished.

In NASTRAN there are four general types of restarts. Unmodified Restart (UMR), Psuedo Modified Restart (PMR), Modified Restart (MR), and Rigid Format Switch (RFS). Note that in the User's Manual UMR's and PMR's are described together as Unmodifed Restarts. These classifications are for descriptive and internal purposes. The user need not know anything about which type is which. The basic characteristics of each type will be described below. An Unmodified Restart results when the user simply resubmits a problem with no data changes. It is used to continue a solution from the point of interruption. Presumably the problem aborted previously due to time expiring, machine error, system error, etc. The restart dictionary (created while checkpointing) is processed, and the solution is started again at the last re-entry point (after the last successful checkpoint). A Psuedo Modified Restart occurs when the user requests additional output from the program which simply requires the re-execution of an output module such as the Structure Plotter, the Grid Point

Weight Generator, or the Stress Data Recovery module etc. The numerical solution is not affected by these modules; only output is generated. Note that a PMR is the common case since printer output, plotter output, etc. is usually requested. A true UMR is rare. On a PMR, output modules are re-executed to display requested output, and then the problem is continued at the re-entry point. A true Modified Restart occurs when some numerically significant data change. The modules which process this type of data must be re-executed. These modules are re-executed to regenerate their output data blocks based on the new data, and the problem is continued at the re-entry point. A Rigid Format Switch is a special form of Modified Restart in which a problem changes from one solution type to another. One example would be: a user has solved for the static solution on Rigid Format 1 and now wants to find the normal modes by using Rigid Format 3. This may or may not require data changes. The key difference here is that the re-entry point cannot be used to determine the proper place to restart. The technique by which a RFS is accomplished is to re-execute the final modules on the new Rigid Format and let the File Name Table chain the solution back to the proper restart point.

To understand, in general, how the above types of restart are implemented, it is necessary to consider the Module Execution Decision Table (MEDT), which is associated with each Rigid Format. The Module Execution Decision Table is a table which has one entry for every DMAP instruction in the Rigid Format. Each entry is 5 words long; each word contains 31 bits. For convenience, these bits are numbered sequentially from left to right with the numbers 1 through 155. If the entry in the MEDT for a module has, say, bit 55 turned on, this module will be executed whenever a card or data block change associated with bit 55 occurs on a restart. The Card Name Table associates bits of the MEDT with selected bulk data card names, Case Control selections and parameter names. The File Name Table associates bits of the MEDT with selected data block names. For consistency, bits 1 through 62 for each entry in the MEDT are reserved for the Card Name Table, and bits 94 through 155 are reserved for the File Name Table. The following example illustrates the use of these tables in determining the effects of changing a bulk data card on a Modified Restart. Suppose the FØRCE bulk data card is to be changed when executing Rigid Format 1. The table in section 3.2.3.1 of the User's Manual associates bit 60 with the FØRCE card. The decision table for bits 1 through 62 is shown in section 3.2.3.3 of the User's Manual. DMAP modules BEGIN, FILE, FILE, GP3, SAVE, PARAM, PURGE, CHKPNT, SSG1, CHKPNT, EQUIV, etc., will be executed since bit 60 is on for each.

There is one more table, the Rigid Format Switch Table, which is constant for all Rigid Formats, and hence resides in Preface module XCSA. The Rigid Format Switch Table associates with

each Rigid Format a bit for each entry in the MEDT: bit 63 is associated with Rigid Format 1, bit 64 is associated with Rigid Format 2, etc. If the restart involves a Rigid Format change, the bit in the decision table which is set is the bit corresponding to the Rigid Format of the previous execution.

Each part of the NASTRAN Preface contributes to processing the information for a restart. XCSA extracts and stores the Card Name Table, the File Name Table, the Module Execution Decision Table, the DMAP sequence and the Rigid Format Switch bit if any. These are written in the XCSA Executive Control Table (see section 2.4.2.5) on the New Problem Tape for later use by module XGPI. IFP1 compares the current CASECC data block with the one submitted on the previous run (a copy of CASECC is stored on the Old Problem Tape for this purpose). Three types of changes are noted by IFP1:

1. Changes in data set selection such as Load set, SPC set, etc.;
2. The occurence of output requests for printer, plotter, etc.;
3. Changes in the looping structure of the problem.

The results of this analysis are stored in common block /IFPXØ/. Each bit in /IFPXØ/ is associated with a key name. These names will appear in some Rigid Format's Card Name Table. /IFPXØ/ contains one bit for every unique entry in the Card Name Table. /IFPX1/ contains these names in order given by /IFPXØ/. Thus, bit 135 in /IFPXØ/ corresponds to the key word, LØAD$. If bit 135 is on (non-zero), the status of LØAD$ has changed on this restart. XSØRT analyzes the bulk data card changes in a similar manner, setting the proper bits in /IFPXØ/. IFP applies certain logical rules to combinations of the bits. XGPI then analyzes this information in the following manner. For each bit in /IFPXØ/ the BCD equivalent is extracted from /IFPX1/. This mnemonic is searched for a match in the Card Name Table. If a match occurs, the appropriate bit in a master module execution mask is turned on. After all changes have been processed, the master mask is logically multiplied (logical and) with each module execution entry. A non-zero results indicates that this module is to be executed.

All bits in /IFPXØ/ are classified as either significant to the solution or as only reflecting output requests. If only output request bits are on, a PMR is indicated. If the restart is a Modified Restart, one further table look-up may be necessary: the resulting DMAP sequence determined from the execution flags of the modules may not have the required input data blocks. (All

input data blocks must first appear as output data blocks). If this should be the case (most often caused by switching rigid formats), the File Name Table is consulted to determine which bits are on and hence which modules should be re-executed to generate the missing data blocks. The resulting DMAP sequence causes the selective execution of only those modules necessary to reflect the data changes and complete the requested solution.

2.1 INTRODUCTION

This section contains descriptions of a) those NASTRAN data blocks which appear in one or more Rigid Formats (section 2.3), b) Executive tables maintained by the NASTRAN Executive System (section 2.4), and c) Miscellaneous tables used by more than one module (section 2.5).

Data blocks that appear in Rigid Formats are structural problem oriented and reside on physical files. A file is "allocated" to a data block, and a data block is "assigned" to a file. The Executive Segment File Allocator (XSFA) Module is the "administrative manager" of files for NASTRAN.

Executive Tables have true executive functions in the sense that they are not oriented to a particular problem solution or even to structural analysis in general. They may be core resident or may reside on physical files.

Miscellaneous tables are common blocks which are used by the Executive System and/or a particular class of modules (e.g., /GPTA1/ is used only by modules GP1, GP2, GP3 and TA1). Common blocks that are used for intra-module communications are documented in section 4, Module Functional Descriptions.

Section 2.2.1 contains an index for data block descriptions sorted on data block names, and section 2.2.2 contains an index for data block descriptions sorted on the names of modules from which they are output. Alphabetical indexes are given for Executive table descriptions and miscellaneous table descriptions at the beginning of sections 2.4 and 2.5 respectively.

2.2 DATA BLOCK DESCRIPTIONS - GENERAL COMMENTS AND INDEXES

Data block descriptions have been organized so that all data blocks output from the same module are grouped together. The name of each data block is given, and the data block is classified as a matrix or a table. A data block is classified as a matrix only if it is in NASTRAN matrix form, that is, generated by one of the NASTRAN matrix packing routines, PACK or BLDPK, the latter having secondary entry points BLDPKI, ZBLPKI and BLDPKN. All other data blocks are classified as tables.

Following a data block's name and classification is a brief description of its contents, followed by its format if it is a table. Since all matrices are in standard NASTRAN packed format a repeated description of the format is unnecessary for matrices. Each data block has a header record (consisting in general of two BCD words) which is the alphanumeric name of the data block as it appears in a Rigid Format, and this header record is designated "Record 0" in table formats. For those few data block which contain more than these two BCD words in their header record, e.g., SLT, GPTT, DLT, the contents are described explicitly. The conventions used for describing the types of words in records of tables are: R implies real; I implies integer; B implies BCD, four characters per computer word left adjusted with the remaining characters, if any, filled with BCD blanks; and L implies a "logical" -- not in the FØRTRAN sense -- word which is a mask of bits, right adjusted.

There is associated with each data block a six word control block called a trailer. Trailer information is "written" by the module which outputs the corresponding data block and can be "read" by any module accessing the corresponding data block as input. If a module "writes" a zero trailer for a data block, this implies no data was written in the data block. If a module "writes" a non-zero trailer, this implies data was written in the data block. Non-zero trailer information is often used by modules to allocate core storage before reading the corresponding data block. Trailer information for each data block is stored in and retrieved from the FIAT Executive table (see section 2.4.1.2) by the utility routines WRTTRL (write trailer) and RDTRL (read trailer), which are described in section 3.4.16. While residing in the FIAT, a trailer is stored in 6 half-words; each half-word consists of 16 binary digits.

Trailer information is standardized for matrix data blocks, not standardized for table data blocks. The format of a matrix trailer is as follows:

Word 1 = number of columns = N

Word 2 = number of rows = M

Word 3 = form = 1 square matrix

2 rectangular matrix

3 diagonal matrix { N = 1, M = number of rows }

4 lower triangular matrix

5 upper triangular matrix

6 symmetric matrix

7 row vector { N = 1, M = number of rows }

8 identity matrix

Word 4 = type = 1 elements of the matrix are real single precision

2 elements of the matrix are real double precision

3 elements of the matrix are complex single precision

4 elements of the matrix are complex double precision.

Word 5 = maximum number of non-zero words (rather than non-zero matrix elements) in any one column (e.g., if a real double precision matrix is diagonal and non-zero word 5 = 2)

Word 6 = not defined

Word 5 is dependent upon the structural model and the user's grid point sequencing rather than on any intrinsic property of the matrix and is therefore not described in this report.

The lower case letters, e.g., g, n, m, s, o, ℓ, etc., used as subscripts designate the subsets of displacement to which the root symbol (e.g., [K], for a stiffness matrix) applies. The reader is referred to section 3 of the Theoretical Manual and to section 1.7 of the Programmer's Manual for further details.

2.2.1 Index for Data Block Descriptions Sorted on Data Block Names

Section Number	Data Block Name	Output from Module	Page Number
2.3.33.7	UBØØV	DSMG2	2.3-131
2.3.44.1	UDVF	FRRD	2.3-158
2.3.50.2	UDV1F	DDR1	2.3-184
2.3.53.3	UDV2F	DDR2	2.3-192
2.3.48.1	UDVT	TRD	2.3-181
2.3.50.3	UDV1T	DDR1	2.3-184
2.3.53.6	UDV2T	DDR2	2.3-193
2.3.53.1	UEVF	DDR2	2.3-192
2.3.53.4	UEVT	DDR2	2.3-192
2.3.27.1	UGV	SDR1	2.3-84
2.3.36.1	UGV1	PLA2	2.3-138
2.3.44.5	UHVF	FRRD	2.3-159
2.3.48.6	UHVT	TRD	2.3-182
2.3.20.2	ULL	RBMG2	2.3-75
2.3.25.1	ULV	SSG3	2.3-81
2.3.27.14	UPV	SDR1	2.3-87
2.3.27.13	UPVC	SDR1	2.3-87
2.3.18.5	UØØ	SMP1	2.3-71
2.3.25.2	UØØV	SSG3	2.3-81
2.3.13.3	USET	GP4	2.3-61
2.3.29.3	USETD	DPD	2.3-115
2.3.1.3	XYCDB	IFP1	2.3-4
2.3.46.2	XYPLTFA	XYTRAN	2.3-178
2.3.46.3	XYPLTF	XYTRAN	2.3-178
2.3.46.4	XYPLTR	XYTRAN	2.3-178
2.3.46.1	XYPLTT	XYTRAN	2.3-175
2.3.46.5	XYPLTTA	XYTRAN	2.3-178
2.3.33.6	YBS	DSMG2	2.3-131
2.3.13.2	YS	GP4	2.3-61

2.2.2 Index for Data Block Descriptions Sorted Alphabetically by Module

2.3 DATA BLØCK DESCRIPTIONS

2.3.1 Data Blocks Output From Module IFP1

2.3.1.1 CASECC (TABLE)

Description

Case Control Data Table

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Subcase number
	2	I	Multipoint constraint set
	3	I	Single-point constraint set
	4	I	External static load set
	5	I	Real eigenvalue extraction set
	6	I	Element deformation set
	7	I	Thermal load set
	8	I	Thermal material set
	9	I	Transient initial conditions
	10	I	Non-linear load output set
	11	I	Output media selection - 1 = print, 4 = punch
	12	I	Format of output - 1 = real 2 = real/imag 3 = mag/phase If word 12 < 0, SØRT2 is requested
	13	I	Dynamic load set
	14	I	Frequency response set
	15	I	Transfer function set
	16	I	Symmetry flag
	17	I	
	18	I	Same as 10-12 for load output
	19	I	
	20	I	
	21	I	Same as 10-12 for displacement output
	22	I	
	23	I	
	24	I	Same as 10-12 for stress output
	25	I	
	26	I	
	27	I	Same as 10-12 for force output
	28	I	
	29	I	
	30	I	Same as 10-12 for acceleration output
	31	I	
	32	I	
	33	I	Same as 10-12 for velocity output
	34	I	
	35	I	
	36	I	Same as 10-12 for forces of constraint output
	37	I	
	38	I	Time step set selection for transient problem
	39	B	32 words of TITLE
	.		
	.	B	
	.		
	70	B	

Record	Word	Type	Item
	71	B	32 words of SUBTITLE
	.		
	.	B	
	.		
	102	B	
	103	B	32 words of LABEL
	.		
	.	B	
	.		
	134	B	
	135	I	Structure plotter flag
	136		Axisymmetric set - CØSINE = 2 SINE = 1 FLUID = 2
	137	I	Number of harmonics to output
	138	I	Differential stiffness coefficient set
	139	B	Name of K2PP matrix
	140	B	
	141	B	Name of M2PP matrix
	142	B	
	143	B	Name of B2PP matrix
	144	B	
	145	I	OUTPUT frequency set selection
	146		Not defined
	147		Not defined
	148	I	Complex eigenvalue extraction set
	149	I	Structural damping table set
	150	I	Inertia relief set (Force method only)
	151	I	Same as 10-12 for solution set displacements
	152	I	
	153	I	
	154	I	Same as 10-12 for solution set velocities
	155	I	
	156	I	
	157	I	Same as 10-12 for solution set accelerations
	158	I	
	159	I	
	160	I	Non-linear load set in transient problems
	161	I	Delete set (Force method only)
	162		Not defined
	163	I	Random analysis set
	164	I	Piecewise linear coefficient set
	165		Not defined
	166	I	Length of symmetry sequence (LSEM)
	167	R	Coefficients for symmetry sequence
	.		
	.	R	
	.		
	166+LSEM	R	
	167+LSEM	I	Set ID
	168+LSEM	I	Length of the set (LSET)
	169+LSEM		Set members
	.		
	.		
	.		
	169+LSEM+LSET	I	

Note

The above record is repeated for each subcase and symmetry combination.

Table Trailer

Word 1 = 0
Word 2 = 7
Word 3 = 0
Word 4 = 7
Word 5 = 0
Word 6 = 7

2.3.1.2 PCDB (TABLE)

Description

Plot Control Data Table for the structure plotter.

Table Format

Record	Item
0	Header record
1	The data here is the XRCARD translation of the Structure Plotter
.	Packet cards in the Case Control Deck (See Subroutine Description
.	for XRCARD). There is one record for each physical card.
.	
N+1	End-of-file

Table Trailer

Words 1 through 3 are zero
Word 4 = 7777
Word 5 and Word 6 are zero

2.3.1.3 XYCDB (TABLE)

Description

XY Output Control Data Block.

Record one contains the subroutine IFP1XY interpretations of the XY plot output request case control data cards. Record two contains an N by 6 matrix stored by rows and sorted such that the columns are in sort left to right. N is the total number of combinations specified by the XY-plot-request case control data cards.

Table Format

Record	Word	Type	Item
0			Header record
1	1-Last	Mixed	IFP1XY interpretations of the XY-output-requests, translated for rapid processing by the XYTRAN module.
2	1	I	Subcase number (0 implies all)
	2	I	Vector request type
	3	I	Point or element ID
	4	I	Component
	5	I	XY output type
	6	I	Destination code

(words 2-6: repeats for all rows)

Notes

1. Vector request type =
   1 = Displacement
   2 = Velocity
   3 = Acceleration
   4 = Single-point forces of constraint
   5 = Load
   6 = Stress
   7 = Force
   8 = Adisplacement
   9 = Avelocity
   10 = Aacceleration
   11 = Nonlinear Force

2. XY output type =
   1 = Response
   2 = PSDF
   3 = AUTØ

3. Destination code =
   1 = Print
   2 = Plot
   3 = Print, plot
   4 = Punch
   5 = Print, punch
   6 = Plot, punch
   7 = Print, plot, punch

4. Either of records 1 and 2 may be null, however they will always exist.

Table Trailer

Words 1-5 = nonzero
Word 6 = one

2.3.2 Data Blocks Output From Module IFP.

Module IFP (Input File Processor, part of the NASTRAN Preface) processes the Bulk Data Deck sorted by module XSØRT and writes the following data blocks that appear in one or more Rigid Formats: GEØM1, GEØM2, GEØM3, GEØM4, EPT, MPT, DIT, EDT, DYNAMICS, MATPØØL. Each of these data blocks has the usual 2-word BCD header record.

Each data block contains bulk data card images or modified card images of a subset of bulk data card types. Each logical record of each of the above data blocks contains all the data of a particular card type. If a card type is not present in the Bulk Data Deck, there is no record. For each card type present, 3 words are written as header information for the record. Then for every logical bulk data card of that type in the Bulk Data Deck, a card image or a modified card image is written sequentially in the record. Following the last data record, a final three word record is written; the data values are all 65535.

The first two words of the header information of each record are used by entry point LØCATE of subroutine PRELØC. The third word of the header information is the card number used by the IFP programmer to reference tables internal to the IFP module.

LØCATE is used by routines that wish to read data blocks output by the IFP. The second word of the header information portion of each record corresponds to a bit position in a 96-bit, 6-word data block trailer, each word containing 16 bits. If a routine requests LØCATE to locate (position) the file to) a particular card type, LØCATE will determine if the card type is present by interrogating the corresponding bit in the trailer, the bit number having been supplied through the calling sequent to LØCATE. If the bit is zero, the card type is not present and LØCATE executes a non-standard RETURN. If the bit is one, the card type is present and LØCATE uses the first word of the header information, also supplied through the calling sequence, to find the proper logical record (card type).

Since the Bulk Data Deck is sorted alphabetically before IFP processes it, and since IFP processes the deck sequentially, the order of the card types in each data block is alphabetical. It should be noted that when two trailer bit numbers are given in the description for a card type, this implies that: (1) the card is a "multi-entry" card type (more than one logical card on one physical card, e.g., CELAS3, CELAS4, CRØD, CTUBE); (2) these card types may or may not be sorted with respect to the primary field, in the above examples element identification; and (3) a module

accessing these card types must know whether or not they are in sort. If they are in sort, the second bit number is set to 1; if they are not in sort, the second bit number is set to 0.

Card type formats correspond to a typical card entry in the logical record allocated to a card type. A number (literal) in a card type format implied that the IFP has placed this number in its output buffer before writing the information on the file and that this number is not on the bulk data card itself. The mnemonics used in the card type formats correspond to the mnemonics in the bulk data card section of the NASTRAN User's Manual. It is advised that anyone using the information on the following pages secure a copy of this section of the User's Manual for cross reference purposes.

IFP also generates the AXIC and FØRCE data blocks, the Parameter Value Table (PVT) and writes Direct Matrix Input (DMI) and Direct Table Input (DTI) cards on the Data Pool File. The AXIC data block, whose presence implies a conical shell (a unique structural element) problem solution, a hydroelastic analysis problem, or an acoustic problem, is processed by the Preface modules IFP3, IFP4 and IFP5. The PVT, which is an Executive Table and is documented in Section 2.4, contains the names and values of all parameters input by means of the PARAM bulk data card. The PVT is written on the Problem Tape. Each DMI in the Bulk Data Deck is output on the Data Pool File in NASTRAN packed matrix format and is indistinguishable from any matrix data block pooled by the XSFA, that is, a matrix trailer is written on the last logical record of the data block. IFP also stores the name of each DMI on the DPL (see Section 2.4). Similarly, each DTI is output on the Data Pool File, a table trailer is written, and the name of the DTI is stored in the DPL.

The preface modules IFP3, IFP4, and IFP5 also will generate some of the data on the data blocks output from IFP. These modules are used to process data cards written by IFP and replace them with equivalent data blocks. For instance, data card CFLUID2 is initially placed on data block AXIC by the IFP module. The IFP3 module will generate CFLUID2 elements and add them to data block GEØM2.

2.3.2.1 GEØM1 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
blank	0	0	89
ADUM1	0	0	3
ADUM2	0	0	32
ADUM3	0	0	51
ADUM4	0	0	88
ADUM5	0	0	99
ADUM6	0	0	100
ADUM7	0	0	101
ADUM8	0	0	103
ADUM9	0	0	106
CØRD1C	1701	17	6
CØRD1R	1801	18	5
CØRD1S	1901	19	7
CØRD2C	2001	20	9
CØRD2R	2101	21	8
CØRD2S	2201	22	10
GRDSET	0	0	2
GRID	4501	45	1
SEQGP	5301	53	4

Card Type Formats:

Blank cards are not written.

ADUMi cards are not written. Rather, the contents are coded and stored in words 46-54 of /SYSTEM/ .

CØRD1C (6 words)	CID	2	1
	G1	G2	G3
CØRD1R (6 words)	CID	1	1
	G1	G2	G3
CØRD1S (6 words)	CID	3	1
	G1	G2	G3
CØRD2C (13 words)	CID	2	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		
CØRD2R (13 words)	CID	1	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		
CØRD2S (13 words)	CID	3	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		

2.3.2.1 GEØM1 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
blank	0	0	89
ADUM1	0	0	3
ADUM2	0	0	32
ADUM3	0	0	51
ADUM4	0	0	88
ADUM5	0	0	99
ADUM6	0	0	100
ADUM7	0	0	101
ADUM8	0	0	103
ADUM9	0	0	106
CØRD1C	1701	17	6
CØRD1R	1801	18	5
CØRD1S	1901	19	7
CØRD2C	2001	20	9
CØRD2R	2101	21	8
CØRD2S	2201	22	10
GRDSET	0	0	2
GRID	4501	45	1
SEQGP	5301	53	4

Card Type Formats:

Blank cards are not written.

ADUMi cards are not written. Rather, the contents are coded and stored in words 46-54 of /SYSTEM/ .

CØRD1C (6 words)	CID	2	1
	G1	G2	G3
CØRD1R (6 words)	CID	1	1
	G1	G2	G3
CØRD1S (6 words)	CID	3	1
	G1	G2	G3
CØRD2C (13 words)	CID	2	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		
CØRD2R (13 words)	CID	1	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		
CØRD2S (13 words)	CID	3	2
	RID	A1	A2
	A3	B1	B2
	B3	C1	C2
	C3		

Card Type Formats Cont'd.:

The GRDSET card is not written. Rather, the contents are stored locally for use when processing the GRID cards.

GRID (8 words)	ID	CP	X1
	X2	X3	CD
	PS	FØ	

If a GRDSET card is present, and if any of fields 3, 7, or 8 of any GRID card are blank, IFP will insert corresponding data fields from the GRDSET card. Only one GRDSET card may appear in the Bulk Data Deck.

SEQGP (2 words)	ID	SEQID

2.3.2.2 GEØM2 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
BARØR	0	0	179
CAXIF2	2108	21	224
CAXIF3	2208	22	225
CAXIF4	2308	23	226
CBAR	2408	24	180
CDAMP1	201	2	69
CDAMP2	301	3	70
CDAMP3	401	4,92	71
CDAMP4	501	5,89	72
CDUM1	6108	61	107
CDUM2	6208	62	108
CDUM3	6308	63	109
CDUM4	6408	64	110
CDUM5	6508	65	111
CDUM6	6608	66	112
CDUM7	6708	67	113
CDUM8	6808	68	114
CDUM9	6908	69	115
CELAS1	601	6	73
CELAS2	701	7	74
CELAS3	801	8,91	75
CELAS4	901	9,88	76
CFLUID2	8515	85	0*
CFLUID3	8615	86	0*
CFLUID4	8715	87	0*
CHBDY	4208	42	232
CHEXA1	5708	57	219
CHEXA2	5808	58	220
CMASS1	1001	10	65
CMASS2	1101	11	66
CMASS3	1201	12,93	67
CMASS4	1301	13,90	68
CMFREE	2508	25	0*
CØNM1	1401	14	63
CØNM2	1501	15	64
CØNRØD	1601	16	47
CQDMEM	2601	26	60
CQDPLT	2701	27	59
CQUAD1	2801	28	57
CQUAD2	2901	29	58
CRØD	3001	30,96	48
CSHEAR	3101	31	61
CSLØT3	4408	44	227
CSLØT4	4508	45	228
CTETRA	5508	55	217
CTØRDRG	1908	19	104
CTRAPRG	1808	18	80
CTRBSC	3201	32	54
CTRIA1	3301	33	52
CTRIA2	3401	34	53
CTRIARG	1708	17	79
CTRMEM	3501	35	56
CTRPLT	3601	36	55
CTUBE	3701	37,95	49

*Generated by IFP3, IFP4 or IFP5.

Card Types and Header Information Cont'd.:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
CTWIST	3801	38	62
CVISC	3901	39,94	50
CWEDGE	5608	56	218
GENEL	4301	43	28
PLØTEL	5201	52,87	11
SPØINT	5551	49	105

Card Type Formats:

The BARØR card is not written. Rather, the contents are stored locally for use when processing the CBAR cards.

CAXIF2 (6 words)	EID	G1	G2
	RHØ	B	N
CAXIF3 (7 words)	EID	G1	G2
	G3	RHØ	B
	N		
CAXIF4 (8 words)	EID	G1	G2
	G3	G4	RHØ
	B	N	
CBAR (16 words)	EID	PID	GA
	GB	X1	X2
	X3	F	PA
	PB	Z1A	Z2A
	Z3A	Z1B	Z2B
	Z3B		

If a BARØR card is present in the Bulk Data Deck, any if any of the fields 3, 6, 7, 8, 9 of any CBAR card are blank, IFP will insert the corresponding data fields from the BARØR card. Only one BARØR card may appear in the Bulk Data Deck.

CDAMP1 (6 words)	EID	PID	G1
	G2	C1	C2
CDAMP2 (6 words)	EID	B	G1
	G2	C1	C2
CDAMP3 (4 words)	EID	PID	S1
	S2		
CDAMP4 (4 words)	EID	B	S1
	S2		

CDUMi (variable number of words, depending on the contents of the ADUMi card)

CELAS1 (6 words)	EID	PID	G1
	G2	C1	C2
CELAS2 (8 words)	EID	K	G1
	G2	C1	C2
	GE	S	
CELAS3 (4 words)	EID	PID	S1
	S2		

Card Type Formats Cont'd.:

CELAS4 (4 words)	EID	K	S1
	S2		
CFLUID2 (6 words)	EID	S1	S2
	ρ	B	N
CFLUID3 (7 words)	EID	S1	S2
	S3	ρ	B
	N		
CFLUID4 (8 words)	EID	S1	S2
	S3	S4	ρ
	B	N	
CHBDY (8 words)	EID	FLAG	H
	AF	G1	G2
	G3	G4	
CHEXA1 (10 words)	EID	MID	G1
	G2	G3	G4
	G5	G6	G7
	G8		
CHEXA2 (10 words)	EID	MID	G1
	G2	G3	G4
	G5	G6	G7
	G8		
CMASS1 (6 words)	EID	PID	G1
	G2	C1	C2
CMASS2 (6 words)	EID	M	G1
	G2	C1	C2
CMASS3 (4 words)	EID	PID	S1
	S2		
CMASS4 (4 words)	EID	M	S1
	S2		
CMFREE (5 words)	EID	S1	S2
	γ	N	
CØNM1 (24 words)	EID	G	CID
	M11	M21	M22
	M31	M32	M33
	M41	M42	M43
	M44	M51	M52
	M53	M54	M55
	M61	M62	M63
	M64	M65	M66
CØNM2 (13 words)	EID	G	CID
	M	X1	X2
	X3	I11	I21
	I22	I31	I32
	I33		
CØNRØD (8 words)	EID	G1	G2
	MID	A	J
	C	NSM	

Card Type Formats Cont'd.:

CQDMEM (7 words)	EID	PID	G1
	G2	G3	G4
	TH		
CQDPLT (7 words)	EID	PID	G1
	G2	G3	G4
	TH		
CQUAD1 (7 words)	EID	PID	G1
	G2	G3	G4
	TH		
CQUAD2 (7 words)	EID	PID	G1
	G2	G3	G4
	TH		
CRØD (4 words)	EID	PID	G1
	G2		
CSHEAR (6 words)	EID	PID	G1
	G2	G3	G4
CSLØT3 (8 words)	EID	G1	G2
	G3	RHØ	B
	M	N	
CSLØT4 (9 words)	EID	G1	G2
	G3	G4	RHØ
	B	M	N
CTETRA (6 words)	EID	MID	G1
	G2	G3	G4
CTØRDRG (7 words)	EID	PID	G1
	G2	A1	A2
	O		
CTRAPRG (7 words)	EID	G1	G2
	G3	G4	TH
	MID		
CTRBSC (6 words)	EID	PID	G1
	G2	G3	TH
CTRIA1 (6 words)	EID	PID	G1
	G2	G3	TH
CTRIA2 (6 words)	EID	PID	G1
	G2	G3	TH
CTRIARG (6 words)	EID	G1	G2
	G3	TH	MID
CTRMEM (6 words)	EID	PID	G1
	G2	G3	TH
CTRPLT (6 words)	EID	PID	G1
	G2	G3	TH
CTUBE (4 words)	EID	PID	G1
	G2		

Card Type Formats Cont'd.:

CTWIST (6 words)	EID	PID	G1
	G2	G3	G4
CVISC (4 words)	EID	PID	G1
	G2		
CWEDGE (8 words)	EID	MID	G1
	G2	G3	G4
	G5	G6	
GENEL (open ended)	EID	UI1	CI1
	UI2	CI2	...
	UIM	CIM	-1
	M	UD1	CD1
	UD2	CD2	...
	UDN	CDN	-1
	N	Z11	Z21
	Z22	Z31	Z32
	Z33	...	ZMM
	N	S11	S12
	...	S1N	S21
	S22	...	S2N
	...	SM1	SM2
	...	SMN	
PLØTEL (3 words)	EID	G1	G2
SPØINT (1 word)	ID		

2.3.2.3 GEØM3 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
FØRCE	4201	42	18
FØRCE1	4001	40	20
FØRCE2	4101	41	22
GRAV	4401	44	26
LØAD	4551	61	84
MØMENT	4801	48	19
MØMENT1	4601	46	21
MØMENT2	4701	47	23
PLØAD	5101	51	24
PLØAD1*	6909	69	198
PLØAD2	6802	68	199
QHBDY	4309	43	233
RFØRCE	5509	55	190
SLØAD	5401	54	25
TEMP	5701	57	27
TEMPD	5641	65	98
TEMPP1	8109	81	201
TEMPP2	8209	82	202
TEMPP3	8309	83	203
TEMPRB	8409	84	204

Card Type Formats:

FØRCE (7 words)	SID	G	CID
	F	N1	N2
	N3		
FØRCE1 (5 words)	SID	G	F
	G1	G2	
FØRCE2 (7 words)	SID	G	F
	G1	G2	G3
	G4		
GRAV (6 words)	SID	CID	G
	N1	N2	N3
LØAD (open ended)	SID	S	S1
	L1	S2	L2
	...	S_n	L_n
	-1	-1	
MØMENT (7 words)	SID	G	CID
	M	N1	N2
	N3		
MØMENT1 (5 words)	SID	G	M
	G1	G2	
MØMENT2 (7 words)	SID	G	M
	G1	G2	G3
	G4		

Card Type Formats Cont'd.:

PLØAD (6 words)	SID	P	G1
	G2	G3	G4
PLØAD1* Not available			
PLØAD2 (3 words)	SID	P	EID
QHBDY (8 words)	SID	FLAG	Q0
	AF	G1	G2
	G3	G4	
RFØRCE (7 words)	SID	G	CID
	A	N1	N2
	N3		
SLØAD (3 words)	SID	S	F
TEMP (3 words)	SID	G	T
TEMPD (2 words)	SID	T	
TEMPP1 (6 words)	SID	EID	T
	T'	T1	T2
TEMPP2 (8 words)	SID	EID	T
	MX	MY	MXY
	T1	T2	
TEMPP3 (24 words)	SID	EID	Z0
	T0	Z1	T1
	Z2	T2	Z3
	T3	Z4	T4
	Z5	T5	Z6
	T6	Z7	T7
	Z8	T8	Z9
	T9	Z10	T10
TEMPRB (16 words)	SID	EID	TA
	TB	T'1a	T'1b
	T'2a	T'2b	TCa
	TDa	TEa	TFa
	TCb	TDb	TEb
	TFb		

2.3.2.4 GEØM4 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
ASET	5561	76	215
ASET1	5571	77	216
MPC	4901	49	17
MPCADD	4891	60	83
ØMIT	5001	50	15
ØMIT1	4951	63	92
SPC	5501	55	16
SPC1	5481	58	12
SPCADD	5491	59	13
SUPØRT	5601	56	14
U1SET	110	41	167
U1SET1	1110	11	176
U2SET	210	2	168
U2SET1	1210	12	177
U3SET	310	3	169
U3SET1	1310	13	178
U4SET	410	4	170
U4SET1	1410	14	186
U5SET	500	5	171
U5SET1	1510	15	187
U6SET	610	6	172
U6SET1	1610	10	188
U7SET	710	7	173
U7SET1	1710	17	192
U8SET	810	8	174
U8SET1	1810	18	193
U9SET	910	9	175
U9SET1	1910	19	194

Card Type Formats:

ASET (2 words)	ID	C	
ASET1 (open ended)	C	G	G
	...	G	-1
MPC (open ended)	SID	G	C
	A	G	C
	A	...	G
	C	A	-1
	-1	-1	
MPCADD (open ended)	SID	S1	S2
	...	S_n	-1
ØMIT (2 words)	ID	C	

The note below concerning the ØMIT card applies to the ASET card as well.

Components can be input in any unique combination of digits 1-6. Output format will be ID and one digit, the digits for any one entry being in sort.

Example:	ID	C
	12	3516

Card Type Formats Cont'd.:

Output as:	12 3 12	1 12 6	12 5
ØMIT1 (open ended)	C ...	G G	G -1
SPC (4 words)	SID D	G	C
SPC1 (open ended)	SID G2 -1	C ...	G1 G_n
SPCADD (open ended)	SID ...	S1 S_n	S2 -1
SUPØRT (2 words)	ID	C	

The note above concerning the ØMIT card applies to the SUPØRT card as well.

U1SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U1SET card as well.

U1SET1 (open ended)	C ...	G G	G -1
U2SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U2SET card as well.

U2SET1 (open ended)	C ...	G G	G -1
U3SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U3SET card as well.

U3SET1 (open ended)	C ...	G G	G -1
U4SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U4SET card as well.

U4SET1 (open ended)	C ...	G G	G -1
U5SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U5SET card as well.

U5SET1 (open ended)	C ...	G G	G -1
U6SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U6SET card as well.

U6SET1 (open ended)	C ...	G G	G -1

Card Type Formats Cont'd.:

U7SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U7SET card as well.

U7SET1 (open ended)	C	G	G
	...	G	-1

U8SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U8SET card as well.

U8SET1 (open ended)	C	G	G
	...	G	-1

U9SET (2 words)	ID	C	

The note above concerning the ØMIT card applies to the U9SET card as well.

U9SET1 (open ended)	C	G	G
	...	G	-1

2.3.2.5 EPT (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
PBAR	52	20	181
PCØNEAX	152	19	147
PDAMP	402	2	45
PDUM1	6102	61	116
PDUM2	6202	62	117
PDUM3	6302	63	118
PDUM4	6402	64	159
PDUM5	6502	65	160
PDUM6	6602	66	161
PDUM7	6702	67	163
PDUM8	6802	68	164
PDUM9	6902	69	165
PELAS	302	3	46
PMASS	402	4	44
PQDMEM	502	5	41
PQDPLT	602	6	40
PQUAD1	702	7	38
PQUAD2	802	8	39
PRØD	902	9	29
PSHEAR	1002	10	42
PTØRDRG	2102	21	121
PTRBSC	1102	11	35
PTRIA1	1202	12	33
PTRIA2	1302	13	34
PTRMEM	1402	14	37
PTRPLT	1502	15	36
PTUBE	1602	16	30
PTWIST	1702	17	43
PVISC	1802	18	31

Card Type Formats:

PBAR (19 words)	PID	MID	A
	I1	I2	J
	NSM	FE	C1
	C2	D1	D2
	E1	E2	F1
	F2	K1	K2
	I12		
PCØNEAX (24 words)	ID	MID1	T1
	MID2	I	MID3
	T2	NSM	Z1
	Z2	PHI1	PHI2
	PHI3	PHI4	PHI5
	PHI6	PHI7	PHI8
	PHI9	PHI10	PHI11
	PHI12	PHI13	PHI14
PDAMP (2 words)	PID	B	

Card Type Formats Cont'd.:

PDUMi (variable number of words, depending on the contents of the ADUMi card)

PELAS (4 words)	PID	K	GE
	S		
PMASS (2 words)	PID	M	
PQDMEM (4 words)	PID	MID	T
	NSM		
PQDPLT (8 words)	PID	MID1	I
	MID2	T	NSM
	Z1	Z2	
PQUAD1 (10 words)	PID	MID1	T1
	MID2	I	MID3
	T3	NSM	Z1
	Z2		
PQUAD2 (4 words)	PID	MID	T
	NSM		
PRØD (6 words)	PID	MID	A
	J	C	NSM
PSHEAR (4 words)	PID	MID	T
	NSM		
PTØRDRG (4 words)	PID	MID	TM
	TF		
PTRBSC (8 words)	PID	MID1	I
	MID2	T	NSM
	Z1	Z2	
PTRIA1 (10 words)	PID	MID1	T1
	MID2	I	MID3
	T3	NSM	Z1
	Z2		
PTRIA2 (4 words)	PID	MID	T
	NSM		
PTRMEM (4 words)	PID	MID	T
	NSM		
PTRPLT (8 words)	PID	MID1	I
	MID2	T2	NSM
	Z1	Z2	
PTUBE (5 words)	PID	MID	ØD
	T	NSM	
PTWIST (4 words)	PID	MID	T
	NSM		
PVISC (3 words)	PID	C1	C2

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2.3.2.6 MPT (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
DSFACT	53	10	143
MAT1	103	1	77
MAT2	203	2	78
MAT3	1403	14	122
MAT4	2103	21	234
MAT5	2203	22	235
MATS1	503	5	90
MATT1	703	7	91
MATT2	803	8	102
MATT3	1503	15	189
PLFACT	1103	11	185

Card Type Formats:

DSFACT (open ended)	SID	B1	B2
	...	B_n	-1
MAT1 (11 words)	MID	E	G
	NU	RHØ	A
	TREF	GE	ST
	SC	SS	

If any one of E, G or NU is blank, it will be computed to satisfy the identity E = 2 (1+NU)G; otherwise, values supplied by the user will be used.

MAT2 (16 words)	MID	G11	G12
	G13	G22	G23
	G33	RHØ	A1
	A2	A12	TO
	GE	ST	SC
	SS		
MAT3 (16 words)	MID	EX	EY
	EZ	NUXY	NUYZ
	NUZX	RHØ	GXY
	GYZ	GZX	AX
	AY	AZ	TREF
	GE		
MAT4 (3 words)	MID	K	0
MAT5 (8 words)	MID	KXX	KXY
	KXZ	KYY	KYZ
	KZZ	0	
MATS1 (11 words)	MID	R1	R2
	R3	R4	...
	R10		
MATT1 (11 words)	MID	R1	R2
	R3	R4	...
	R10		

Card Type Formats Cont'd.:

MATT2 (16 words)	MID	R1	R2
	R3	R4	...
	R15		
MATT3 (16 words)	MID	R1	R2
	R3	R4	...
	R15		
PLFACT (open ended)	SID	B1	B2
	...	B_n	-1

2.3.2.7 DIT (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
TABDMP1	15	21	162
TABLED1	1105	11	133
TABLED2	1205	12	134
TABLED3	1305	13	140
TABLED4	1405	14	141
TABLEM1	105	1	93
TABLEM2	205	2	94
TABLEM3	305	3	95
TABLEM4	405	4	96
TABLES1	3105	31	97
TABRND1	55	25	191

Card Type Formats:

TABDMP1 (open ended)	ID	0	0
	0	0	0
	0	0	f_1
	g_1	f_2	g_2
	...	f_n	g_n
	-1	-1	
TABLED1 (open ended)	ID	0	0
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLED2 (open ended)	ID	X1	0
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLED3 (open ended)	ID	X1	X2
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLED4 (open ended)	ID	X1	X2
	X3	X4	0
	0	0	A_0
	A_1	A_2	...
	A_n	-1	

Card Type Formats Cont'd.:

TABLEM1 (open ended)	ID	0	0
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLEM2 (open ended)	ID	X1	0
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLEM3 (open ended)	ID	X1	X2
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABLEM4 (open ended)	ID	X1	X2
	X3	X4	0
	0	0	A_0
	A_1	A_2	...
	A_n	-1	
TABLES1 (open ended)	ID	0	0
	0	0	0
	0	0	x_1
	y_1	x_2	y_2
	...	x_n	y_n
	-1	-1	
TABRND1 (open ended)	ID	0	0
	0	0	0
	0	0	f_1
	g_1	f_2	g_2
	...	f_n	g_n
	-1	-1	

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2.3.2.8 EDT (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
DEFØRM	104	1	81

Card Type Formats:

DEFØRM (3 words)	SID	EID	D

2.3.2.9 DYNAMICS (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
DAREA	27	17	182
DELAY	37	18	183
DLØAD	57	5	123
DPHASE	77	19	184
EIGB	107	1	86
EIGC	207	2	87
EIGP	257	4	158
EIGR	307	3	85
EPØINT	707	7	124
FREQ	1307	13	126
FREQ1	1007	10	125
FREQ2	1107	11	166
NØLIN1	3107	31	127
NØLIN2	3207	32	128
NØLIN3	3307	33	129
NØLIN4	3407	34	130
RANDPS	2107	21	195
RANDT1	2207	22	196
RANDT2*	2307	23	197
RLØAD1	5107	51	131
RLØAD2	5207	52	132
SEQEP	5707	57	135
TF	6207	62	136
TIC	6607	66	137
TLØAD1	7107	71	138
TLØAD2	7207	72	139
TSTEP	8307	83	142

Card Type Formats:

DAREA (4 words)	SID A	P	C
DELAY (4 words)	SID T	P	C
DLØAD (open ended)	SID L1 ... -1	S S2 S_n -1	S1 L2 L_n
PHASE (4 words)	SID TH	P	C
EIGB (18 words)	SID L2 NDN G 0 0	METHØD (2 words) NEP E C 0	L1 NDP NØRM (2 words) 0 0

Card Type Formats Cont'd.:

EIGC (open ended)	SID	METHØD (2 words)	NØRM (2 words)
	G	C	E
	α_{a1}	ω_{a1}	α_{b1}
	ω_{b1}	ℓ_1	N_{e1}
	N_{d1}	α_{a2}	ω_{a2}
	α_{b2}	ω_{b2}	ℓ_2
	N_{e2}	N_{d2}	...
	α_{an}	ω_{an}	α_{bn}
	ω_{bn}	ℓ_n	N_{en}
	N_{dn}	-1	-1
	-1	-1	-1
	-1	-1	
EIGP (4 words)	SID	α	ω
	M		
EIGR (18 words)	SID	METHØD (2 words)	F1
	F2	NE	ND
	NZ	E	NØRM (2 words)
	G	C	0
	0	0	0
	0		
EPØINT (1 word)	ID		
FREQ (open ended)	SID	F	F
	F	...	F
	-1		
FREQ1 (4 words)	SID	F1	DF
	NDF		
FREQ2 (4 words)	SID	F1	F2
	NF		
NØLIN1 (8 words)	SID	GI	CI
	S	GJ	CJ
	T	0	
NØLIN2 (8 words)	SID	GI	CI
	S	GJ	CJ
	GK	CK	
NØLIN3 (8 words)	SID	GI	CI
	S	GJ	CJ
	A	0	
NØLIN4 (8 words)	SID	GI	CI
	S	GJ	CJ
	A	0	
RANDPS (6 words)	SID	J	K
	X	Y	TID

Card Type Formats Cont'd.:

RANDT1 (4 words)	SID	N	TO
	TMAX		
RANDT2* Not available			
RLØAD1 (6 words)	SID	L	M
	N	TC	TD
RLØAD2 (6 words)	SID	L	M
	N	TB	TP
SEQEP (2 words)	ID	SEQID	
TF (open ended)	SID	GD	CD
	BO	B1	B2
	G(1)	C(1)	AO(1)
	A1(1)	A2(1)	G(2)
	C(2)	AO(2)	A1(2)
	A2(2)	...	G(N)
	C(N)	AO(N)	A1(N)
	A2(N)	-1	-1
	-1	-1	-1
TIC (5 words)	SID	G	C
	UO	VO	
TLØAD1 (5 words)	SID	L	M
	0	TF	
TLØAD2 (10 words)	SID	L	M
	0	T1	T2
	F	P	C
	B		
TSTEP (open ended)	SID	N(1)	DT(1)
	NØ(1)	N(2)	DT(2)
	NØ(2)	...	N(N)
	DT(N)	NØ(N)	-1
	-1	-1	

2.3.2.10 MATPØØL (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
DMIAX	214	2	221
DMIG	114	1	120
BNDFL	9614	96	0**

Card Type Formats:

DMIAX (open ended)			NAME (2 words)		0	IFØ	TIN	TØUT	Header Information for the matrix (9 words)
			0		0	0			
GJ	CJ	NJ	GI	CI	NI	V*			
			GI	CI	NI	V*			
			.	.	.	.			Non-zero terms of the first non-zero column
			.	.	.	.			
			.	.	.	.			
			GI	CI	NI	V*			
			-1	-1	-1				End of column indicators
GJ	CJ	NJ	GI	CI	NI	V*			
			GI	CI	NI	V*			
			.	.	.	.			Non-zero terms of the second non-zero column
			.	.	.	.			
			.	.	.	.			
			GI	CI	NI	V*			
			-1	-1	-1				End of column indicators
.									
.									
.									
GJ	CJ	NJ	GI	CI	NI	V*			
			GI	CI	NI	V*			
			.	.	.	.			Non-zero terms of the last non-zero column
			.	.	.	.			
			.	.	.	.			
			GI	CI	NI	V*			
			-1	-1	-1				End of column indicators
-1	-1	-1							End of matrix indicators

*V may be 1, 2, or 4 words depending on TIN.

**Generated by IFP3, IFP4 or IFP5.

Card Type Formats Cont'd.:

DMIG (open ended)	NAME (2 words)		0	IFØ	TIN	TØUT	Header Information for the matrix (9 words)
	0		0	0			
GJ	CJ	GI	CI		V*		
		GI	CI		V*		
		.	.		.		Non-zero terms of the first non-zero column
		.	.		.		
		.	.		.		
		GI	CI		V*		
		-1	-1				End of column indicators
GJ	CJ	GI	CI		V*		
		GI	CI		V*		
		.	.		.		Non-zero terms of the second non-zero column
		.	.		.		
		.	.		.		
		GI	CI		V*		
		-1	-1				End of column indicators
.							
.							
.							
GJ	CJ	GI	CI		V*		
		GI	CI		V*		
		.	.		.		Non-zero terms of the last non-zero column
		.	.		.		
		.	.		.		
		GI	CI		V*		
		-1	-1				End of column indicators
-1	-1						

*V may be 1, 2, or 4 words depending on TIN.

BNDFL (open ended)

CS_f	g	ρ	B	NØSYM	Header Information
M	S1	S2	NHARM	N1.....	
Id_{f1}	r	z	ℓ	c	Fluid point data
	s	ρ			
	G_1	ϕ_1			Surface grid point Id's and azimuth angles.
	G_2	ϕ_2			
	G_3	ϕ_3			
	:				
-1	-1	End of data for fluid point			
Id_{f2}	r	z	ℓ	c	Fluid point data
	s	ρ			
	.				
	.				
	etc.				
-1	-1	-1	End of Record		

2.3.2.11 AXIC (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
Conical Shell			
AXIC	515	5	144
CCØNEAX	2315	23	146
FØRCEAX	2115	21	156
MØMAX	3815	38	157
MPCAX	4015	40	149
ØMITAX	4315	43	150
PØINTAX	4915	49	152
PRESAX	5215	52	154
RINGAX	5615	56	145
SECTAX	6015	60	153
SPCAX	6215	62	148
SUPAX	6415	64	151
TEMPAX	6815	68	155
Hydroelastic			
AXIF	8815	88	212
BDYLIST	8915	89	213
CFLUID2	8515	85	209
CFLUID3	8615	86	210
CFLUID4	8715	87	211
FLSYM	9115	91	222
FREEPT	9015	90	214
FSLIST	8215	82	206
GRIDB	8115	81	205
PRESPT	8415	84	208
RINGFL	8315	83	207
Acoustic Cavity			
AXSLØT	1115	11	223
GRIDF	1215	12	229
GRIDS	1315	13	230
SLBDY	1415	14	231

Card Type Formats:

Conical Shell

AXIC (2 words)	H	O	
CCØNEAX (4 words)	ID	PID	RA
	RB		
FØRCEAX (8 words)	SID	RID	HID1
	HID2	S	FR
	FP	FZ	
MØMAX (8 words)	SID	RID	HID1
	HID2	S	MR
	MP	MZ	

Card Type Formats Cont'd.:

MPCAX (open ended)	SID C HID ... C -1	RID A C RID A -1	HID RID A HID -1 -1
ØMITAX (3 words)	RID	HID	C
PØINTAX (3 words)	ID	RID	PHI
PRESAX (6 words)	SID RID2	P PHI1	RID1 PHI2
RINGAX (4 words)	ID C	R	Z
SECTAX (5 words)	ID PHI1	RID PHI2	R
SPCAX (5 words)	SID C	RID V	HID
SUPAX (3 words)	RID	HID	C
TEMPAX (4 words)	SID TEMP	RID	PHI

Hydroelastic

AXIF (open ended)	CSF B N1	G NØSYM	RHØ NHARM -1
BDYLIST (open ended)	RHØ IDF	IDF	IDF -1
CFLUID2 (5 words)	ID RHØ	IDF B	IDF
CFLUID3 (6 words)	ID IDF	IDF RHØ	IDF B
CFLUID4 (7 words)	ID IDF B	IDF IDF	IDF RHØ
FLSYM (3 words)	M	S1	S2
FREEPT (3 words)	IDF	ID	PHI
FSLIST (open ended)	RHØ IDF	IDF	IDF -1
GRIDB (5 words)	ID PS	PHI IDF	CID

Card Type Formats Cont'd.:

PRESPT (3 words)	IDF	ID	PHI
RINGFL (4 words)	IDF X3	X1	X2

Acoustic Cavity

AXSLØT (5 words)	RHØ W	B M	N
GRIDF (3 words)	IDG	R	Z
GRIDS (5 words)	IDG W	R IDF	Z
SLBDY (open ended)	RHØ ID2	M ..... -1	ID1 ..... -1

THE INFORMATION FORMERLY ON THIS PAGE

HAS BEEN DELETED

2.3.3 Data Blocks Output From Module GP1

2.3.3.1 GPL (TABLE)

Description

Grid Point List.

First logical record contains a list of external grid and scalar numbers in internal sort. Second logical record contains pairs of external grid and scalar numbers and sequence numbers in internal sort.

Table Format

Record	Word	Item	
0		Header record	
1	1	External grid or scalar number	repeated for each grid or scalar point in model
2	1	External grid or scalar number	repeated for each grid or scalar point in model
	2	Sequence number	
3		End-of-file	

Notes

1. Internal is implied by word position in record one.
2. Sequence number = 1000 * external number unless replaced by a new sequence number on a SEQGP card.
3. All data words are integers.

Table Trailer

Word 1 = number of external grid points + number of scalar points.

Word 2-6 = zero.

2.3.3.2 EQEXIN (TABLE)

Description

Equivalence between external grid or scalar numbers and internal numbers.

First record contains pairs of external grid and scalar numbers and internal numbers in external sort. Second logical record contains pairs of external grid and scalar numbers and coded SIL numbers in external sort.

Table Format

Record	Word	Item	
0		Header record	
1	1	External grid or scalar number	repeated for each grid or scalar point in model
	2	Internal number	
2	1	External grid or scalar number	repeated for each grid or scalar point in model
	2	10*SIL number + code	
3		End-of-file	

Notes

1. All data words are integers.
2. Code = {1 for grid point; 2 for scalar point}

Table Trailer

Word 1 = number of grid points + number of scalar points.

Word 2-6 = zero.

2.3.3.3 GPDT (TABLE)

Description

Grid Point Definition Table.

One logical record contains list of all grid and scalar points with associated coordinate system and constraint information. List is in internal sort.

Table Format

Record	Word	Item	
0		Header record	
1	1	Internal number	repeated for each grid or scalar
	2	Coordinate system ID that defines x, y, z	
	3	$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$ or $\begin{pmatrix} R \\ \theta \\ z \end{pmatrix}$ or $\begin{pmatrix} \rho \\ \theta \\ \phi \end{pmatrix}$ depending on	
	4	defining coordinate	
	5	system	
	6	Coordinate system ID for displacements	
	7	Constraint code	
2		End-of-file	

Notes

1. Words 3-5 are single precision floating point; all other words are integer.
2. Scalar points are identified by coordinate system ID = -1, and words 3-7 are all zero.
3. See description of the GRID bulk data card in the User's Manual for a definition of the constraint code.
4. If a single degree of freedom, such as a hydroelastic fluid point, is desired, the integer -1, is used in position 6.

Table Trailer

Word 1 = number of grid points + number of scalar points.

Word 2-6 = zero.

2.3.3.4 CSTM (TABLE)

Description

Coordinate System Transformation Matrices.

One logical record contains all coordinate system transformations. Transformation is from global to basic by the following formulation:

(1) rectangular

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_B = \begin{pmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_g + \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}$$

(2) cylindrical

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_B = \begin{pmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix} \begin{pmatrix} R\cos\theta \\ R\sin\theta \\ z \end{pmatrix}_g + \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}$$

(3) spherical

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_B = \begin{pmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix} \begin{pmatrix} \rho\sin\theta\cos\Phi \\ \rho\sin\theta\sin\Phi \\ \rho\cos\theta \end{pmatrix}_g + \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}$$

Table Format

Record	Word	Item
0		Header record
1	1	Coordinate system ID
	2	Coordinate system type { 1 = rectangular, 2 = cylindrical, 3 = spherical }
	3-5	t_1, t_2, t_3
	6-14	r_{11}, r_{12}, r_{13}, r_{21}, r_{22}, r_{23}, r_{31}, r_{32}, r_{33}
		} repeated for each coordinate system
2		End-of-file

Notes

1. Coordinate system ID and coordinate system type are integers.

2. t_i and r_{ij} are single precision floating point.

Table Trailer

Word 1 = number of grid points + number of scalar points.

Word 2 = number of coordinate systems.

Word 3-6 = zero.

2.3.3.5 BGPDT (TABLE)

Description

Basic Grid Point Definition Table.

One logical record contains a list of all grid and scalar points in internal sort, with (for grid points) their x, y, z coordinates in the basic system along with a coordinate system ID for displacement computations.

Table Format

Record	Word	Item
0		Header record
1	1	Coordinate system ID } repeated for each
	2-4	x, y, z in basic system } grid or scalar point
2		End-of-file

Notes

1. Coordinate system ID is integer; x, y, z are single precision, floating point.

2. Scalar points are identified by coordinate system ID = -1, and x, y, z = 0.

Table Trailer

Word 1 = number of grid points + number of scalar points.

Word 2-6 = zero.

2.3.3.6 SIL (TABLE)

Description

Scalar Index List.

One logical record that contains a list of SIL numbers for each grid or scalar point. The list is in internal sort, therefore, internal number is implied by word position in the record. Definition of SIL numbers is as follows:

Let i = internal number, then

$$SIL_1 = 1,$$

$$SIL_{i+1} = \begin{cases} SIL_i + 6 & \text{if } i = \text{grid point} \\ SIL_i + 1 & \text{if } i = \text{scalar point} \end{cases}$$

Table Format

Record	Word	Item
0		Header record
1	1	SIL_1
	⋮	⋮
	n	SIL_n
2		End-of-file

Notes

SIL numbers are integers.

Table Trailer

Word 1 = number of grid points + number of scalar points.

Word 2 = degrees of freedom in the g-displacement set.

Word 3-6 = zero.

2.3.4 Data Blocks Output From Module GP2

2.3.4.1 ECT (TABLE)

Description

Element Connection Table.

The ECT contains one logical record for each element connection card type that has been input. Additionally, the ECT contains one logical record for GENEL elements if they have been input.

Table Format

The ECT is identical in format to data block GEØM2, output from module IFP. All external grid or scalar numbers are replaced by internal numbers. SPØINT data is not copied on the ECT.

Table Trailer

Identical to trailer on GEØM2 data block.

2.3.5 Data Blocks Output From Module PLTSET

2.3.5.1 PLTSETX (TABLE)

Description

User error messages related to the definition of element plot sets for the structure plotter.

Table Format

See the description of the MESSAGE table, section 2.3.5.5.

Note

PLTSETX is generated in subroutine SETINP.

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.5.2 PLTPAR (TABLE)

Description

Plot parameters and plot control table.

Table Format

Record	Word	Item
0		Header record
1 2 3 etc.		Duplicate of the plot control data block (PCDB) created in the IFP1 module except that all plot set definitions have been deleted.
Last		End-of-file

Note

PLTPAR is generated in subroutine SETINP.

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.5.3 GPSETS (TABLE)

Description

Grid point sets related to the element plot sets.

Table Format

Record	Word	Item
0		Header record
1	1-NSETS	Element plot set ID's (integer)
2-(NSETS+1)	1	Number of grid points in an element set
	2-(NGP+1)	Pointers to the grid points in this element set (integers) 1 If = 0, the grid point is not in this set 2 If ≠ 0, this is an internal index relative to only the grid points in this element set (if negative, this grid point is to be excluded when used to draw deformed shapes and vectors)
NSETS+2		End-of-file

Notes

1. NSETS = number of element sets
2. NGP = total number of structural grid points
3. GPSETS is generated in subroutines SETINP and CNSTRC

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.5.4 ELSETS (TABLE)

Description

Element plot set connection tables.

Table Format

Record	Group	Word	Item
0			Header record
1-NSETS	1-NTYPS	1	Number of grid points per element of a given element type (integer) Note: If less than 3 or negative, this element type does not define a closed area.
		2-(N+1)	Grid point indices relative to all grid points defining each element of this type (integers)
		N+2	Integer zero
NSETS+1			End-of-file

Notes

1. NSETS = number of element plot sets
2. NTYPS = number of element types represented in an element plot set
3. N = number of connection grid points for all elements of a given type in an element plot set
   = (number of grid points per element of a given type) X (number of elements of a given type in an element set)
4. ELSETS is generated in subroutine CNSTRC

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.5.5 MESSAGE (TABLE)

Description

Messages to be processed by the message writer module (PRTMSG). Each message may either be a physical or logical record. This data block is never really created as such, but is included so as to explain other data blocks such as PLØTX1, PLØTX2, etc., and is referenced in the Table Formats of these data blocks.

Table Format

Record	Word	Item
0		Header record

A given logical record in a given physical record can be of two alternate forms

A.

Record	Word	Item
i	j	If = -1, -2, -3, -4, -5, or -6, then the next 32 words is a new title for the 1st, 2nd, 3rd, 4th, 5th, or 6th lines on all printed pages to follow from this message table (integer)
	(j+1)-(j+32)	The 32 4-character BCD words for this title

B.

Record	Word	Item
i	j	NLIST = number of list items (integer)
	(j+1)-(j+NLIST)	List items (mixed mode)
	j+NLIST+1	NF = size of format to be used to print these list items (integer)
	(j+NLIST+2)-(j+NLIST+NF+1)	Format to be used to print this list (series of consecutive BCD characters)

2.3.6 Data Blocks Output From Module PLØT

2.3.6.1 PLØTX1 (TABLE)

Description

User messages from the plot module relative to the undeformed structural shapes

Table Format

See the description of the MESSAGE table, section 2.3.5.5

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.6.2 PLØTX2 (TABLE)

Description

User messages from the plot module relative to the deformed structural shapes generated in the statics analysis

Table Format

See the description of the MESSAGE table, section 2.3.5.5

Table Trailer

Word 1-5 = 0
Word 6 = 1

2.3.7 Data Blocks Output From Module GP3

2.3.7.1 SLT (TABLE)

Description

Static Loads Table.

The header record of the SLT contains a sorted list of all unique load set ID's contained on static load cards except the LØAD card itself. The n logical records that follow the header record comprise all static loads data belonging to each of the n load sets, one logical record per load set. The (n+1)st logical record contains all LØAD cards (if any).

Table Format

Record	Word	Type	Item	
0	1-2	B	Data block name	
	3	I	Load set ID_1	
	⋮		⋮	
	2+n	I	Load set ID_n	
1	1,2	I	Load card type, m	repeated for each different load card type belonging to load set number 1
	3		Load data as function of load card type... repeated m times	
	⋮			
	2+m			
⋮				
n			Same format as record 1 Data belongs to load set number n	
n+1	1,2	I,R	Combination load Id, Overall scale factor	repeated for each LØAD card
	3,4	R,I	Scale factor, load set ID	
	5,6	R,I	Scale factor, load set ID	
	2k+3,2k+4	I	-1, -1	
n+2			End-of-file	

Notes

1. The SLT is generated in subroutine GP3A.
2. Card type ID's and format for data for each bulk data card type are as follows:

   3 = FØRCE1

Word	Type	Item
1	I	Internal grid number
2	R	Signed magnitude of applied load
3-4	I	Internal grid numbers of grid points that define direction

5 = FØRCE2

Word	Type	Item
1	I	Internal grid number
2	R	Signed magnitude of applied load
3-6	I	Internal grid numbers of grid points that define direction

1 = FØRCE

Word	Type	Item
1	I	Internal grid number
2	I	Coordinate system ID
3	R	Signed scale factor for applied force
4-6	R	Force components

8 = GRAV

Word	Type	Item
1	I	Coordinate system ID
2	R	Gravity vector scale factor
3-5	R	Gravity vector components

4 = MØMENT1

See FØRCE1, substituting "moment" for "force".

6 = MØMENT2

See FØRCE2, substituting "moment" for "force".

2 = MØMENT

See FØRCE, substituting "moment" for "force".

9 = PLØAD

Word	Type	Item
1	R	Pressure
2-5	I	Internal grid numbers

7 = SLØAD

Word	Type	Item
1	I	Internal scalar number
2	R	Applied load

10 = RFØRCE

Word	Type	Item
1	I	Internal grid number
2	I	Coordinate system ID
3	R	Scale factor
4-6	R	Components of rotation direction vector

11 = PRESAX

Word	Type	Item
1	R	Pressure value
2-3	I	Ring ID's
4-5	R	Azimuthal angles
6	I	Number of harmonics

3. With the exception of GRAV and PLØAD card types, data of a given card type within a logical record is in sort on internal grid (or scalar) number at which the load is applied.

4. If no LØAD cards have been input, the (n+1)st record does not exist.

Table Trailer

Word 1 = number of load sets.

Word 2-6 = zero.

2.3.7.2 GPTT (TABLE)

Description

Grid Point Temperature Table.

The header record of the GPTT contains sorted triples of temperature set ID, default temperature, and flag. For each temperature set for which temperature data is defined at the grid points or structural elements, a logical record of the GPTT is present.

Table Format

Record	Word	Item	
0	1-2	Data block name (BCD)	
	3	Temperature set ID, (integer)	repeated for each temperature set
	4	Default temperature (floating point) -1 if no default temperature defined (integer)	
	5	0 if only default temperature for set (integer) >0 record number of temperature data for set (integer)	
1	1	Temperature set ID	Repeats for all element types in problem.
	2	Element type	
	3	Element type count of temperature data (number of values for element ID)	
	4	Element ID	
	5 . . . 5+count-1	Temperature values (nonexistent if element ID is negative)	Repeats for all elements of element type in problem.
	0	Flag indicating end of element data for element type.	
: : k		Same format as record 1	
k+1		End-of-file	

Notes

1. The GPTT is generated in subroutine GP3D.
2. A temperature set may be defined as consisting only of a default temperature that applies to all grid points, and thus elements connecting those grid points.
3. A default temperature (if defined) is to apply to all grid points for which a temperature has not been defined.

Table Trailer

Trailer contains no specific information.

2.3.8 Data Blocks Output From Module TA1

2.3.8.1 EST (TABLE)

Description

Element Summary Table.

The EST is a collection of data for all elements of the structural model. It contains one logical record for each element type. For each element: connection data, properties data, basic grid point data and the element temperature are grouped. General elements and elements that belong to super elements are not included in the EST.

Table Format

Record	Word	Type	Item		
0			Header record		
1	1	I	Element type		repeated for each element type
	2-i+1		ECT section	repeated for each element	
	i+2-i+j+1		EPT section		
	i+j+2-i+j+k+1		BGPDT section		
	i+j+k+2		Element temperature		
n+1			End-of-file		

Notes

1. i = number of words in ECT section.
   j = number of words in EPT section.
   k = number of words in BGPDT section.
2. The number of records in the EST corresponds to the number of separate element types in the model.
3. The EST is generated in subroutine TA1A.

Summary of EST Formats

Element Type	Mnemonic	ECT Section Number of Words	EPT Section Number of Words	BGPDT Section Number of Words	Element Temperature	Total Words Per Element
1	ROD	3	5	8	Yes	17
2	BEAM	19	19	8	Yes	47
3	TUBE	3	4	8	Yes	16
4	SHEAR	5	3	16	Yes	25
5	TWIST	5	3	16	Yes	25
6	TRIA1	5	9	12	Yes	27
7	TRBSC	5	7	12	Yes	25
8	TRPLT	5	7	12	Yes	25
9	TRMEM	5	3	12	Yes	21
10	CONROD	8	0	8	Yes	17
11	ELAS1	5	3	0	No	8
12	ELAS2	8	0	0	No	8
13	ELAS3	3	3	0	No	6
14	ELAS4	4	0	0	No	4
15	QDPLT	6	7	16	Yes	30
16	QDMEM	6	3	16	Yes	26
17	TRIA2	5	3	12	Yes	21

Element Type	Mnemonic	ECT Section Number of Words	EPT Section Number of Words	BGPDT Section Number of Words	Element Temperature	Total Words Per Element
18	QUAD2	6	3	16	Yes	26
19	QUAD1	6	9	16	Yes	32
20	DAMP1	5	1	0	No	6
21	DAMP2	6	0	0	No	6
22	DAMP3	3	1	0	No	4
23	DAMP4	4	0	0	No	4
24	VISC	3	2	8	Yes	14
25	MASS1	5	1	0	No	6
26	MASS2	6	0	0	No	6
27	MASS3	3	1	0	No	4
28	MASS4	4	0	0	No	4
29	CØNM1	24	0	4	Yes	29
30	CØNM2	13	0	4	Yes	18
31	PLØTEL	3	0	8	Yes	12
34	BAR	15	18	8	Yes	42
35	CØNEAX	3	23	8	Yes	35
36	TRIARG	6	0	12	Yes	19
37	TRAPRG	7	0	16	Yes	24
38	TØRDRG	6	3	2	Yes	18
39	TETRA	5	0	17	Yes	23
40	WEDGE	7	0	25	Yes	33
41	HEXA1	9	0	33	Yes	43
42	HEXA2	9	0	33	Yes	43
43	FLUID2	6	0	8	No	14
44	FLUID3	7	0	12	No	19
45	FLUID4	8	0	16	No	24
46	IFREE	5	0	8	No	13
47	AXIF2	6	0	8	No	14
48	AXIF3	7	0	12	No	19
49	AXIF4	8	0	16	No	24
50	SLØT3	9	0	12	No	21
51	SLØT4	10	0	16	No	26
52	IHBDY	7	0	17	Yes	25
53	DUM1	*	*	*	Yes	*
54	DUM2	*	*	*	Yes	*
55	DUM3	*	*	*	Yes	*
56	DUM4	*	*	*	Yes	*
57	DUM5	*	*	*	Yes	*
58	DUM6	*	*	*	Yes	*
59	DUM7	*	*	*	Yes	*
60	DUM8	*	*	*	Yes	*
61	DUM9	*	*	*	Yes	*

*For the dummy elements, DUM1 thru DUM9, these values are determined at execution time upon presence of the respective ADUM1 thru ADUM9 bulk data cards.

We have from the ADUMi card thus;

GN = Number of grid points connected by PUMi

NC = Number of additional connection card values found on the CDUMi card in addition to the element ID, property or material ID, and GN = count of grid ID's.

NP = Number of additional property card values, found on the PDUMi card in addition to the property ID and material ID.

The number of words in the BGPDT section is then 4 times GN.

The number of words in the EPT section is then 1 + NP if NP is greater than zero, or is zero otherwise.

The number of words in the ECT section is then 1 + GN if NP is given greater than zero or is 2 + GN if NP is zero.

The total number of words is then the total of the ECT section plus the EPT section plus the BGPDT section plus 1 for the temperature.

Detailed EST Formats

ECT section for element type = 2:

Word	Type	Item
1	I	Element ID
2-3	I	SIL numbers for grid points 1, 2
4-6	R	x, y, z (orientation vector)
7	I	Coordinate system ID for x, y, z
8-9	I	P_a, P_b
10-12	R	Z_a^1, Z_a^2, Z_a^3
13-15	R	Z_b^1, Z_b^2, Z_b^3
16-19	R	g_1, g_2, g_3, g_4

ECT Section for element type = 1, 3, 24, 31:

Word	Type	Item
1	I	Element ID
2-3	I	SIL number for grid points 1, 2

ECT Section for element type = 4, 5:

Word	Type	Item
1	I	Element ID
2-5	I	SIL numbers for grid points 1, 2, 3, 4

ECT section for element type = 6, 7, 8, 9, 17:

Word	Type	Item
1	I	Element ID
2-4	I	SIL numbers for grid points 1, 2, 3
5	R	θ (degrees)

ECT section for element type = 15, 16, 18, 19:

Word	Type	Item
1	I	Element ID
2-5	I	SIL numbers for grid points 1, 2, 3, 4
6	R	θ (degrees)

ECT section for element type = 10:

Word	Type	Item
1	I	Element ID
2-3	I	SIL numbers for grid points 1, 2
4	I	Material ID
5	R	A
6	R	J
7	R	C
8	R	non-structural mass (nsm)

ECT section for element type = 11, 20, 25:

Word	Type	Item
1	I	Element ID
2-3	I	SIL numbers for grid points 1, 2
4-5	I	Component codes for grid points 1, 2

ECT section for element type = 12:

Word	Type	Item
1	I	Element ID
2	R	Value
3-4	I	SIL numbers for grid points 1, 2
5-6	I	Component codes for grid points 1, 2
7-8	R	g_e, S

ECT section for element type = 13, 22, 27:

Word	Type	Item
1	I	Element ID
2-3	I	SIL numbers for scalar points 1, 2

ECT section for element type = 14, 23, 28:

Word	Type	Item
1	I	Element ID
2	R	Value
3-4	I	SIL numbers for scalar points 1, 2

ECT section for element type = 21, 26:

Word	Type	Item
1	I	Element ID
2	R	Value
3-4	I	SIL numbers for grid points 1, 2
5-6	I	Component codes for grid points 1, 2

ECT section for element type = 29:

Word	Type	Item
1	I	Element ID
2	I	SIL number for grid point
3	I	Coordinate system ID
4-24	R	m_{11}, m_{21}, m_{22}, m_{31}, etc., (6x6 symmetric matrix)

ECT section for element type = 30:

Word	Type	Item
1	I	Element ID
2	I	SIL number for grid point
3	I	Coordinate system ID
4	R	m
5-7	R	x_1, x_2, x_3
8-13	R	I_{11}, I_{21}, I_{22}, I_{31}, I_{32}, I_{33}

ECT section for element type = 34:

Word	Type	Item
1	I	Element ID
2-3	I	SIL values for grid points 1, 2
4-6	R	X_1, X_2, X_3
7	I	Coordinate system ID for X_1, X_2, X_3
8-9	I	P_a, P_b
10-12	R	Z_a^1, Z_a^2, Z_a^3
13-15	R	Z_b^1, Z_b^2, Z_b^3

ECT section for element type = 35:

Word	Type	Item
1	I	Element ID
2-3	I	SIL values for rings 1, 2

ECT section for element type = 36:

Word	Type	Item
1	I	Element ID
2-4	I	SIL values for grid points 1, 2, 3
5	R	θ (degrees)
6	I	Material ID

ECT section for element type = 37:

Word	Type	Item
1	I	Element ID
2-5	I	SIL values for grid points 1, 2, 3, 4
6	R	θ (degrees)
7	I	Material ID

ECT section for element type = 38:

Word	Type	Item
1	I	Element ID
2-3	I	SIL values for grid points 1, 2
4-5	R	A_1, A_2
6		Not defined

ECT section for element type = 39:

Word	Type	Item
1	I	Element ID
2	I	Material ID
3-6	I	SIL values for grid points 1, 2, 3, 4

ECT section for element type = 40:

Word	Type	Item
1	I	Element ID
2	I	Material ID
3-8	I	SIL values for grid points 1, 2, 3, 4, 5, 6

ECT section for element type = 41, 42:

Word	Type	Item
1	I	Element ID
2	I	Material ID
3-10	I	SIL values for grid points 1, 2, 3, 4, 5, 6, 7, 8

ECT section for element type = 43:

Word	Type	Item
1	I	Element ID
2,3	I	SIL values for grid points 1, 2
4	R	Density, ρ
5	R	Bulk modulus, B
6	I	Harmonic Index, N

ECT section for element type = 44:

Word	Type	Item
1	I	Element ID
2-4	I	SIL values for grid points 1, 2, 3
5	R	Density, ρ
6	R	Bulk modulus, B
7	I	Harmonic Index, N

ECT section for element type = 45:

Word	Type	Item
1	I	Element ID
2-5	I	SIL values for grid points 1, 2, 3, 4
6	R	Density, ρ
7	R	Bulk modulus, B
8	I	Harmonic Index, N

ECT section for element type = 46:

Word	Type	Item
1	I	Element ID
2,3	I	SIL values for grid points 1,2
4	R	Weight density, ρ
5	I	Harmonic Index, N

ECT section for element type = 47:

Word	Type	Item
1	I	Element ID
2,3	I	SIL values for grid points 1, 2
4	R	Density, ρ
5	R	Bulk modulus, B
6	I	Harmonic Index, N

ECT section for element type = 48:

Word	Type	Item
1	I	Element ID
2,3,4	I	SIL values for grid points 1, 2, 3
5	R	Density, ρ
6	R	Bulk modulus, B
7	I	Harmonic Index, N

ECT section for element type = 49:

Word	Type	Item
1	I	Element ID
2,3,4,5	I	SIL values for grid points 1, 2, 3, 4
6	R	Density, ρ
7	R	Bulk modulus, B
8	I	Harmonic Index, N

ECT section for element type = 50:

Word	Type	Item
1	I	Element ID
2,3,4	I	SIL values for grid points 1, 2, 3
5	R	Density, ρ
6	R	Bulk modulus, B
7	I	Number of Slots, M
8	I	Harmonic Index, N

ECT section for element type = 51:

Word	Type	Item
1	I	Element ID
2,3,4,5	I	SIL values for grid points 1, 2, 3, 4
6	R	Density, ρ
7	R	Bulk modulus, B
8	I	Number of Slots, M
9	I	Harmonic Index, N

ECT section for element type = 52:

Word	Type	Item
1	I	Element ID
2	B	FLAG
3	R	H
4	R	AF
5-8	I	SIL values for grid points 1, 2, 3, 4

ECT section for element type = 53 thru 61:
(Refer to the note under the Table Summary of EST Formats above)

Word	Type	Item
1	I	Element ID
2	I	Material ID (NP=0)
3 thru (GN+2)	I	SIL values for GN grid points. (NP=0)
(GN+3) thru (GN+2+NC)	Mixed	Additional connection data as determined by the user-programmer (Present only if NC is greater than zero)

Note that if NP is given greater than zero, the material ID will appear in the EPT section and thus words 3 thru (GN+2+NC) will be shifted up by the 1 word removed.

EPT section for element type = 1:

Word	Type	Item
1	I	Material ID
2	R	A
3	R	J
4	R	C
5	R	nsm

EPT section for element type = 2:

Word	Type	Item
1	I	Material ID
2	R	A
3-4	R	I_1, I_2
5	R	J
6	R	nsm
7	I	Force Element Code (FE)
8-9	R	C_1, C_2
10-11	R	D_1, D_2
12-13	R	E_1, E_2
14-15	R	F_1, F_2
16-17	R	K_1, K_2
18	R	I_{12}
19		Not defined

EPT section for element type = 3:

Word	Type	Item
1	I	Material ID
2	R	O.D.
3	R	t
4	R	nsm

EPT section for element type = 4, 5, 9, 16, 17, 18:

Word	Type	Item
1	I	Material ID
2	R	t
3	R	nsm

EPT section for element type = 6, 19:

Word	Type	Item
1	I	Material ID for membrane
2	R	t_1
3	I	Material ID for bending
4	R	I
5	I	Material ID for transverse shear
6	R	t_2
7	R	nsm
8-9	R	Z_1, Z_2

EPT section for element type = 7, 8, 15:

Word	Type	Item
1	I	Material ID for bending
2	R	I
3	I	Material ID for transverse shear
4	R	t_2
5	R	nsm
6-7	R	Z_1, Z_2

EPT section for element type = 11, 13:

Word	Type	Item
1	R	K
2	R	g_e
3	R	s

EPT section for element type = 20, 22:

Word	Type	Item
1	R	B_e

EPT section for element type = 24:

Word	Type	Item
1	R	C_1
2	R	C_2

EPT section for element type = 25, 27:

Word	Type	Item
1	R	M_e

EPT section for element type = 33:

Word	Type	Item
1	I	Super element property ID

EPT section for element type = 34:

Word	Type	Item
1	I	Material ID
2	R	A
3-4	R	I_1, I_2
5	R	J
6	R	nsm
7	I	FE (Force Method only)
8-9	R	C_1, C_2
10-11	R	D_1, D_2
12-13	R	E_1, E_2
14-15	R	F_1, F_2
16-17	R	K_1, K_2
18	R	I_{12}

EPT section for element type = 35:

Word	Type	Item
1	I	Material ID for membrane
2R	R	T_1
3	I	Material ID for bending
4	R	I
5	I	Material ID for transverse shear
6	R	T_2
7	R	nsm
8-9	R	Z_1, Z_2
10-23	R	Φ_i, i = 1, 14

EPT section for element type = 38:

Word	Type	Item
1	I	Material ID
2	R	TM
3	R	TF

EPT section for element types = 53 thru 61:
(Refer to note under the table Summary of EST Formats above)

Word	Type	Item
1	I	Material ID
2 thru (1+NP)	Mixed	Property data determined by the user-programmer

The EPT section for element types 53 thru 61 is present only if NP is greater than zero as described above.

Table Trailer

Word 1 = number of elements in model.

Word 2-6 = are undefined.

2.3.8.2 GEI (TABLE)

Description

General Element Input.

The GEI contains one logical record for each general element in the model.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	ID for general element
	2	I	n = number of elements in U_I list
	3	I	m = number of elements in U_D list
	4	I	SIL value for first U_I
	⋮		
	3+n	I	SIL value for n^{th} U_I
	4+n	I	SIL value for first U_D
	⋮		⋮
	3+n+m	I	SIL value for m^{th} U_D (not present if m = 0)
	4+n+m	R	Elements of Z matrix
	⋮		
	$3+n+m+n^2$		
	$4+n+m+n^2$	R	Elements of S matrix
	⋮		
	$3+n+m+n^2+nm$		
2			Same format as record 1
⋮			
k			Same format as record 1
k+1			End-of-file

Table Trailer

Word 1 = number of general elements in the model.
Words 2-6 = zero.

2.3.8.3 ECPT (TABLE)

Description

Element Connection and Properties Table.

The ECPT is essentially the EST in a different sort. The ECPT contains one logical record for each grid or scalar point of the model. Each logical record contains Element Summary Table data for each element connected to the grid or scalar point.

Table Format

Record	Word	Item	
0		Header record	
1	1	SIL number for "pivot" grid or scalar point (integer)	repeated for each grid or scalar in the model
	2	Element type	repeated for each element connected to the pivot; repeated for each grid or scalar in the model
	3-i+2	ECT section	
	i+3-i+j+2	EPT section	
	i+j+3-i+j+k+2	BGPDT section	
	i+j+k+3	Element temperature	
n+1		End-of-file	

Notes

1. Detailed formats are given in the EST writeup (see section 2.3.8.1).
2. If no elements are connected to a grid or scalar point, the record contains only one word.

Table Trailer

Word 1 = 7

Word 2-6 = are undefined

2.3.8.4 GPCT (TABLE)

Description

Grid Point Connection Table.

The GPCT is a condensation of the ECPT. It contains one logical record for each grid or scalar point of the model. Each logical record contains a list of all grid or scalar points that are connected (by means of structural elements) to the pivot grid or scalar point.

Table Format

Record	Word	Item	
0		Header record	
1	1	± SIL number for pivot grid or scalar point (integer)	repeated for each grid or scalar in the model
	2	m = number of connected points (integer)	
	3-2+m	Sorted list of SIL numbers of connected points	
n+1		End-of-file	

Notes

1. If the SIL number for the pivot (first word) < 0, then the pivot is a scalar point.
2. If no elements are connected to the pivot (and therefore no other grid or scalar points), the record contains only one word.

Table Trailer

Word 1 = 7

Word 2-6 = are undefined

2.3.9 Data Blocks Output From Module SMA1

2.3.9.1 KGGX (MATRIX)

Description

$[K^{x}_{gg}]$ - Partition of stiffness matrix exclusive of general elements - g set.

Matrix Trailer

Number of columns = g
Number of rows = g
Form = symmetric
Type = real double precision

2.3.9.2 K4GG (MATRIX)

Description

$[K^{4}_{gg}]$ - Partition of structural damping matrix - g set.

Matrix Trailer

Number of columns = g
Number of rows = g
Form = symmetric
Type = real double precision

2.3.9.3 GPST (TABLE)

Description

Grid Point Singularity Table

Table Format

Record	Word	Item	
0		Header record	
1	1	Order of singularity (1, 2, or 3)	Repeated for each singularity
	2	N = number of SIL numbers that follow	
	3	SIL_1	
	4	SIL_2	
	.		
	.		
	.		
	2+N	SIL_N	
2		End-of-file	

Note

All entries are integers.

Table Trailer

Word 1 = undefined
Word 2 = 0
Word 3 = 1
Word 4 = 2
Word 5 = 1
Word 6 = 0

2.3.10 Data Blocks Output From Module SMA2

2.3.10.1 MGG (MATRIX)

Description

$[M_{gg}]$ - Partition of mass matrix - g set.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.10.2 BGG (MATRIX)

Description

$[B_{gg}]$ - Partition of damping matrix - g set.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.11 Data Blocks Output From Module GPWG.

2.3.11.1 ØGPWG (TABLE)

Description

Grid Point Weight Generator Øutput Table.

Table Format

Record	Word	Type	Item
0			Header record
1			ØFP ID record
	1	I	1
	2	I	13
	3	I	External ID of grid point about which moments and interias were calculated. If External ID = 0 the basic origin was used.
	4-9		Not defined.
	10	I	98
	11-50		Not defined.
	51-146	B	96 words of title, subtitle, and label from /ØUTPUT/
2			ØFP data record
	1-36	R	[MO] 6x6 moment matrix
	37-45	R	[S] 3x3 matrix
	46-49	R	Mx, Xx, Yx, Zx
	50-53	R	My, Xy, Yy, Zy
	54-57	R	Mz, Xz, Yz, Zz
	58-66	R	Inertia matrix (3x3)
	67-69	R	Principal inertias
	70-78	R	Q matrix (3x3)
3			End-of-file

Table Trailer

Word 1 = 0

Word 2 = nonzero.

Words 3-6 = 0

2.3.12 Data Blocks Output From Module SMA3

2.3.12.1 KGG (MATRIX)

Description

$[K_{gg}]$ - Partition of stiffness matrix - g set. Contains contributions from all elements in the model, including general elements.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.12.2 KGGL (MATRIX)

Description

$[K^{\ell}_{gg}]$ - Partition of the stiffness matrix of linear elements - g set. Contains contributions from all linear elements of the model including general elements. Used only in Piecewise Linear Analysis.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.13 Data Blocks Output From Module GP4

2.3.13.1 RG (MATRIX)

Description

$[R_g]$ - Multipoint constraint equations matrix.

Matrix Header

Number of columns = g
Number of rows = m
Form = rectangular
Type = real single precision

2.3.13.2 YS (MATRIX)

Description

$\{Y_s\}$ - Constrained displacement vector - s set.

Matrix Trailer

Number of columns = 1
Number of rows = s
Form = rectangular
Type = real single precision

2.3.13.3 USET (TABLE)

Description

Displacement set definitions table.

USET contains one logical record. Each word corresponds to each degree of freedom in the g-displacement set (in internal order) and contains ones in specified bit positions indicating the displacement sets to which the degree of freedom belongs.

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3	I	SPC set ID
	4	I	MPC set ID
1	1	L	Mask for first degree of freedom
	⋮		⋮
	n	L	Mask for n^{th} degree of freedom
2			End-of-file

Notes

1. Bit positions for the various displacement sets are defined as follows:

s_b	s_g	ℓ	a	f	n	g	r	o	s	m
22	23	24	25	26	27	28	29	30	31	32

Table Trailer

Word 1 = zero.

Word 2 = degrees of freedom in the g-displacement set (LUSET).

Word 3 = zero.

Word 4 = logical "or" of all USET masks.

Word 5 = zero.

Word 6 = zero.

2.3.14 Data Blocks Output From Module GPSP.

2.3.14.1 ØGPST (TABLE)

Description

Unremoved Grid Point Singularities.

Table Format

Record	Word	Type	Item
0			Header record
1			ØFP ID record
	1	I	0
	2	I	8
	3	I	SPC set ID
	4	I	MPC set ID
	5-9		Not defined
	10	I	12
	11-50		Not defined
	51-146	B	96 words of title, subtitle, and label from /ØUTPUT/
2			ØFP data record
	1	I	External grid point ID
	2	I	Scalar point flag
	3	I	Singularity order
	4-6	I	Strongest singularity components
	7-9	I	Next strongest singularity components
	10-12	I	Weakest singularity components

*Note: The above 12 words are repeated in record 2 for each grid point with an unremoved singularity.

3			End-of-file

Table Trailer

Word 1 = 8

Word 2-6 = 0

2.3.15 Data Blocks Output From Module MCE1

2.3.15.1 GM (MATRIX)

Description

$[G_m]$ - Multipoint constraint transformation matrix - m set.

Matrix Header

Number of columns	=	n
Number of rows	=	m
Form	=	rectangular
Type	=	real double precision

2.3.16 Data Blocks Output From Module MCE2

2.3.16.1 KNN (MATRIX)

Description

$[K_{nn}]$ - Partition of stiffness matrix - n set.

Matrix Trailer

Number of columns	=	n
Number of rows	=	n
Form	=	symmetric
Type	=	real double precision

2.3.16.2 MNN (MATRIX)

Description

$[M_{nn}]$ - Partition of mass matrix - n set.

Matrix Trailer

Number of columns	=	n
Number of rows	=	n
Form	=	symmetric
Type	=	real double precision

2.3.16.3 KDNN (MATRIX)

Description

$[K^{d}_{nn}]$ - Partition of differential stiffness matrix - n set.

Matrix Trailer

Number of columns	=	n
Number of rows	=	n
Form	=	symmetric
Type	=	real double precision

2.3.16.4 BNN (MATRIX)

Description

$[B_{nn}]$ - Partition of damping matrix - n set.

Matrix Trailer

Number of columns	=	n
Number of rows	=	n
Form	=	symmetric
Type	=	real double precision

2.3.16.5 K4NN (MATRIX)

Description

$[K^{4}_{nn}]$ - Partition of the structural damping matrix - n set.

Matrix Trailer

Number of columns	=	n
Number of rows	=	n
Form	=	symmetric
Type	=	real double precision

2.3.17 Data Blocks Output From Module SCE1

2.3.17.1 KFF (MATRIX)

Description

$[K_{ff}]$ - Partition of stiffness matrix after single-point constraints have been removed - f set.

Matrix Trailer

Number of columns	=	f
Number of rows	=	f
Form	=	symmetric
Type	=	real double precision

2.3.17.2 KFS (MATRIX)

Description

$[K_{fs}]$ - Partition of stiffness matrix after single-point constraints have been removed.

Matrix Trailer

Number of columns	=	s
Number of rows	=	f
Form	=	rectangular
Type	=	real double precision

2.3.17.3 KSS (MATRIX)

Description

$[K_{ss}]$ - Partition of stiffness matrix after single-point constraints have been removed - s set.

Matrix Trailer

Number of columns	=	s
Number of rows	=	s
Form	=	symmetric
Type	=	real double precision

2.3.17.4 MFF (MATRIX)

Description

$[M_{ff}]$ - Partition of mass matrix after single-point constraints have been removed - f set.

Matrix Trailer

Number of columns	=	f
Number of rows	=	f
Form	=	symmetric
Type	=	real double precision

2.3.17.5 KDFF (MATRIX)

Description

$[K^d_{ff}]$ - Partition of differential stiffness matrix - f set.

Matrix Trailer

Number of columns = f
Number of rows = f
Form = symmetric
Type = real double precision

2.3.17.6 KDFS (MATRIX)

Description

$[K^d_{fs}]$ - Partition of differential stiffness matrix.

Matrix Trailer

Number of columns = s
Number of rows = f
Form = rectangular
Type = real double precision

2.3.17.7 KDSS (MATRIX)

Description

$[K^d_{ss}]$ - Partition of differential stiffness matrix - s set.

Matrix Trailer

Number of columns = s
Number of rows = s
Form = symmetric
Type = real double precision

2.3.17.8 BFF (MATRIX)

Description

$[B_{ff}]$ - Partition of damping matrix after single point constraints have been removed - f set.

Matrix Trailer

Number of columns = f
Number of rows = f
Form = symmetric
Type = real double precision

2.3.17.9 K4FF (MATRIX)

Description

$[K^4_{ff}]$ - Partition of structural damping matrix with single-point constraints removed - f set.

Matrix Trailer

Number of columns	=	f
Number of rows	=	f
Form	=	symmetric
Type	=	real double precision

2.3.18 Data Blocks Output From Module SMP1

2.3.18.1 GØ (MATRIX)

Description

$[G_o]$ - Structural matrix partitioning transformation matrix.

Matrix Trailer

Number of columns	=	a
Number of rows	=	o
Form	=	rectangular
Type	=	real double precision

2.3.18.2 KAA (MATRIX)

Description

$[K_{aa}]$ - Partition of stiffness matrix - a set.

Matrix Trailer

Number of columns	=	a
Number of rows	=	a
Form	=	symmetric
Type	=	real double precision

2.3.18.3 KØØB (MATRIX)

Description

$[\overline{K}_{oo}]$ - Partition of stiffness matrix - o set.

Matrix Trailer

Number of columns	=	o
Number of rows	=	o
Form	=	symmetric
Type	=	real double precision

2.3.18.4 LØØ (MATRIX)

Description

$[L_{oo}]$ - Lower triangular factor of KØØB - o set.

Matrix Trailer

Number of columns	=	o
Number of rows	=	o
Form	=	lower triangular
Type	=	real double precision

2.3.18.5 UØØ (MATRIX)

Description

$[U_{oo}]$ - Upper triangular factor of KØØB - o set.

Matrix Trailer

Number of columns	=	o
Number of rows	=	o
Form	=	upper triangular
Type	=	real double precision

Note

This matrix is not a standard upper triangular factor. Its format is acceptable only to subroutine FBS.

2.3.18.6 MAA (MATRIX)

Description

$[M_{aa}]$ - Partition of mass matrix - a set.

Matrix Trailer

Number of columns	=	a
Number of rows	=	a
Form	=	symmetric
Type	=	real double precision

2.3.18.7 MØØB (MATRIX)

Description

$[\bar{M}_{oo}]$ - Partition of mass matrix - o set.

Matrix Trailer

Number of columns	=	o
Number of rows	=	o
Form	=	symmetric
Type	=	real double precision

2.3.18.8 MØAB (MATRIX)

Description

$[\overline{M}_{oa}]$ - Partition of mass matrix.

Matrix Trailer

Number of columns = a
Number of rows = o
Form = rectangular
Type = real double precision

2.3.18.9 BAA (MATRIX)

Description

$[B_{aa}]$ - Partition of damping matrix - a set.

Matrix Trailer

Number of columns = a
Number of rows = a
Form = symmetric
Type = real double precision

2.3.18.10 K4AA (MATRIX)

Description

$[K^4_{aa}]$ - Partition of structural damping matrix - a set.

Matrix Trailer

Number of columns = a
Number of rows = a
Form = symmetric
Type = real double precision

2.3.19 Data Blocks Output From Module RBMG1

2.3.19.1 KLL (MATRIX)

Description

$[K_{\ell\ell}]$ - Partition of stiffness matrix - ℓ set.

Matrix Trailer

Number of columns = ℓ
Number of rows = ℓ
Form = symmetric
Type = real double precision

2.3.19.2 KLR (MATRIX)

Description

$[K_{\ell r}]$ - Partition of stiffness matrix

Matrix Trailer

Number of columns = ℓ
Number of rows = r
Form = rectangular
Type = real double precision

2.3.19.3 KRR (MATRIX)

Description

$[K_{rr}]$ - Partition of stiffness matrix - r set.

Matrix Trailer

Number of columns = r
Number of rows = r
Form = symmetric
Type = real double precision

2.3.19.4 MLL (MATRIX)

Description

$[M_{\ell\ell}]$ - Partition of mass matrix - ℓ set.

Matrix Trailer

Number of columns = ℓ
Number of rows = ℓ
Form = symmetric
Type = real double precision

2.3.19.5 MLR (MATRIX)

Description

$[M_{\ell r}]$ - Partition of mass matrix.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	r
Form	=	rectangular
Type	=	real double precision

2.3.19.6 MRR (MATRIX)

Description

$[M_{rr}]$ - Partition of mass matrix - r set.

Matrix Trailer

Number of columns	=	r
Number of rows	=	r
Form	=	symmetric
Type	=	real double precision

2.3.20 Data Blocks Output From Module RBMG2

2.3.20.1 LLL (MATRIX)

Description

$[L_{\ell\ell}]$ - Lower triangular factor of KLL - ℓ set.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	ℓ
Form	=	lower triangular
Type	=	real double precision

2.3.20.2 ULL (MATRIX)

Description

$[U_{\ell\ell}]$ - Upper triangular factor of KLL - ℓ set.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	ℓ
Form	=	upper triangular
Type	=	real double precision

Note

This matrix is not a standard upper triangular factor. Its format is acceptable only to subroutine FBS.

2.3.20.3 LBLL (MATRIX)

Description

$[L^{b}_{\ell\ell}]$ - Lower triangular factor of KBLL - ℓ set.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	ℓ
Form	=	lower triangular
Type	=	real double precision

2.3.20.4 UBLL (MATRIX)

Description

$[U^{b}_{\ell\ell}]$ - Upper triangular factor of KBLL - ℓ set.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	ℓ
Form	=	upper triangular
Type	=	real double precision

Note

This matrix is not a standard upper triangular factor. Its format is acceptable only to subroutine FBS.

2.3.21 Data Blocks Output From Module RBMG3

2.3.21.1 DM (MATRIX)

Description

[D] - Rigid body transformation matrix.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	r
Form	=	rectangular
Type	=	real double precision

2.3.22 Data Blocks Output From Module RBMG4

2.3.22.1 MR (MATRIX)

Description

$[m_r]$ - Rigid body mass matrix - r set.

Matrix Trailer

Number of columns	=	r
Number of rows	=	r
Form	=	symmetric
Type	=	real double precision

2.3.23 Data Blocks Output From Module SSG1.

2.3.23.1 PG (MATRIX)

Description

$[P_g]$ - Static load vector matrix giving static loads - g set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.23.2 PG1 (MATRIX)

Description

$[P_g^1]$ - Static load vector giving static loads for Piecewise Linear Analysis problem - g set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.24 Data Blocks Output From Module SSG2

2.3.24.1 QR (MATRIX)

Description

$[q_r]$ - Determinate support forces matrix - r set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	r
Form	=	rectangular
Type	=	real single precision

2.3.24.2 PØ (MATRIX)

Description

$[P_o]$ - Partition of the load vector matrix giving loads due to static force - o set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	o
Form	=	rectangular
Type	=	real single precision

2.3.24.3 PS (MATRIX)

Description

$[P_s]$ - Partition of load vector matrix giving loads in s set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	s
Form	=	rectangular
Type	=	real single precision

2.3.24.4 PL (MATRIX)

Description

$[P_\ell]$ - Partition of the load vector matrix giving static loads on ℓ set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real single precision

2.3.25 Data Blocks Output From Module SSG3

2.3.25.1 ULV (MATRIX)

Description

$[u_\ell]$ - Partition of the displacement vector matrix giving displacements - ℓ set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real double precision

2.3.25.2 UØØV (MATRIX)

Description

$[u_o^o]$ - Partition of the displacement vector matrix giving displacements in the o set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	o
Form	=	rectangular
Type	=	real double precision

2.3.25.3 RULV (MATRIX)

Description

$[\delta P_\ell]$ - Residual vector matrix for the ℓ set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real single precision

2.3.25.4 RUØV (MATRIX)

Description

$\{\delta P_o\}$ - Residual vector matrix for the o set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	o
Form	=	rectangular
Type	=	real single precision

2.3.25.5 UBLV (MATRIX)

Description

$[u_{\ell}^{b}]$ - Partition of the differential stiffness displacement vector - ℓ set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real double precision

2.3.25.6 RUBLV (MATRIX)

Description

$[\delta P_{\ell}^{b}]$ - Differential stiffness residual vector - ℓ set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real single precision

2.3.26 Data Blocks Output From Module SSG4.

2.3.26.1 PLI (MATRIX)

Description

$[P_{\ell}^{i}]$ - Partition of load vector for inertia relief matrix giving loads due to static + inertial forces on ℓ set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real single precision

2.3.26.2 PØI (MATRIX)

Description

$[P_{o}^{i}]$ - Partition of load vector for inertia relief matrix giving loads due to inertial force + static forces on o set.

Matrix Trailer

Number of columns	=	number of subcases
Number of rows	=	o
Form	=	rectangular
Type	=	real single precision

2.3.27 Data Blocks Output From Module SDR1

2.3.27.1 UGV (MATRIX)

Description

$[u_g]$ - Displacement vector matrix giving displacements in the g set.

Matrix Trailer

Number of columns	=	number of subcases in CASECC
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.2 PGG (MATRIX)

Description

$[P_g]$ - Static load vector appended to include all boundary conditions - g set.

Matrix Trailer

Number of columns	=	number of subcases in CASECC
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.3 QG (MATRIX)

Description

$[q_g]$ - Single-point constraint forces and determinate support forces matrix - q set.

Matrix Trailer

Number of columns	=	number of subcases in CASECC
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.4 PHIG (MATRIX)

Description

$[\Phi_g]$ - Eigenvector matrix giving eigenvectors (displacements) in the g set.

Matrix Trailer

Number of columns	=	number of eigenvalues found in READ
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.5 UBGV (MATRIX)

Description

$[u_g^b]$ - Displacement vector matrix for differential stiffness giving displacements in the g set.

Matrix Trailer

Number of columns	=	number of factors on a DSFACT bulk data card
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.6 QBG (MATRIX)

Description

$[q_g^b]$ - Single-point forces of constraint matrix for differential stiffness - g set.

Matrix Trailer

Number of columns	=	number of factors on a DSFACT bulk data card
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.7 BQG (MATRIX)

Description

$[q_g^b]$ - Single-point forces of constraint matrix for a buckling analysis problem - g set.

Matrix Trailer

Number of columns	=	number of buckling modes found in READ
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.8 DELTAUGV (MATRIX)

Description

$\{\delta u_g\}$ - Incremental displacement vector in piecewise linear analysis - g set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.27.9 DELTAPG (MATRIX)

Description

$\{\delta P_g\}$ - Incremental load vector in piecewise linear analysis - g set.

Matrix Trailer

Number of columns = 1
Number of rows = g
Form = rectangular
Type = real single precision

2.3.27.10 DELTAQG (MATRIX)

Description

$\{\delta q_g\}$ - Incremental vector of single-point forces of constraint in piecewise linear analysis - g set.

Matrix Trailer

Number of columns = 1
Number of rows = g
Form = rectangular
Type = real single precision

2.3.27.11 CPHIP (MATRIX)

Description

$[\Phi_p]$ - Complex eigenvectors in p set.

Matrix Trailer

Number of columns = number of eigenvalues found in CEAD
Number of rows = p
Form = rectangular
Type = complex single precision

2.3.27.12 QPC (MATRIX)

Description

$[q_p^c]$ - Complex single-point forces of constraint - p set.

Matrix Trailer

Number of columns = number of eigenvalues found in CEAD
Number of rows = p
Form = rectangular
Type = complex single precision

2.3.27.13 UPVC (MATRIX)

Description

$[u_p^c]$ - Frequency response solution vectors - p set.

Matrix Trailer

Number of columns	=	the product of the number of frequencies and number of loads
Number of rows	=	p
Form	=	rectangular
Type	=	complex single precision

2.3.27.14 UPV (MATRIX)

Description

$[u_p]$ - Transient solution vectors - p set.

Matrix Trailer

Number of columns	=	the number of output times multiplied by 3*
Number of rows	=	p
Form	=	rectangular
Type	=	real single precision

*Each triple is displacement, velocity and acceleration.

2.3.27.15 QP (MATRIX)

Description

$[q_p]$ - Transient single-point forces of constraint - p set.

Matrix Trailer

Number of columns	=	the number of output times
Number of rows	=	p
Form	=	rectangular
Type	=	real single precision

2.3.28 Data Blocks Output From Module SDR2.

2.3.28.1 ØUGV1 (TABLE)

Description

Output displacement vector requests (g set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1
	3	I	0
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } point

Notes

1. Records 1 and 2 are repeated for each vector to be output
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 1, 3, 7, or 10
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.2 ØUBGV1 (TABLE)

Description

Output displacement vector requests (g set, SØRT1, real)

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1
	3	I	0
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }
3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }
4. Approach code = 4
5. Point type = { 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point }

Table Trailer

Words 1-6 contain no significant values.

2.3.28.3 ØUPV1 (TABLE)

Description

Output displacement vector requests (p set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1 = Displacement 10 = Velocity 11 = Acceleration
	3	I	0
	4	I	Subcase number
	5	R	Time
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (repeat for each point)
	2	I	Point type (repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch
3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase
4. Approach code = 6
5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.4 ØUPVC1 (TABLE).

Description

Output displacement vector requests (p set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	{1001 = Displacement 1010 = Velocity 1011 = Acceleration
	3	I	0
	4	I	Subcase number
	5	R	Frequency
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code } repeat for each point
	2	I	Point type } repeat for each point
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } repeat for each point
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) } repeat for each point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = {0 = x y output only; 1 = print; 4 = punch; 5 = print and punch}
3. Format code = {1 = real; 2 = real/imaginary; 3 = magnitude/phase}
4. Approach code = 5
5. Point type = {1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point}

Table Trailer

Words 1-6 contain no significant values.

2.3.28.5 ØPG1 (TABLE).

Description

Output load vector requests (g set, SØRT1, real)

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2
	3	I	0
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (Repeat for each point)
	2	I	Point type (Repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (Repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase

4. Approach code = 1, 3, 7, or 10

5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.6 ØPP1 (TABLE).

Description

Output load vector requests (p set, SØRT1, real).

Table Format

Record	Word	Type		Item
0				Header record
1	1	I		Device code + 10*approach code
	2	I		2
	3	I		0
	4	I		Subcase number
	5	R		Time
	6	I		0
	7	I		0
	8	I		Load set ID
	9	I		Format code
	10	I		Number of words per entry in next record = 8
	11-50			Not defined
	51-82	B		Title
	83-114	B		Subtitle
	115-146	B		Label
2	1	I	-	10*point ID + device code } repeat
	2	I		Point type } for each
	3-8	R		R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }
3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }
4. Approach code = 6
5. Point type = { 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point }

Table Trailer

Words 1-6 contain no significant values.

2.3.28.7 ØPPC1 (TABLE).

Description

Output load vector requests (p set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1002
	3	I	0
	4	I	Subcase number
	5	R	Frequency
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (repeat for each point)
	2	I	Point type (repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each point)
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) (repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 5
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.8 ØQG1 (TABLE)

Description

Output forces of single-point constraint requests (g set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3
	3	I	0
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (repeat for each point)
	2	I	Point type (repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 1, 2, 3, 7, or 10
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.9 ØQBG1 (TABLE)

Description

Output forces of single-point constraint requests (g set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3
	3	I	0
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } point

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch

3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase

4. Approach code = 4

5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.10 ØBQG1 (TABLE).

Description

Output forces of single-point constraint requests (g set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3
	3	I	0
	4	I	Subcase number
	5	I	Mode number
	6	R	Eigenvalue
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (repeat for each point)
	2	I	Point type (repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 8
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.11 ØQP1 (TABLE).

Description

Output forces of single-point constraint requests (p set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3
	3	I	0
	4	I	Subcase number
	5	R	Time
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code — repeat for each point
	2	I	Point type — repeat for each point
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) — repeat for each point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.12 ØQPC1 (TA3LE).

Description

Output forces of single-point constraint requests (p set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1003
	3	I	0
	4	I	Subcase number
	5	R/I	Frequency or mode number
	6	I/R	0 or eigenvalue (real part)
	7	I/R	0 or eigenvalue (imaginary part)
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code) repeat
	2	I	Point type) for
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3)) each
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3)) point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 5, or 9
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.13 ØPHIG (TABLE).

Description

Output eigenvector requests (g set, SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	7
	3	I	0
	4	I	Subcase number
	5	I	Mode number
	6	R	Eigenvalue
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code (repeat for each point)
	2	I	Point type (repeat for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 2, or 8
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.14 ØCPHIP (TABLE).

Description

Output eigenvector requests (p set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1007
	3	I	0
	4	I	Subcase number
	5	I	Mode number
	6	R	Eigenvalue (real part)
	7	R	Eigenvalue (imaginary part)
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*point ID + device code) repeat
	2	I	Point type) for
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3)) each
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3)) point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 9
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.28.15 ØES1 (TABLE).

Description

Output element stress requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	5
	3	I	Element type
	4	I	Subcase number
	5	I/R	Time, Load set ID, or mode number
	6	R/I	Eigenvalue or 0
	7	I	0
	8	I	Load set ID or 0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element stress data } for each
			See 2.3.51 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 1, 2, 3, 6, 7, or 10

Table Trailer

Words 1-6 contain no significant values.

2.3.28.16 ØESB1 (TABLE).

Description

Output element stress requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	5
	3	I	Element type
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element stress data } for each
			See 2.3.51 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 4

Table Trailer

Words 1-6 contain no significant values.

2.3.28.17 ØBES1 (TABLE).

Description

Output element stress requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	5
	3	I	Element type
	4	I	Subcase number
	5	I	Mode number
	6	R	Eigenvalue
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element stress data } for each
			See 2.3.51 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 8

Table Trailer

Words 1-6 contain no significant values.

2.3.28.18 ØESC1 (TABLE).

Description

Output element stress requests (SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1005
	3	I	Element type
	4	I	Subcase number
	5	R/I	Frequency or mode number
	6	I/R	0 or eigenvalue (real part)
	7	I/R	0 or eigenvalue (imaginary part)
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element stress data } for each
			See 2.3.51 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch

3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase

4. Approach code = 5, or 9

Table Trailer

Words 1-6 contain no significant values.

2.3.28.19 ØEF1 (TABLE).

Description

Output element force requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	4
	3	I	Element type
	4	I	Subcase number
	5	I/R	Time, load set ID, or mode number
	6	I/R	0 or eigenvalue
	7	I	0
	8	I	Load set ID or 0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element force data } for each
			See 2.3.52 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }
3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }
4. Approach code = 1, 2, 3, 6, 7, or 10

Table Trailer

Words 1-6 contain no significant values.

2.3.28.20 ØEFB1 (TA3LE).

Description

Output element force requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	4
	3	I	Element type
	4	I	Subcase number
	5	I	Load set ID
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element force data } for each
			See 2.3.52 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 4

Table Trailer

Words 1-6 contain no significant values.

2.3.28.21 ØBEF1 (TABLE).

Description

Output element force requests (SØRT1, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	4
	3	I	Element type
	4	I	Subcase number
	5	I	Mode number
	6	R	Eigenvalue
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code) repeat
	2-NWDS	Mixed	Element force data) for each
			See 2.3.52 for details) element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch

3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase

4. Approach code = 8

Table Trailer

Words 1-6 contain no significant values.

2.3.28.22 ØEFC1 (TABLE).

Description

Output element force requests (SØRT1, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	1004
	3	I	Element type
	4	I	Subcase number
	5	R/I	Frequency or mode number
	6	I/R	0 or eigenvalue (real part)
	7	I/R	0 or eigenvalue (imaginary part)
	8	I	Load set ID or 0
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10*element ID + device code } repeat
	2-NWDS	Mixed	Element force data } for each
			See 2.3.52 for details } element

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 5, or 9

Table Trailer

Words 1-6 contain no significant values.

2.3.28.23 PUGV1 (matrix - see note below)

Description

PUGV1 contains the translation components of UGV1 rotated to the basic coordinate system.

Note

The first four words of each logical record (column) contain identification data for the column. These words must be read prior to calling the appropriate unpacking routine.

Word 1 = subcase number

Word 2 = 1

Word 3 = static load set ID

Word 4 = 0

Matrix Trailer

Trailer is same as that for UGV1 except word 1 = 0, and word 6 = 0 (see section 2.3.36.1).

2.3.28.24 PUBGV1 (matrix - see note below)

Description

PUBGV1 contains the translation components of UBGV rotated to the basic coordinate system.

Note

The first four words of each logical record (column) contain identification data for the column. These words must be read prior to calling the appropriate unpacking routine.

Word 1 = subcase number

Word 2 = 1

Word 3 = static load set ID

Word 4 = 0

Matrix Trailer

Trailer is same as that for UBGV with word 1 = 0, and word 6 = 0.

2.3.28.25 PPHIG (matrix - see note below)

Description

PPHIG contains the translation components of PHIG rotated to the basic coordinate system.

Note

The first four words of each logical record (column) contain identification data for the column. These words must be read prior to calling the appropriate unpacking routine.

Word 1 = subcase number

Word 2 = 2

Word 3 = mode number

Word 4 = eigenvalue (λ)

Matrix Trailer

Trailer is same as that for PHIG with word 1 = 0, and word 6 = 0, (see section 2.3.27.4).

2.3.28.26 PUGV (matrix - see note below)

Description

PUGV contains the translation components of UPV (excluding extra points) rotated to the basic coordinate system.

Note

The first four words of each logical record (column) contain identification data for the column. These words must be read prior to calling the appropriate unpacking routine.

Word 1 = subcase number

Word 2 = 3

Word 3 = 0

Word 4 = time

Matrix Trailer

Trailer is same as that for UGV with word 1 = 0, and word 6 = 0, (see section 2.3.27.1).

2.3.29 Data Blocks Output From Module DPD

2.3.29.1 GPLD (TABLE)

Description

Grid Point List Dynamics.

One logical record which contains a list of all grid points, scalar points and extra points in the model in internal sort.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	ID for first point
	⋮		⋮
	n	I	ID for n^{th} point
2			End-of-file

Table Trailer

Word 1 = number of grid points + number of scalar points + number of extra points.

Word 2-6 = zero.

2.3.29.2 SILD (TABLE)

Description

Scalar Index List Dynamics.

Two logical records. First logical record contains scalar index values in the p-displacement set for each point in the dynamics model (internal order). These values are defined as follows:

$$SILD_1 = 1$$

$$SILD_{i+1} = \begin{cases} SILD_i + 6 & \text{if i corresponds to a grid point} \\ SILD_i + 1 & \text{if i corresponds to a scalar or an extra point} \end{cases}$$

The second logical record contains an equivalence between scalar index values in the g-displacement set and scalar index values in the p-displacement set.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Scalar index for first point
	⋮	⋮	⋮
	n	I	Scalar index for n^{th} point
2	1, 2	I	SIL value, SILD value
	⋮	⋮	⋮
	2m-1,2m	I	SIL value, SILD value
3			End-of-file

Table Trailer

Word 1 = degrees of freedom in the p-displacement set (LUSETD).

Word 2 = number of extra points.

Word 3-6 = zero.

2.3.29.3 USETD (TABLE)

Description

Displacement set definitions table dynamics.

USETD contains one logical record. Each word corresponds to each degree of freedom in the p-displacement set (in internal order) and contains ones in specified bit positions indicating the displacement sets to which the point belongs.

Table Format

Record	Word	Type	Item
0			Header record
1	1	L	Mask for first degree of freedom
	⋮	⋮	⋮
	n	L	Mask for n^{th} degree of freedom
2			End-of-file

Notes

Bit positions for the various displacement sets are defined as follows:

d	f_e	n_e	p	e	s_b	s_g	ℓ	a	f	n	g	r	o	s	m
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Table Trailer

Word 1 = degrees of freedom in the p-displacement set (LUSETD).

Word 2 = number of extra points.

Word 3 = zero.

Word 4 = logical "or" of all USETD masks.

Word 5 = zero.

Word 6 = zero.

2.3.29.4 EED (TABLE)

Description

Eigenvalue Extraction Data.

The EED contains one logical record for each eigenvalue extraction card type (EIGB, EIGC, EIGP, EIGR). Each logical record contains data from all cards of a given type.

Table Format

Record	Word	Item
0		Header record
1		EIGB data (if EIGB cards in bulk data)
2		EIGC data (if EIGC cards in bulk data)
3		EIGP data (if EIGP cards in bulk data)
4		EIGR data (if EIGR cards in bulk data)
5		End-of-file

Detailed format for EIGB data:

Word	Type	Item	
1-3	I	107, 1, 0	
4	I	Set ID	repeated for each EIGB card in bulk data
5-6	B	Method	
7-8	R	F_1, F_2	
9-11	I	N_e, N_d, N_z	
12	R	E	
13-14	B	Norm	
15	I	If norm = "PØINT", SIL value in a-set of normalization point	
16-21		Not defined	

Detailed format for EIGC card:

Word	Type	Item	
1-3	I	207, 2, 0	repeated for each EIGC card in bulk data
4	I	Set ID	
5-6	B	Method	
7-8	B	Norm	
9	I	If Norm = "PØINT", SIL value in analysis set of normalization point	
10		Not defined	
11	R	E	
12-13		Not defined	
14-15	R	α_a, ω_a	repeated for each region definition
16-17	R	α_b, ω_b	
18	R	ℓ	
19-20	I	N_e, N_d	
21		Not defined	
14+8k-21+8k	I	-1 (k = number of regions)	

Detailed format for EIGP card:

Word	Type	Item	
1-3	I	257, 4, 0	repeated for each EIGP card in bulk data
5	I	Set ID	
6-7	R	α, ω	
8	I	M	

Detailed format for EIGR card:

Word	Type	Item	
1-3	I	307, 3, 0	repeated for each EIGR card in bulk data
4	I	Set ID	
5-6	B	Method	
7-8	R	F_1, F_2	
9-11	I	N_e, N_d, N_z	
12	R	E	
13-14	B	Norm	
15	I	If norm = "PØINT", SIL value in a-set of normalization point	
16-21		Not defined	

Table Trailer

Word 1 =

bit 17 = 1 if EIGB record exists
18 = 1 if EIGC record exists
19 = 1 if EIGP record exists
20 = 1 if EIGR record exists
other bits = 0

Word 2-6 = zero.

2.3.29.5 EQDYN (TABLE)

Description

Equivalence between external points and scalar index values - dynamics.

EQDYN contains two logical records. The first record contains pairs of external point numbers and scalar index values in the p-displacement set for the points in external order. The second record is essentially the same as the first except that the type of point (grid, scalar, extra) is coded in the second word of the pair.

Table Format

Record	Word	Type	Item
0			Header record
1	1,2	I	ID for first point, scalar index for first point
	⋮	⋮	⋮
	2n-1,2n	I	ID for n^{th} point, scalar index for n^{th} point
2	1,2	I	ID for first point, 10*scalar index + type
	⋮	⋮	⋮
	2n-1,2n	I	ID for n^{th} point, 10*scalar index + type
3			End-of-file

Note

Type = {1 for grid point; 2 for scalar point; 3 for extra point}

Table Trailer

Word 1 = number of grid points + number of scalar points + number of extra points in dynamics model.

Word 2 = number of extra points.

Word 3-6 = zero.

2.3.29.6 TFPØØL (TABLE).

Description

Transfer Function Pool.

The TFPØØL data block contains one logical record for each transfer function set defined in the bulk data on a TF bulk data card. Point and component values are converted to row and column numbers in the p-displacement set.

Table Format

Record	Word	Type	Item	
0			Header record	
1	1	I	Set ID	
	2	I	65536*column number + row number	repeated for each set of non-zero terms
	3-5	R	Coefficients	
n			Same format as first record	
n+1			End-of-file	

Table Trailer

Word 1 = number of transfer function sets.

Word 2-6 = zero.

2.3.29.7 DLT (TABLE).

Description

Dynamic Loads Table.

The header record of the DLT contains a summary of all dynamic load sets defined in the problem. The first record of the DLT contains all DLØAD cards (if DLØAD cards have been input). Each succeeding record contains all data for one dynamic load set.

Table Format

Record	Word	Type	Item	
0	1-2	B	Data block name	
	3	I	m = number of DLØAD set ID's	
	4-3+m	I	Set ID's on DLØAD cards	
	4+m-3+m+n	I	Set ID's on RLØAD1, 2 and TLØAD1, 2 cards	
1	1	I	Set ID	repeated for each DLØAD card
	2	R	Scale factor	
	3-4	R,I	Scale factor, set ID	
	:			
	4+ℓ,5+ℓ	I	-1, -1	

Record	Word	Type	Item
k	1	I	Dynamic load card type
	2	I	= 0 no time delays ≠ 0 time delays
	3-8		See Notes
	9	I	SIL number ⎫ repeated for each
	10-12	R	A, τ, θ ⎭ dynamic load set
n+2			End-of-file

Notes

1. If no DLØAD cards have been input, the third word of the header record is zero and the DLØAD record does not exist. Therefore, record 1 of the DLT corresponds to the load set defined in word 4 of the header record.

2. DLØAD-set ID's are in sort by set ID. In record 1, set ID's within a DLØAD card are in sort.

3. Within other records, data is in sort by SIL number.

4. Formats by dynamic load card type are as follows:

1 = RLØAD1

Word	Type	Item
3	I	Table ID for C(f)
4	I	Table ID for D(f)
5-8		Not defined

2 = RLØAD2

Word	Type	Item
3	I	Table ID for B(f)
4	I	Table ID for ϕ(f)
5-8		Not defined

3 = TLØAD1

Word	Type	Item
3	I	Table ID for F(t)
4-8		Not defined

4 = TLØAD2

Word	Type	Item
3-4	R	T_{K1}, T_{K2}
5-6	R	W_K, Φ_K
7-8	R	n_K, α_K

Table Trailer

Word 1 = GINØ file name of DLT.
Word 2-6 = undefined.

2.3.29.8 PSDL (TABLE)

Description

Power Spectral Density List.

The first logical record of the PSDL contains RANDPS data. Subsequent logical records contain RANDT data, one set per logical record. Each RANDT logical record contains a sorted list of unique time lags defined in the set.

Table Format

Record	Word	Type	Item
0	1,2	B	Data block name
	3	I	RANDT set ID$_1$
	⋮		⋮
	2+n	I	RANDT set ID$_n$
1	1	I	RANDPS set ID) repeated
	2	I	Load set ID (for each
	3	I	Load set ID } RANDPS
	4,5	R	Complex number (card in
	6	I	Table ID) bulk data
2	1-m	R	Time lags
⋮			
n+1			Same format as record 2 Data belongs to RANDT set ID$_n$
n+2			End-of-file

Notes

1. RANDPS cards must be present for data block to exist. Therefore, record one always contains RANDPS data.

2. If no RANDT1 or RANDT2 cards are present in the bulk data, the header record will contain exactly two words and record two will be an end-of-file.

Table Trailer

Word 1 = { number of RANDT sets, or
         { 65535 if no RANDT sets exist.

Word 2-6 = zero.

2.3.29.9 FRL (TABLE)

Description

Frequency Response List.

The FRL contains one logical record for each different frequency set defined in the bulk data. Each record contains a sorted list of the unique frequencies defined in the set.

Table Format

Record	Word	Type	Item
0	1,2	B	Data block name
	3	I	Set ID_1
	⋮		⋮
	2+n	I	Set ID_n
1	1-m	R	Frequencies belonging to set ID_1
⋮			⋮
n	1-k	R	Frequencies belonging to set ID_n
n+1			End-of-file

Table Trailer

Word 1 = number of frequency sets.

Word 2-6 = zero.

2.3.29.10 NLFT (TABLE)

Description

Non-Linear Forcing Table.

The header record of the NLFT contains a sorted list of set identification numbers for all NØLIN sets defined in the bulk data. Each logical record of the NLFT contains all data for a single set. Point and component numbers on the NØLIN cards are converted to scalar index values in both the d- and e-displacement sets.

Table Format

Record	Word	Type	Item
0	1,2	B	Data block name
	3	I	Set ID_1
	⋮		⋮
	2+n	I	Set ID_n

Record	Word	Type	Item	
1	1	I	Type of nonlinear load (1≤type≤4)	repeated for each NOLIN card in set
	2	I	SIL value in d-set	
	3	I	SIL value in e-set	
	4	R	Scale factor	
	5	I	SIL value in d-set	
	6	I	SIL value in e-set	
	7	type = 1 =	Table ID (integer)	
		type = 2 =	SIL value in d-set (integer)	
		type = 3 =	Scale factor (real)	
		type = 4 =	Scale factor (real)	
	8	type = 1 =	Not defined	
		type = 2 =	SIL value in e-set (integer)	
		type = 3 =	Not defined	
		type = 4 =	Not defined	
⋮				
n			Same format as record 1. Data belongs to set ID_n.	
n+1			End-of-file	

Note

Within each record, the data is sorted on word 2 of each 8-word entry in the record.

Table Trailer

Word 1 = number of NOLIN sets.

Word 2-6 = zero.

2.3.29.11 TRL (TABLE).

Description

Transient Response List.

The header record of the TRL contains a list of all transient initial condition set identifications in the bulk data. Subsequent logical records contain TIC data for each set (one set per logical record). If TSTEP cards are present in the bulk data, this data follows the TIC data, one logical record for each TSTEP set.

Table Format

Record	Word	Type	Item
0	1,2	B	Data block name
	3	I	Number of TIC sets
	4	I	Set ID_1
	⋮		⋮
	3+n	I	Set ID_n
	4+n	I	Degrees of freedom in the d-displacement set
1	1	I	SIL value in d-set } repeated for each initial
	2,3	R	U_o, V_o } condition in set
⋮			
n			Same format as record 1 Data belongs to set ID_n
n+1	1	I	TSTEP set ID
	2	I	N } repeated for
	3	R	Δt } each interval
	4	I	NO } in set
⋮			
n+m			Same format as record n+1
n+m+1			End-of-file

Notes

1. Data within each TIC record is sorted on word 1 of each 3-word entry.
2. If word 3 of the header record = 0, then the first logical record of the TRL contains TSTEP data.
3. If TSTEP data is not present in the bulk data, and end-of-file will follow the last TIC record.

Table Trailer

Word 1 = number of TIC sets.

Word 2 = number of TSTEP sets.

Word 3-6 = zero.

2.3.30 Data Blocks Output From Module READ

2.3.30.1 LAMA (TABLE)

Description

λ_a - Real Eigenvalue Table

Table Format

Record	Word	Type	Item
0			Header record
1			OFP ID record
	1	I	21
	2	I	9
	3	I	0
	4-9	I	0
	10	I	7
	11-50		Not defined
	51-146	B	Title, subtitle, and label from /OUTPUT/
2			OFP data record
	1	I	Mode number
	2	I	Extraction order
	3	R	λ - eigenvalue
	4	R	$f = \sqrt{\lvert\lambda\rvert}$
	5	R	$w = f/2\pi$
	6	R	Generalized mass
	7	R	Generalized stiffness
3			End-of-file

Notes

1. The seven data words in record 2 repeat for each eigenvalue found in READ.

Table Trailer

Non-zero trailer

2.3.30.2 PHIA (MATRIX)

Description

$[\Phi_a]$ - Eigenvectors matrix giving the eigenvectors (displacements) in the a set.

Matrix Trailer

Number of columns = number of eigenvectors found in READ
Number of rows = a
Form = rectangular
Type = real single precision

2.3.30.3 MI (MATRIX)

Description

$[m_i]$ - Modal Mass Matrix

Matrix Trailer

Number of columns = number of eigenvectors found in READ
Number of rows = number of eigenvectors found in READ
Form = general
Type = real single precision

2.3.30.4 ØEIGS (TABLE)

Description

Real Eigenvalue Summary Table

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	21
	2	I	9
	3	I	2 If Inverse Power Method 1 If Determinant Method 4 If Givens Method
	4	I	0
	5	I	0
	6	I	0
	7	I	0
	8	I	0
	9	I	0
	10	I	0

Words 11-17 depend on the method used.

Determinant Method:

11	I	Number of eigenvalues extracted
12	I	Number of passes through starting points
13	I	Number of criteria changes
14	I	Number of starting point moves
15	I	Number of triangular decompositions
16	I	Number of failures to iterate to a root
17	I	Reason for termination 1 - All requested roots formed 2 - Out of region predictions from every starting point 3 - Insufficient time to extract another root 4 - Everywhere singular matrix

Record	Word	Type	Item
	Inverse Power Method:		
	11	I	Number of eigenvalues extracted
	12	I	Number of starting points used
	13	I	Number of starting points moved
	14	I	Number of triangular decompositions
	15	I	Number of vector iterations
	16	I	Dummy
	17	I	Reasons for termination 1 - 2 Singularities encountered in a row 2 - 4 Shifts while tracking one root 3 - Regions completed 4 -3* Number of estimated roots were found 5 - All roots of problem found 6 - Number desired roots found 7 - λ outside maximum range 8 - Insufficient time to extract another root 9 - 200 iterations and 1 shift point move before locating a root
	Givens Method:		
	11	I	Number of eigenvalues extracted
	12	I	Number of eigenvectors computed
	13	I	Number of failures to converge to an eigenvalue
	14	I	Number of failures to converge to an eigenvector
	15	I	Dummy
	16	I	Dummy
	17	I	Reason for termination 1 - Normal termination 3 - Insufficient time to evaluate eigenvectors
	18	R	Value of off-diagonal element of modal mass matrix having largest magnitude (zero where not applicable)
	19	I	Column of 18 in MI
	20	I	Row of 18 in MI
	21	I	Number of off-diagonal elements of modal mass matrix that fail to meet error criterion
	22-50		Not used
	51-146	B	Title, subtitle, label
	Records 2 and 3 exist only when the Determinant Method is used.		
2	1	I	21
	2	I	9
	3	I	3
	4	I	0
	5	I	0
	6	I	0
	7	I	0
	8	I	0
	9	I	0
	10	I	6
	11-50		Not used
	51-146	B	Title, subtitle, label
3	1	I	Starting point ID
	2	R	λ - Starting point
	3	R	$\omega = \sqrt{\lambda}$ - Starting point
	4	R	$f = \omega/2\pi$ - Starting point
	5	R	Determinant at λ

Words 1-6 are repeated for each starting point

Record	Word	Type	Item
	6	R	Scale factor (power of 10) of determinant
4			End-of-file

Table Trailer

Nonzero

2.3.31 Data Blocks Output From Module DSMG1

2.3.31.1 KDGG (MATRIX)

Description

$[K^{d}_{gg}]$ - Partition of differential stiffness matrix - g set.

Matrix Trailer

Number of columns	=	q
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.32 Data Blocks Output From Module SMP2

2.3.32.1 KDAA (MATRIX)

Description

$[K^{d}_{aa}]$ - Partition of differential stiffness matrix - a set.

Matrix Trailer

Number of columns	=	a
Number of rows	=	a
Form	=	symmetric
Type	=	real double precision

2.3.33 Data Blocks Output From Module DSMG2

2.3.33.1 KBLL (MATRIX)

Description

$[K^{b}_{\ell\ell}]$ - Partition of the stiffness matrix of the first order approximation to large displacements - ℓ set.

Matrix Trailer

Number of columns	=	ℓ
Number of rows	=	ℓ
Form	=	symmetric
Type	=	real double precision

2.3.33.2 KBFS (MATRIX)

Description

$[K^{b}_{fs}]$ - Partition of the stiffness matrix of the first order approximation to large displacements.

Matrix Trailer

Number of columns	=	s
Number of rows	=	f
Form	=	rectangular
Type	=	real double precision

2.3.33.3 KBSS (MATRIX)

Description

$[K^{b}_{ss}]$ - Partition of the stiffness matrix of the first order approximation to large displacements - s set.

Matrix Trailer

Number of columns	=	s
Number of rows	=	s
Form	=	symmetric
Type	=	real double precision

2.3.33.4 PBL (MATRIX)

Description

$\left\{P_{\ell}^{b}\right\}$ - Partition of the load vector of the first order approximation to the large displacements - ℓ set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	ℓ
Form	=	rectangular
Type	=	real single precision

2.3.33.5 PBS (MATRIX)

Description

$\left\{P_{s}^{b}\right\}$ - Partition of the load vector of the first order approximation to the large displacement problem - s set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	s
Form	=	rectangular
Type	=	real single precision

2.3.33.6 YBS (MATRIX)

Description

$\left\{Y_{s}^{b}\right\}$ - Partition of the constrained displacement vector of the first order approximation to the large displacement vector - s set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	s
Form	=	rectangular
Type	=	real single precision

2.3.33.7 URØØV (MATRIX)

Description

$\left\{u_{o}^{ob}\right\}$ - Partition of the displacement vector of the first order approximation to the large displacement problem - o set.

Matrix Trailer

Number of columns	=	1
Number of rows	=	o
Form	=	rectangular
Type	=	real single precision

2.3.34 Data Blocks Output From Module PLA1.

2.3.34.1 KGGXL (MATRIX).

Description

$[K_{gg}^{x\ell}]$ - Stiffness matrix of linear elements exclusive of general elements - g set.

Matrix Trailer

Number of columns = g
Number of rows = g
Form = symmetric
Type = real double precision

2.3.34.2 ESTL (TABLE).

Description

Element Summary Table for Linear Elements.

The ESTL contains data copied from the EST data block. An element's EST data resides in the ESTL only if it is a linear element of the model.

Table Format

Same format as the EST data block output from module TA1.

Table Trailer

Word 1 = number of element entries in ESTL.

Words 2-6 = zero.

2.3.34.3 ESTNL (TABLE).

Description

Element Summary Table for Non-Linear Elements.

The ESTNL, used only in the Piecewise Linear Analysis Rigid Format, is constructed from the Element Summary Table (EST). It contains one logical record for each element type for which at least one element of that type is non-linear (an element is defined to be non-linear if its modulus of elasticity is defined as the first derivative of a stress-strain tabular function input on a TABLES1 bulk data card) and for which a request for stress output is found. The construction of the ESTNL is as follows: the EST data block is read and each element is tested for possible non-linearity. If the element is non-linear and the user has requested element stress data to be output, its element data is copied onto the ESTNL data block and then initial stress data is appended. The only elements admissible to the ESTNL are: RØD, TUBE, CØNRØD, BAR, TRMEM, TRIA1, TRIA2, QDMEM, QUAD1, QUAD2.

Table Format

Record	Word	Item	
0		Header record	
1	1	Element type (integer)	repeated for each admissible element type
	2 to N+1	Element EST data (repeated for each non-linear element)	
	N+2 to N+M+1	Element stress data (repeated for each non-linear element)	

Notes

1. N is the number of words in the EST data section.
   M is the number of stress words appended.

2. The number of records in the ESTNL corresponds to the number of separate admissible element types for which at least one element is non-linear.

Table Trailer

Word 1 = total number of elements in the ESTNL.

Words 2-6 = zero.

Detailed ESTNL Formats

RØD, CØNRØD:

Word	Item
1-17	EST data
18	ε_0^*, previous strain value once removed, initially zero
19	ε^*, previous strain value, initially zero
20	E^*, the previously calculated modulus of elasticity, initially the value of E given a MAT1 card.
21	T^*, the previously calculated torsional moment, initially zero

TUBE:

Word	Item
1-16	EST data
17-20	Same as words 18-21 for the RØD.

BAR:

Word	Item
1-42	EST data
43	ε_0^*, previous strain value once removed, initially zero
44	ε^*, previous strain value, initially zero
45	E^*, the previously calculated modulus of elasticity, initially the value of E given on a MAT1 card
46	V_1^*
47	V_2^*
48	T^* The previous element forces, initially zero
49	M_{1a}^*
50	M_{2a}^*

TRMEM:

Word	Item
1-21	EST data
22	ε_0^*, previous strain value once removed, initially zero
23	ε^*, previous strain value, initially zero
24	E^*, the previously calculated modulus of elasticity, initially the value of E given on a MAT1 card
25	σ_x^*
26	σ_y^* The current membrane stresses, initially zero
27	σ_{xy}^*

TRIA1:

Word	Item
1-27	EST data
28-33	Same as words 22-27 for the TRMEM

Word	Item
34	M_x^*
35	M_y^*
36	M_{xx}^*
37	V_x^*
38	V_y^*

The previous element forces, initially zero

TRIA2:

Word	Item
1-27	Same as words 1-27 for the TRMEM
28-32	Same as words 34-38 for the TRIA1

QDMEM:

Word	Item
1-26	EST data
27-32	Same as words 22-27 for the TRMEM

QUAD1:

Word	Item
1-32	EST data
33-38	Same as words 22-27 for the TRMEM
39-43	Same as words 34-38 for the TRIA1

QUAD2:

Word	Item
1-26	EST data
27-32	Same as words 22-27 for the TRMEM
33-37	Same as words 34-38 for the TRIA1

2.3.34.4 ECPTNL (TABLE).

Description

Element Connection and Properties Table for Non-Linear Elements.

The ECPTNL, used only in the Piecewise Linear Analysis Rigid Format, is constructed from the ECPT data block. The ECPTNL contains one logical record for each grid point or scalar point of the model. Each logical record contains Element Summary Table (EST) data plus initial element stress data appended to this data for each non-linear element connected to the pivot point. (An element is defined to be non-linear if its modulus of elasticity is defined as the first derivative of a stress-strain tabular function input on a TABLES1 card). The only elements admissible to the ECPTNL are: RØD, TUBE, CØNRØD, BAR, TRMEM, TRIA1, TRIA2, QDMEM, QUAD1, QUAD2.

Table Format

Record	Word	Item	
0		Header record	
1	1	SIL number for "pivot" grid or scalar point (integer)	repeated for each grid or scalar point in the model
	2	Element type (integer)	repeated for each non-linear element connected to the pivot
	3 to N+2	Element EST data	
	N+3 to N+M+2	Element stress data	
n+1		End-of-file	

Notes

1. N is the number of words in the EST data section.
   M is the number of stress words appended. The number of stress words appended in generating the ECPTNL data block is not the same as in generating the ESTNL data block.

2. n is the total number of grid and scalar points in the model.

3. If all elements connected to a pivot point are linear, then the record contains only one word, the pivot point set negative.

Table Trailer

Word 1 = total number of element entries in the ECPTNL.

Words 2-6 = zero.

Detailed ECPTNL Formats

RØD, CØNRØD:

Word	Item
1-20	Same as ESTNL data. Note word 21 of the ESTNL is not present in the ECPTNL data for the RØD, CØNRØD.

TUBE:

Word	Item
1-19	Same as ESTNL data. Note word 20 of the ESTNL is not present in the ECPTNL data for the TUBE.

BAR:

Word	Item
1-45	Same as ESTNL data. Note words 46-50 of the ESTNL are not present in the ECPTNL data for the BAR.

TRMEM:

Word	Item
1-27	Same as ESTNL data.

TRIA1:

Word	Item
1-33	Same as ESTNL data. Note words 34-38 of the ESTNL are not present in the ECPTNL data for the TRIA1.

TRIA2:

Word	Item
1-27	Same as ESTNL data. Note words 28-32 of the ESTNL are not present in the ECPTNL data for the TRIA2.

QDMEM:

Word	Item
1-32	Same as ESTNL data.

QUAD1:

Word	Item
1-38	Same as ESTNL data. Note words 39-43 of the ESTNL are not present in the ECPTNL data for the QUAD1.

QUAD2:

Word	Item
1-32	Same as ESTNL data. Note words 33-37 of the ESTNL are not present in the ECPTNL data for the QUAD2.

2.3.35 Data Blocks Output From Module ADD

2.3.35.1 KGGSUM (MATRIX)

Description

Sum of $[K_{gg}^{\ell}]$ and $[K_{gg}^{n\ell}]$.

Used only in the Piecewise Linear Analysis Rigid Format and is equivalent to $[K_{gg}]$.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.35.2 PG (MATRIX)

Description

$\left\{P_g\right\}$ - Incremental load vector used in Piecewise Linear Analysis.

Matrix Trailer

Number of columns	=	1
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.35.3 KDAAM (MATRIX)

Description

$[K_{aa}^{dm}]$ - The negative of $[K_{aa}^{d}]$ (see section 2.3.32).

Used only in the Buckling Analysis Rigid Format.

Matrix Trailer

Number of columns	=	a
Number of rows	=	a
Form	=	symmetric
Type	=	real double precision

2.3.36 Data Blocks Output From Module PLA2

2.3.36.1 UGV1 (MATRIX)

Description

$[u_g^1]$ - Matrix of successive sums of incremental displacement vectors - g set. Used only in the Piecewise Linear Analysis Rigid Format.

Matrix Trailer

Number of columns	=	number of factors on a PLFACT bulk data card
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.36.2 PGV1 (MATRIX)

Description

$[P_g^1]$ - Matrix of successive sums of incremental load vectors - g set. Used only in the Piecewise Linear Analysis Rigid Format.

Matrix Trailer

Number of columns	=	number of factors on a PLFACT bulk data card
Number of rows	=	g
Form	=	rectangular
Type	=	real single precision

2.3.36.3 QG1 (MATRIX)

Description

$[q_g^1]$ - Matrix of successive sums of incremental vectors of single point constraint forces - g set. Used in the Piecewise Linear Analysis Rigid Format only.

Matrix Trailer

Number of columns	=	number of factors on a PLFACT bulk data card
Number of rows	=	q
Form	=	symmetric
Type	=	real single precision

2.3.37 Data Blocks Output From Module PLA3.

2.3.37.1 ØNLES (TABLE).

Description

Output table for nonlinear element stresses.

Format

Same format as ØES1 table output from module SDR2.

Note

ØNLES is written in subroutine PLA32 of module PLA3.

Table Trailer

Word 1 = total number of element entries in ØNLES.

Word 2-6 = zero.

2.3.37.2 ESTNL1 (TABLE).

Description

Element summary table for nonlinear elements - updated.

Used only in the Piecewise Linear Analysis Rigid Format, the ESTNL1 data block is the same as the ESTNL data block except that the appended stress information is updated. See data block description for ESTNL for further details.

Table Format

Same format as the ESTNL data block.

Table Trailer

Word 1 = number of element entries in ESTNL1.

Word 2-6 = zero.

2.3.38 Data Blocks Output From Module PLA4.

2.3.38.1 KGGNL (MATRIX).

Description

$[K_{gg}^{n\ell}]$ - Stiffness matrix of nonlinear elements - g set.

Used only in the Piecewise Linear Analysis Rigid Format.

Matrix Trailer

Number of columns	=	g
Number of rows	=	g
Form	=	symmetric
Type	=	real double precision

2.3.38.2 ECPTNL1 (TABLE).

Description

Element Connection and Properties Table for Non-Linear Elements - undated.

Used only in the Piecewise Linear Analysis Rigid Format, the ECPTNL1 data block is the same as the ECPTNL data block except that the appended stress information is updated. See description for ECPTNL for further details.

Table Format

Same format as the ECPTNL data block.

Table Trailer

Word 1 = total number of element entries in ECPTNL1.

Word 2-6 = zero.

2.3.39 Data Blocks Output From Module CASE.

2.3.39.1 CASEXX (TABLE).

Description

Case Control data table for dynamics problems.

Table Format

The format of the records is exactly like CASECC, (see section 2.3.1.1) with dynamic looping records deleted.

Table Trailer

Word 1 = number of records in CASEXX.

Word 2-6 = zero.

2.3.40 Data Blocks Output From Module MTRXIN

2.3.40.1 K2PP (MATRIX)

Description

$[K^{2}_{pp}]$ - Direct input stiffness matrix - p set.

Matrix Trailer

Number of columns	=	p
Number of rows	=	p
Form	=	square
Type	=	depends on input

2.3.40.2 M2PP (MATRIX)

Description

$[M^{2}_{pp}]$ - Direct input mass matrix - p set.

Matrix Trailer

Number of columns	=	p
Number of rows	=	p
Form	=	square
Type	=	depends on input

2.3.40.3 B2PP (MATRIX)

Description

$[B^{2}_{pp}]$ - Direct input damping matrix - p set.

Matrix Trailer

Number of columns	=	p
Number of rows	=	p
Form	=	square
Type	=	depends on input

2.3.40.4

The MTRXIN module may be used via DMAP to produce any desired p sized matrix from DMIG input data.

2.3.41 Data Blocks Output From Module GKAD

2.3.41.1 KDD (MATRIX)

Description

$[K_{dd}]$ - Dynamic stiffness matrix - d set.

Matrix Trailer

Number of columns	=	d
Number of rows	=	d
Form	=	square
Type	=	complex double precision - frequency response/complex eigenvalue
	=	real double precision - transient

2.3.41.2 BDD (MATRIX)

Description

$[B_{dd}]$ - Dynamic damping matrix - d set.

Matrix Trailer

Number of columns	=	d
Number of rows	=	d
Form	=	square
Type	=	complex double precision - frequency response/complex eignevalue
	=	real double precision - transient

2.3.41.3 MDD (MATRIX)

Description

$[M_{dd}]$ - Dynamic mass matrix - d set.

Matrix Trailer

Number of columns	=	d
Number of rows	=	d
Form	=	square
Type	=	complex double precision - frequency response/complex eigenvalue
	=	real double precision - transient

2.3.41.4 GMD (MATRIX)

Description

$[G_m^d]$ - Multipoint constraint transformation matrix - dynamics.

Matrix Trailer

Number of columns = d
Number of rows = m
Form = rectangular
Type = real double precision

2.3.41.5 GØD (MATRIX)

Description

$[G_o^d]$ - Omitted coordinate transformation matrix - dynamics.

Matrix Trailer

Number of columns = d
Number of rows = o
Form = rectangular
Type = real double precision

2.3.41.6 K2DD(MATRIX)

Description

$[K_{dd}^2]$ - Direct input stiffness matrix - d set.

Matrix Trailer

Number of columns = d
Number of rows = d
Form = square
Type = complex double precision/real double precision

2.3.41.7 M2DD (MATRIX)

Description

$[M_{dd}^2]$ - Direct input mass matrix - d set.

Matrix Trailer

Number of columns = d
Number of rows = d
Form = square
Type = complex double precision/real double precision

2.3.41.8 B2DD (MATRIX)

Description

$[B^2_{dd}]$ - Direct input damping matrix - d set.

Matrix Trailer

Number of columns	=	d
Number of rows	=	d
Form	=	square
Type	=	complex double precision/real double precision

2.3.42 Data Blocks Output From Module CEAD

2.3.42.1 PHID (MATRIX)

Description

$[\Phi_d]$ - Complex eigenvectors in the d set.

Matrix Trailer

Number of columns = number of eigenvalues found in CEAD
Number of rows = d
Form = rectangular
Type = complex single precision

2.3.42.2 CLAMA (TABLE)

Description

λ - Complex eigenvalue table.

Table Format

Record	Word	Type	Item
0			Header record
1			ØFP ID record
	1	I	90
	2	I	1006
	3-9	I	0
	10	I	6
	11-50		Not defined
	51-146	B	Title, subtitle, and label from /ØUTPUT/
2			ØFP data record
	1	I	Mode number
	2	I	Extraction order
	3	R	Real part of eigenvalue
	4	R	Imaginary part of eigenvalue
	5	R	$\lvert Im\ (\lambda)\rvert/2\pi$
	6	R	$-2*Re\ (\lambda)/\lvert Im\ (\lambda)\rvert$
	Note: The 6 data words are repeated in record 2 for each eigenvalue found in CEAD.		
3			End-of-file

Table Trailer

Word 1 = 1006
Word 2 = 0
Word 3 = 0
Word 4 = 0
Word 5 = 6
Word 6 = 0

2.3.42.3 ØCEIGS (TABLE).

Description

Complex eigenvalue summary table.

Table Format

Record	Word	Type	Item
0		B	Header record
1	1	I	0
	2	I	1009
	3	I	1 if determinant 2 if inverse power
	4-10	I	0
	11	I	Number of eigenvalues extracted
	12-18		Depend on the method used
	Determinant		
	12	I	Number of passes through starting points
	13	I	Number of criteria changes
	14	I	Number of starting point moves
	15	I	Number of decompositions
	16	I	Number of failures to iterate to a root
	17	I	Number of predictions outside the region
	18	I	Reason for termination 1 - all requested roots found 2 - out of region prediction from every starting point 3 - insufficient time to extract another root 4 - everywhere singular matrix
	Inverse Power		
	12-18		Identical to words 12-18 for Inverse Power Method section of the ØEIGS data block output from the READ module (see section 2.3.30.4).
	19-50		Not defined
	51-146	B	Title, subtitle, label

Record 1 will be repeated for each region for Inverse Power.
Records 2 + 3 exist only when METHØD = DETM.

2	1	I	0
	2	I	1009
	3	I	3
	4-9	I	0
	10	I	6
	11-50		Not defined
	51-146	B	Title, subtitle, label

Record	Word	Type	Item
3	1	I	Starting point number in region
	2	R	Real part of starting point
	3	R	Imaginary part of starting point
	4	R	Magnitude of starting point
	5	R	Phase of starting point
	6	I	Scale factor (power of 10) of magnitude
	Words 1-6 are repeated for each starting point in each region.		
4			End-of-file

Table Trailer

Non-zero.

2.3.42.4 PHIH (MATRIX)

Description

$[\Phi_h]$ - Complex eigenvectors in the h set.

Matrix Trailer

Number of columns = number of eigenvalues found in CEAD
Number of rows = h
Form = rectangular
Type = complex single precision

2.3.43 Data Blocks Output From Module VDR

2.3.43.1 ØPHID (TABLE)

Description

Output complex eigenvectors requests (solution set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	1014
	3	I	0
	4	I	Subcase number
	5	I	Mode number
	6-7	R	Complex eigenvalue
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in record 2 = 14.
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10 * point ID + device code } repeated for each point
	2	I	Point type } repeated for each point
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } repeated for each point
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) } repeated for each point

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }
3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }
4. Approach code = 9
5. Point type = { 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point }
6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536

Word 2 = remainder from division above

Word 3-6 = zero.

2.3.43.2 ØUDVC1 (TABLE)

Description

Output displacement requests (solution set, SØRT1, complex)

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	1015 = displacement 1016 = velocity 1017 = acceleration
	3	I	0
	4	I	Subcase number
	5	R	Frequency
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code
	10	I	Number of words per entry in record 2 = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10 * point ID + device code — repeated for each point
	2	I	Point type — repeated for each point
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) — repeated for each point
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) — repeated for each point

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginery
   - 3 = magnitude/phase

4. Approach code = 6

Notes cont'd.

5. Point type = 1 = grid point, 2 = scalar point, 3 = extra point, 4 = modal point

6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.43.3 ØUDV1 (TABLE)

Description

Output displacement requests (solution set, SØRT1, real).

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	15 = displacement, 16 = velocity, 17 = acceleration
	3	I	0
	4	I	Subcase number
	5	R	Time
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in record 2 = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10 * point ID + device code } repeated
	2	I	Point type } for each
	3-8	R	T1, T2, T3, R1, R2, R3 } point

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = {0 = x y output only; 1 = print; 4 = punch; 5 = print and punch}

3. Format code = {1 = real; 2 = real/imaginary; 3 = magnitude/phase}

4. Approach code = 7

5. Point type = {1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point}

6. Components (words 3-8 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.43.4 ØPNL1 (TABLE)

Description

Output nonlinear load requests (solution set, SØRT1, real)

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	12
	3	I	0
	4	I	Subcase number
	5	R	Time
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code
	10	I	Number of words per entry in record 2 = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label

Record	Word	Type	Item+	
2	1	I	10 * point ID + device code	repeated for each point
	2	I	Point type	
	3-8	R	T1, T2, T3, R1, R2, R3	

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 7
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point
6. Components (words 3-8 in even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.43.5 ØPHIH (TABLE)

Description

Output complex eigenvector requests (solution set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	1014
	3	I	0
	4	I	Subcase number
	5	I	Mode number
	6-7	R	Complex eigenvalue
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in record 2 = 14

Record	Word	Type	Item	
	11-50		Not defined	
	51-82	B	Title	
	83-114	B	Subtitle	
	115-146	B	Label	
2	1	I	10 * point ID + device code	repeated for each point
	2	I	Point type	
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3)	
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3)	

Notes

1. Records 1 and 2 are repeated for each vector to be output

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase

4. Approach code = 9

5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.43.6 ØUHVC1 (TABLE)

Description

Output displacement requests (solution set, SØRT1, complex).

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	1015 = displacement 1016 = velocity 1017 = acceleration
	3	I	0
	4	I	Subcase number
	5	R	Frequency
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code
	10	I	Number of words per entry in record 2 = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10 * point ID + device code (repeated for each point)
	2	I	Point type (repeated for each point)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeated for each point)
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) (repeated for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase

4. Approach code = 6

5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.43.7 ØUHV1 (TABLE)

Description

Output displacement requests (solution set, SØRT1, real).

Table Format

Record	Word	Type	Item
0	1-2	B	Data block name
	3-5	I	Month, day, year
	6	I	Time
	7	I	1
1	1	I	Device code + 10 * approach code
	2	I	15 = displacement 16 = velocity 17 = acceleration
	3	I	0
	4	I	Subcase number
	5	R	Time
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in record 2 = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	I	10 * point ID + device code (repeated for each point)
	2	I	point type (repeated for each point)
	3-8	R	T1, T2, T3, R1, R2, R3 (repeated for each point)

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase

4. Approach code = 7

5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

6. Components (words 3-8 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Word 1 = (sum of all words in even numbered records)/65536.

Word 2 = remainder from division above.

Word 3-6 = zero.

2.3.44 Data Blocks Output From Module FRRD

2.3.44.1 UDVF (MATRIX)

Description

$[u_d^f]$ - Displacement vector matrix in a frequency response problem - d set.

Matrix Trailer

Number of columns	=	number of frequencies multiplied by the number of loads
Number of rows	=	d
Form	=	rectangular
Type	=	complex single precision

2.3.44.2 PSF (MATRIX)

Description

$[P_s^f]$ - Load vector for frequency response - s set.

Matrix Trailer

Number of columns	=	number of frequencies multiplied by the number of loads
Number of rows	=	s
Form	=	rectangular
Type	=	complex single precision

2.3.44.3 PDF (MATRIX)

Description

$\{P_d^f\}$ - Dynamic load matrix for frequency analysis - d set.

Matrix Trailer

Number of columns	=	number of frequencies multiplied by the number of loads
Number of rows	=	d
Form	=	rectangular
Type	=	complex single precision

2.3.44.4 PPF (MATRIX)

Description

$[P_p^f]$ - Dynamic loads for frequency response - p set.

Matrix Trailer

Number of columns	=	number of frequencies multiplied by the number of loads
Number of rows	=	p
Form	=	rectangular
Type	=	complex single precision

Note

The header record contains the list of frequencies.

2.3.44.5 UHVF (MATRIX)

Description

$[u_h^f]$ - Modal frequency response solution vectors - h set.

Matrix Trailer

Number of columns	=	number of frequencies multiplied by the number of loads
Number of rows	=	h
Form	=	rectangular
Type	=	complex single precision

2.3.45 Data Blocks Output From Module SDR3.

2.3.45.1 ØPP2 (TABLE)

Description

Output load vector requests (p set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2002
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.2 ØQP2 (TABLE).

Description

Output forces of single-point constraint (p set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2003
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time — repeat for each time step
	2	I	Point type — repeat for each time step
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) — repeat for each time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.3 ØUPV2 (TABLE).

Description

Output displacement vector requests (p set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2001 = Displacement 2010 = Velocity 2011 = Acceleration
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time (repeat for each time step)
	2	I	Point type (repeat for each time step)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each time step)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.4 ØES2 (TABLE).

Description

Output element stress requests (SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2005
	3	I	Element type
	4	I	Subcase number
	5	I	10*element ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time } repeat
	2-NWDS	Mixed	Element stress data } for each
			See section 2.3.51 for details } time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6

Table Trailer

Words 1-6 contain no significant values.

2.3.45.5 ØEF2 (TABLE).

Description

Output element force requests (SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2004
	3	I	Element type
	4	I	Subcase number
	5	I	10*element ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time } repeat
	2-NWDS	Mixed	Element force data } for each
			See section 2.3.52 for details } time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 6

Table Trailer

Words 1-6 contain no significant values.

2.3.45.6 ØPNL2 (TABLE).

Description

Output nonlinear load requests (solution set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2012
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point
6. Components (words 3-8 in even numbered records) which are not in the solution set are replaced by integer 1.

Table Trailer

Words 1-6 contain no significant values.

2.3.45.7 ØUDV2 (TABLE).

Description

Output displacement vector requests (solution set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	2015 = Displacement; 2016 = Velocity; 2017 = Acceleration
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time (repeat for each time step)
	2	I	Point type (repeat for each time step)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each time step)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 6
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point
6. Components (words 3-8 of even numbered records) which are not in the solution set are replaced by integer 1.

Table Trailer

Words 1-6 contain no significant values.

2.3.45.8 ØUHV2 (TABLE).

Description

Output displacement vector requests (solution set, SØRT2, real).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	{2015 = Displacement 2016 = Velocity 2017 = Acceleration
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code = 1
	10	I	Number of words per entry in next record = 8
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Time } repeat
	2	I	Point type } for each
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) } time step

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = {0 = x y output only
1 = print
4 = punch
5 = print and punch

3. Format code = {1 = real
2 = real/imaginary
3 = magnitude/phase

4. Approach code = 6

5. Point type = {1 = grid point
2 = scalar point
3 = extra point
4 = modal point

6. Components (words 3-8 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Words 1-6 contain no significant values.

2.3.45.9 ØPPC2 (TABLE).

Description

Output load vector requests (p set, SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3002
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	0
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-145	B	Label
2	1	R	Frequency (repeat for each frequency)
	2	I	Point type (repeat for each frequency)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each frequency)
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) (repeat for each frequency)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 5
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.10 ØQPC2 (TABLE).

Description

Output forces of single-point constraint requests (p set, SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3003
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency (repeat for each frequency)
	2	I	Point type (repeat for each frequency)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each frequency)
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) (repeat for each frequency)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 5
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.11 ØUPVC2 (TABLE).

Description

Output displacement vector requests (p set, SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3001 = Displacement 3010 = Velocity 3011 = Acceleration
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency — repeat for each frequency
	2	I	Point type — repeat for each frequency
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) — repeat for each frequency
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) — repeat for each frequency

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch

3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase

4. Approach code = 5

5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point

Table Trailer

Words 1-6 contain no significant values.

2.3.45.12 ØESC2 (TABLE).

Description

Output element stress requests (SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3005
	3	I	Element type
	4	I	Subcase number
	5	I	10*Element ID + device code
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency } repeat
	2-NWDS	Mixed	Element stress data } for each
			See 2.3.51 for details } frequency

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 5

Table Trailer

Words 1-6 contain no significant values.

2.3.45.13 ØEFC2 (TABLE).

Description

Output element force requests (SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3004
	3	I	Element type
	4	I	Subcase number
	5	I	10*element ID + device code
	6	I	0
	7	I	0
	8	I	Load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = NWDS
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency } repeat
	2-NWDS	Mixed	Element force data } for each
			See 2.3.52 for details } frequency

Notes

Records 1 and 2 are repeated for each vector to be output.

2. Device code = { 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch }

3. Format code = { 1 = real; 2 = real/imaginary; 3 = magnitude/phase }

4. Approach code = 5

Table Trailer

Words 1-6 contain no significant values.

2.3.45.14 ØUDVC2 (TABLE).

Description

Output displacement vector requests (solution set, SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3015 = Displacement 3016 = Velocity 3017 = Acceleration
	3	I	0
	4	I	Subcase Number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency — repeat for each frequency
	2	I	Point type — repeat for each frequency
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) — repeat for each frequency
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) — repeat for each frequency

Notes

1. Records 1 and 2 are repeated for each vector to be output.

2. Device code =
   - 0 = x y output only
   - 1 = print
   - 4 = punch
   - 5 = print and punch

3. Format code =
   - 1 = real
   - 2 = real/imaginary
   - 3 = magnitude/phase

4. Approach code = 5

5. Point type =
   - 1 = grid point
   - 2 = scalar point
   - 3 = extra point
   - 4 = modal point

6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by integer 1.

Table Trailer

Words 1-6 contain no significant values.

2.3.45.15 ØUHVC2 (TABLE).

Description

Output displacement vector requests (solution set, SØRT2, complex).

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	Device code + 10*approach code
	2	I	3015 = Displacement 3016 = Velocity 3017 = Acceleration
	3	I	0
	4	I	Subcase number
	5	I	10*point ID + device code
	6	I	0
	7	I	0
	8	I	Dynamic load set ID
	9	I	Format code
	10	I	Number of words per entry in next record = 14
	11-50		Not defined
	51-82	B	Title
	83-114	B	Subtitle
	115-146	B	Label
2	1	R	Frequency (repeat for each frequency)
	2	I	Point type (repeat for each frequency)
	3-8	R	R(T1), R(T2), R(T3), R(R1), R(R2), R(R3) (repeat for each frequency)
	9-14	R	I(T1), I(T2), I(T3), I(R1), I(R2), I(R3) (repeat for each frequency)

Notes

1. Records 1 and 2 are repeated for each vector to be output.
2. Device code = 0 = x y output only; 1 = print; 4 = punch; 5 = print and punch
3. Format code = 1 = real; 2 = real/imaginary; 3 = magnitude/phase
4. Approach code = 5
5. Point type = 1 = grid point; 2 = scalar point; 3 = extra point; 4 = modal point
6. Components (words 3-14 of even numbered records) which are not in the solution set are replaced by an integer 1.

Table Trailer

Words 1-6 contain no significant values.

2.3.46 Data Blocks Output From Module XYTRAN.

2.3.46.1 XYPLTT (TABLE).

Description

Output plot request data in form for direct plotting of SØRT2 Transient Response output.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I-R	Subcase ID or if a Random Response problem, the Mean Response
	2	I	Frame number
	3	I	Curve number
	4	I	Point ID or element ID
	5	I	Component number
	6	I	Vector number (1, 2, ... 11)
	7	I	1--Graph uses top half of frame 0--Graph uses full frame -1--Graph uses lower half of frame
	8	I	0--Axis, tics, labels, values, etc. have been drawn and this curve is to be scaled and plotted identically as last except for curve symbols. 1--Axis, tics, labels, scaling, etc. are to be performed or computed and if word 7 of this record = 0 or 1, a skip to new frame is to be made.
	9	I	Number of blank frames between frames (frame-skip)
	10		Not used
	11	R	XMIN } Define exact corners of this upper, lower, or full frame graph
	12	R	XMAN }
	13	R	YMIN }
	14	R	YMAX }
	15	R	Actual value of first tic } x-direction tics
	16	R	Actual increment to successive tics
	17	I	Integer value to be printed on first tic
	18	I	Maximum number of digits in any print-value
	19	I	+ or - power for print values
	20	I	Total number of tics to print this edge
	21	I	Value print skip 0,1,2,3---
	22	I	Delta integer print value to successive tics
	23	R	} Same as 15 through 22 But for y-direction tics
	24	R	
	25	I	
	26	I	
	27	I	
	28	I	
	29	I	
	30	I	

Record	Word	Type	Item
	31	I	Top edge tics) each of 31-34 may be less
	32	I	Bottom edge tics { than 0--tics without values
	33	I	Left edge tics { equal to 0--no tics here
	34	I	Right edge tics) greater 0--tics with values
	35	I	0--x-direction is linear Greater than 0--number of cycles and x-direction is logarithmic
	36	I	0--y-direction is linear Greater than 0--number of cycles and y-direction is logarithmic
	37	I	0--no x-axis 1--draw x-axis
	38	R	x-axis y-intercept
	39	I	0--no y-axis 1--draw y-axis
	40	R	y-axis x-intercept
	41	I	Less than 0 -- plot symbol for each curve point. Select symbol corresponding to curve number in word 3 of this record. Equal to 0 -- connect points by lines where points are continuous i.e., (no integer 1 pairs). Greater than 0 -- do both of above.
	42 . . .		Not used
	50		
	51	B	Title (32 words)
	.	B	Subtitle (32 words)
	.	B	Label (32 words)
	.	B	Curve Title (32 words)
	.	B	x-axis Title (32 words)
	242	B	y-axis Title (32 words)
	243 . . .		Not used
	282		
	283	I	Pensize
	284	I	Plotter 1 = SC4020, 2 = EAI3500
	285	R	Inches paper x-direction
	286	R	Inches paper y-direction
	287	I	Camera for SC4020 less than 0 = 35mm, 0 = F80, Greater 0 = Both
	288	I	Print flag 0 = no, 1 = yes
	289	I	Plot flag 0 = no, 1 = plotter, -1 = paper, 2 = plotter and paper
	290	I	Punch flag 0 = no, 1 = yes
	291	R	x-min of all data
	292	R	x-max of all data
	293	R	y-min within x-limits of graph
	294	R	x-value at this y-min
	295	R	y-max within x-limits of graph
	296	R	x-value at this y-max
	297	R	y-min for all data
	298	R	x-value at this y-min
	299	R	y-max for all data
	300	R	x-value at this y-max

Record	Word	Type	Item
2	1	I	1 } Always is present
	2	I	1 }
	3	R	x-value } coordinate pair
	4	R	y-value } repeats for all pairs plotted

Notes

1. Records 1 and 2 repeat for each curve plotted.
2. Even numbered records will contain integer 1 pairs to indicate where curve has moved outside of graph limits.

Table Trailer

Words 1-6 contain no significant values.

2.3.46.2 XYPLTFA (TABLE).

Description

Identical to XYPLTT, for Frequency Response plots (solution set).

2.3.46.3 XYPLTF (TABLE).

Description

Identical to XYPLTT, for Frequency Response plots.

2.3.46.4 XYPLTR (TABLE).

Description

Identical to XYPLTT, for Random Response plots.

2.3.46.5 XYPLTTA (TABLE).

Description

Identical to XYPLTT, for Transient Response plots (solution set).

2.3.47 Data Blocks Output From Module RANDØM

2.3.47.1 PSDF (TABLE)

Description

Power Spectral Density Table.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	50
	2	I	Code for data type DISP = 2001 VELØ = 2010 ACCE = 2011 LØAD = 2002 SPCF = 2003 ELFØ = 2004 STRE = 2005
	3	I	4001
	4	I	0
	5	I	Point or element ID times 10
	6	I	Component ID + 2
	7	I	0
	8	R	Mean response
	9	I	0
	10	I	2
	11-50	I	0
	51-145	B	Title, subtitle, label
2	1	R	Frequency
	2	R	Power spectral density

Notes

1. Words 1 and 2 of record 2 are repeated for each frequency.
2. Records 1 and 2 are repeated for each power spectral density request.

Table Trailer

Words 1-5 = zero.

Word 6 = number of requests.

2.3.47.2 AUTØ (TABLE).

Description

Autocorrelation function table.

Table Format

Record	Word	Type	Item
0			Header record
1	1	I	50
	2	I	Code for data type DISP = 2001 VELØ = 2010 ACCE = 2011 LØAD = 2002 SPCF = 2003 ELFØ = 2004 STRE = 2005
	3	I	4002
	4	I	0
	5	I	Point or element ID times 10
	6	I	Component ID + 2
	7	I	0
	8	R	Mean response
	9	I	0
	10	I	2
	11-50	I	0
	51-146	B	Title, subtitle, label
2	1	R	TAU
	2	R	Auto correlation function

Notes

1. Words 1 and 2 of record 2 are repeated for each TAU.
2. Records 1 and 2 are repeated for each autocorrelation request.

Table Trailer

Words 1-5 = zero.

Word 6 = number of requests.

2.3.48 Data Blocks Output From Module TRD.

2.3.48.1 UDVT (MATRIX)

Description

$[u_d^t]$ - Displacement, velocity, and acceleration vector matrix in a transient analysis problem - d set.

Matrix Trailer

Number of columns	=	three times the number of output time steps
Number of rows	=	d
Form	=	rectangular
Type	=	real single precision

2.3.48.2 PDT (MATRIX)

Description

$[P_d^t]$ - Linear dynamic load matrix for transient analysis - d set.

Matrix Trailer

Number of columns	=	number of output times
Number of rows	=	d
Form	=	rectangular
Type	=	real single precision

2.3.48.3 PST (MATRIX)

Description

$[P_s^t]$ - Linear load vector for transient analysis - s set.

Matrix Trailer

Number of columns	=	number of output times
Number of rows	=	s
Form	=	rectangular
Type	=	real single precision

2.3.48.4 PPT (MATRIX)

Description

$[p_p^t]$ - Linear dynamic loads for transient analysis - p set.

Matrix Trailer

Number of columns	=	number of output times
Number of rows	=	p
Form	=	rectangular
Type	=	real single precision

*Note: The header record contains the list of output times.

2.3.48.5 PNLD (MATRIX)

Description

$[p_d^{n\ell}]$ - Nonlinear loads in transient problem - d set.

Matrix Trailer

Number of columns	=	number of output times
Number of rows	=	d
Form	=	rectangular
Type	=	real single precision

2.3.48.6 UHVT (MATRIX)

Description

$[u_h^t]$ - Modal transient solution vectors - h set.

Matrix Trailer

Number of columns	=	three times the number of output times
Number of rows	=	h
Form	=	rectangular
Type	=	real single precision

2.3.48.7 PNLH (MATRIX)

Description

$[p_h^{n\ell}]$ - Nonlinear loads in modal transient problem - h set.

Matrix Trailer

Number of columns	=	number of output times
Number of rows	=	h
Form	=	rectangular
Type	=	real single precision

2.3.49 Data Blocks Output From Module GKAM

2.3.49.1 MHH (MATRIX)

Description

$[m_{hh}]$ - Modal mass matrix - h set.

Matrix Trailer

Number of columns = h
Number of rows = h
Form = symmetric
Type = real double precision

2.3.49.2 BHH (MATRIX)

Description

$[b_{hh}]$ - Modal damping matrix - h set.

Matrix Trailer

Number of columns = h
Number of rows = h
Form = symmetric
Type = real double precision

2.3.49.3 KHH (MATRIX)

Description

$[k_{hh}]$ - Modal stiffness matrix - h set.

Matrix Trailer

Number of columns = h
Number of rows = h
Form = symmetric
Type = real double precision

2.3.49.4 PHIDH (MATRIX)

Description

$[\Phi_{dh}]$ - Transformation matrix from d set to modal coordinates.

Matrix Trailer

Number of columns = h
Number of rows = d
Form = rectangular
Type = real single precision

2.3.50 Data Blocks Output From Module DDR1

2.3.50.1 CPHID (MATRIX)

Description

$[\Phi_d]$ - Complex eigenvector matrix transformed from modal to physical coordinates.

Matrix Trailer

Number of columns	=	number of eigenvectors
Number of rows	=	d
Form	=	rectangular
Type	=	complex single precision

2.3.50.2 UDV1F (MATRIX)

Description

$[u_d^f]$ - Displacement vectors matrix in a frequency response problem - d set.

Matrix Trailer

Number of columns	=	number of frequencies times number of loads
Number of rows	=	d
Form	=	rectangular
Type	=	complex single precision

2.3.50.3 UDV1T (MATRIX)

Description

$[u_d^t]$ - Displacement vectors matrix in a transient response problem - d set.

Matrix Trailer

Number of columns	=	number of output times multiplied by 3
Number of rows	=	d
Form	=	rectangular
Type	=	real single precision

2.3.51 Element Stress Output Data Description.

Note particular data block description (e.g., ØES1, ØESB1) for contents of word 1 for each element.

Element Type	Element Name	Real Element Stresses Word or Component	Real Element Stresses Item	Complex Element Stresses Word or Component	Complex Element Stresses Item	Complex Element Stresses Real Imag.
1	CRØD	2	Axial	2	Axial	R
		3	Axial Safety Margin *	3	Axial	I
		4	Torsional	4	Torsional	R
		5	Torsional Safety Margin*	5	Torsional	I
2	CBEAM	2	SA1		Undefined	
		3	SA2			
		4	SA3			
		5	Axial			
		6	SA-maximum			
		7	SA-minimum			
		8	Safety Margin in Tension*			
		9	SB1			
		10	SB2			
		11	SB3			
		12	SB-maximum			
		13	SB-minimum			
		14	Safety Margin in Comp*			
3	CTUBE		Same as CRØD		Same as CRØD	
4	CSHEAR	2	Maximum Shear	2	Maximum Shear	R
		3	Average Shear	3	Maximum Shear	I
		4	Safety Margin*	4	Average Shear	R
				5	Average Shear	I
5	CTWIST	2	Maximum	2	Maximum	R
		3	Average	3	Maximum	I
		4	Safety Margin*	4	Average	R
				5	Average	I
6	CTRIA1	2	Z1 = Fibre Distance 1	2	Z1 = Fibre Distance 1	
		3	Normal-x at Z1	3	Normal-x at 1	R
		4	Normal-y at Z1	4	Normal-x at 1	I
		5	Shear-xy at Z1	5	Normal-y at 1	R
		6	0-Shear Angle at Z1	6	Normal-y at 1	I
		7	Major-Principal at Z1	7	Shear-xy at 1	R
		8	Minor-Principal at Z1	8	Shear-xy at 1	I
		9	Max-Shear at Z1	9	Z2 = Fibre Distance 2	
		10	Z2 = Fibre Distance 2	10	Normal-x at 2	R
		11	Normal-x at Z2	11	Normal-x at 2	I
		12	Normal-y at Z2	12	Normal-y at 2	R
		13	Shear-xy at Z2	13	Normal-y at 2	I
		14	0-Shear Angle at Z2	14	Shear-xy at 2	R
		15	Major-Principal at Z2	15	Shear-xy at 2	I
		16	Minor-Principal at Z2			
		17	Maximum-Shear at Z2			

Element		Real Element Stresses		Complex Element Stresses		
Type	Name	Word or Component	Item	Word or Component	Item	Real Imag.
7	CTRBSC		Note CTRIA1		Note CTRIA1	
8	CTRPLT		Note CTRIA1		Note CTRIA1	
9	CTRMEM	2	Normal-x	2	Normal-x	R
		3	Normal-y	3	Normal-x	I
		4	Shear-xy	4	Normal-y	R
		5	0-Shear Angle	5	Normal-y	I
		6	Major-Principal	6	Shear-xy	R
		7	Minor-Principal	7	Shear-xy	I
		8	Maximum Shear			
10	CØNRØD		Note CRØD		Note CRØD	
11	CELAS1	2	Stress	2	Stress	R
				3	Stress	I
12	CELAS2	2	Stress	2	Stress	R
				3	Stress	I
13	CELAS3	2	Stress	2	Stress	R
				3	Stress	I
14	CELAS4		Undefined		Undefined	
15	CQDPLT		Note CTRIA1		Note CTRIA1	
16	CQDMEM		Note CTRMEM		Note CTRMEM	
17	CTRIA2		Note CTRIA1		Note CTRIA1	
18	CQUAD2		Note CTRIA1		Note CTRIA1	
19	CQUAD1		Note CTRIA1		Note CTRIA1	
20	CDAMP1		Undefined		Undefined	
21	CDAMP2		Undefined		Undefined	
22	CDAMP3		Undefined		Undefined	
23	CDAMP4		Undefined		Undefined	
24	CVISC		Undefined		Undefined	
25	CMASS1		Undefined		Undefined	
26	CMASS2		Undefined		Undefined	
27	CMASS3		Undefined		Undefined	
28	CMASS4		Undefined		Undefined	
29	CØNM1		Undefined		Undefined	
30	CØNM2		Undefined		Undefined	
31	CPLØTEL		Undefined		Undefined	

Element Type	Element Name	Real Element Stresses Word or Component	Real Element Stresses Item	Complex Element Stresses Word or Component	Complex Element Stresses Item	Complex Element Stresses Real Imag.
34	CBAR	2	SA1	2	SA1	R
		3	SA2	3	SA2	R
		4	SA3	4	SA3	R
		5	SA4	5	SA4	R
		6	Axial	6	Axial	R
		7	SA-maximum	7	SA1	I
		8	SA-minimum	8	SA2	I
		9	Safety Margin in Tension*	9	SA3	I
		10	SB1	10	SA4	I
		11	SB2	11	Axial	I
		12	SB3	12	SB1	R
		13	SB4	13	SB2	R
		14	SB-maximum	14	SB3	R
		15	SB-minimum	15	SB4	R
		16	Safety Margin in Comp*	16	SB1	I
				17	SB2	I
				18	SB3	I
				19	SB4	I
35	CCØNEAX	2	Harmonic or point angle		Undefined	
		3	Z1 = Fibre Distance 1			
		4	Normal-u at 1			
		5	Normal-v at 1			
		6	Shear-uv at 1			
		7	O-Shear Angle at 1			
		8	Major-Principal at 1			
		9	Minor-Principal at 1			
		10	Maximum Shear at 1			
		11	Z2 = Fibre Distance 2			
		12	Normal-u at 2			
		13	Normal-v at 2			
		14	Shear-uv at 2			
		15	O-Shear Angle at 2			
		16	Major-Principal at 2			
		17	Minor-Principal at 2			
		18	Maximum-Shear at 2			
36	CTRIARG	2	Radial (x)		Undefined	
		3	Circum (Theta)			
		4	Axial (z)			
		5	Shear (zx)			
37	CTRAPRG	2	Radial (x) at 1		Undefined	
		3	Circum (Theta) at 1			
		4	Axial (z) at 1			
		5	Shear (zx) at 1			
		6	Radial (x) at 2			
		7	Circum (Theta) at 2			
		8	Axial (z) at 2			
		9	Shear (zx) at 2			
		10	Radial (x) at 3			
		11	Circum (Theta) at 3			
		12	Axial (z) at 3			
		13	Shear (zx) at 3			
		14	Radial (x) at 4			
		15	Circum (Theta) at 4			
		16	Axial (z) at 4			
		17	Shear (zx) at 4			
		18	Radial (x) at 5			

Element Type	Element Name	Real Element Stresses Word or Component	Item		Complex Element Stresses Word or Component	Item	Real Imag.
37 cont'd.		19	Circum(Theta)	at 5			
		20	Axial (z)	at 5			
		21	Shear (zx)	at 5			
38	CTØRDRG	2	Mem.-Tagen.	at 1		Undefined	
		3	Mem.-Circum.	at 1			
		4	Flex.-Tangen.	at 1			
		5	Flex.-Circum.	at 1			
		6	Shear-Force	at 1			
		7	Mem.-Tangen.	at 2			
		8	Mem.-Circum.	at 2			
		9	Flex.-Tangen.	at 2			
		10	Flex.-Circum.	at 2			
		11	Shear-Force	at 2			
		12	Mem.-Tangen.	at 3			
		13	Mem.-Circum.	at 3			
		14	Flex.-Tangen.	at 3			
		15	Flex.-Circum.	at 3			
		16	Shear-Force	at 3			
53 - 61	CDUM1 thru CDUM9	2	S1		2	S1	R
		3	S2		3	S2	R
		4	S3		4	S3	R
		5	S4		5	S4	R
		6	S5		6	S5	R
		7	S6		7	S6	R
		8	S7		8	S7	R
		9	S8		9	S8	R
		10	S9		10	S9	R
					11	S1	I
					12	S2	I
					13	S3	I
					14	S4	I
					15	S5	I
					16	S6	I
					17	S7	I
					18	S8	I
					19	S9	I

*If not equal to integer 1.

Note:

If output is magnitude/phase the magnitude replaces the real part and the phase replaces the imaginary part.

2.3.52 Element Force Output Data Description.

Note particular data block description (e.g., ØEF1, ØEFB1) for contents word 1 for each element.

Element Type	Element Name	Real Element Forces Word or Component	Item		Complex Element Forces Word or Component	Item	Real Imag.
1	CRØD	2	Axial Force		2	Axial Force	R
		3	Torque		3	Axial Force	I
					4	Torque	R
					5	Torque	I
2	CBEAM	2	Bend-Mom	A1		Undefined	
		3	Bend-Mom	A2			
		4	Bend-Mom	B1			
		5	Bend-Mom	B2			
		6	Shear-1				
		7	Shear-2				
		8	Axial Force				
		9	Torque				
3	CTUBE		Same as CRØD			Same as CRØD	
4	CSHEAR	2	Force Pts 1,3		2	Force Pts 1,3	R
		3	Force Pts 2,4		3	Force Pts 1,3	I
					4	Force Pts 2,4	R
					5	Force Pts 2,4	I
5	CTWIST	2	Moment Pts 1,3		2	Moment Pts 1,3	R
		3	Moment Pts 2,4		3	Moment Pts 1,3	I
					4	Moment Pts 2,4	R
					5	Moment Pts 2,4	I
6	CTRIA1	2	Bend-Mom-x		2	Bend-Mom-x	R
		3	Bend-Mom-y		3	Bend-Mom-y	R
		4	Twist-Moment		4	Twist-Moment	R
		5	Shear-x		5	Shear-x	R
		6	Shear-y		6	Shear-y	R
					7	Bend-Mom-x	I
					8	Bend-Mom-y	I
					9	Twist-Moment	I
					10	Shear-x	I
					11	Shear-y	I
7	CTRBSC		Same as CTRIA1			Same as CTRIA1	
8	CTRPLT		Same as CTRIA1			Same as CTRIA1	
9	CTRMEM		Undefined			Undefined	
10	CØNRØD		Same as CRØD			Same as CRØD	
11	CELAS1	2	Force		2	Force	R
					3	Force	I
12	CELAS2	2	Force		2	Force	R
					3	Force	I
13	CELAS3	2	Force		2	Force	R
					3	Force	I

Element		Real Element Forces			Complex Element Forces			
Type	Name	Word or Component	Item		Word or Component	Item		Real Imag.
14	CELAS4	2	Force		2	Force		R
					3	Force		I
15	CQDPLT		Note CTRIA1			Note CTRIA1		
16	CQDMEM		Undefined			Undefined		
17	CTRIA2		Note CTRIA1			Note CTRIA1		
18	CQUAD2		Note CTRIA1			Note CTRIA1		
19	CQUAD1		Note CTRIA1			Note CTRIA1		
20	CDAMP1		Undefined			Undefined		
21	CDAMP2		Undefined			Undefined		
22	CDAMP3		Undefined			Undefined		
23	CDAMP4		Undefined			Undefined		
24	CVISC		Undefined			Undefined		
25	CMASS1		Undefined			Undefined		
26	CMASS2		Undefined			Undefined		
27	CMASS3		Undefined			Undefined		
28	CMASS4		Undefined			Undefined		
29	CØNM1		Undefined			Undefined		
30	CØNM2		Undefined			Undefined		
31	CPLØTEL		Undefined			Undefined		
34	CBAR	2	Bend-Mom	A1	2	Bend-Mom	A1	R
		3	Bend-Mom	A2	3	Bend-Mom	A2	R
		4	Bend-Mom	B1	4	Bend-Mom	B1	R
		5	Bend-Mom	B2	5	Bend-Mom	B2	R
		6	Shear-1		6	Shear-1		R
		7	Shear-2		7	Shear-2		R
		8	Axial Force		8	Axial Force		R
		9	Torque		9	Torque		R
					10	Bend-Mom	A1	I
					11	Bend-Mom	A2	I
					12	Bend-Mom	B1	I
					13	Bend-Mom	B2	I
					14	Shear-1		I
					15	Shear-2		I
					16	Axial Force		I
					17	Torque		I

Element		Real Element Forces		Complex Element Forces		
Type	Name	Word or Component	Item	Word or Component	Item	Real Imag.
35	CCØNEAX	2	Harmonic or point angle		Undefined	
		3	Bend-Mom u			
		4	Bend-Mom v			
		5	Twist-Moment			
		6	Shear u			
		7	Shear v			
36	CTRIARG	2	Radial (x) at 1		Undefined	
		3	Circum (Theta) at 1			
		4	Axial (z) at 1			
		5	Radial (x) at 2			
		6	Circum (Theta) at 2			
		7	Axial (z) at 2			
		8	Radial (x) at 3			
		9	Circum (Theta) at 3			
		10	Axial (z) at 3			
37	CTRAPRG	2	Radial (x) at 1		Undefined	
		3	Circum (Theta) at 1			
		4	Axial (z) at 1			
		5	Radial (x) at 2			
		6	Circum (Theta) at 2			
		7	Axial (z) at 2			
		8	Radial (x) at 3			
		9	Circum (Theta) at 3			
		10	Axial (z) at 3			
		11	Radial (x) at 4			
		12	Circum (Theta) at 4			
		13	Axial (z) at 4			
38	CTØRDRG	2	Radial (x) at 1		Undefined	
		3	Circum (Theta) at 1			
		4	Axial (z) at 1			
		5	Moment (zx) at 1			
		6	Direct Strain at 1			
		7	Curvature at 1			
		8	Radial (x) at 2			
		9	Circum (Theta) at 2			
		10	Axial (z) at 2			
		11	Moment (zx) at 2			
		12	Direct Strain at 2			
		13	Curvature at 2			
53-61	CDUM1 thru CDUM9	2	F1	2	F1	R
		3	F2	3	F2	R
		4	F3	4	F3	R
		5	F4	5	F4	R
		6	F5	6	F5	R
		7	F6	7	F6	R
		8	F7	8	F7	R
		9	F8	9	F8	R
		10	F9	10	F9	R
				11	F1	I
				12	F2	I
				13	F3	I
				14	F4	I

Element		Real Element Forces		Complex Element Forces		
Type	Name	Word or Component	Item	Word or Component	Item	Real Imag.
53-61 cont'd.				15	F5	I
				16	F6	I
				17	F7	I
				18	F8	I
				19	F9	I

2.3.53 Data Blocks Output From Module DDR2

2.3.53.1 UEVF (MATRIX)

Description

$[u_e^f]$ - Displacements at the extra points for a frequency response problem.

Matrix Trailer

Number of columns	=	number of frequencies times number of loads
Number of rows	=	e
Form	=	rectangular
Type	=	single precision

2.3.53.2 PAF (MATRIX)

Description

$[P_a^f]$ - Equivalent load vector for mode acceleration computations in a frequency response problem - a set.

Matrix Trailer

Number of columns	=	number of frequencies times number of loads
Number of rows	=	d
Form	=	rectangular
Type	=	single precision

2.3.53.3 UDV2F (MATRIX)

Description

$[u_d^{fa}]$ - Mode accelerated displacement vectors for a frequency response problem.

Matrix Trailer

Number of columns	=	number of frequencies times number of loads
Number of rows	=	d
Form	=	rectangular
Type	=	complex single precision

2.3.53.4 UEVT (MATRIX)

Description

$[u_e^t]$ - Displacement at the extra points for a transient analysis problem.

Matrix Trailer

Number of columns	=	number of output times multiplied by 3
Number of rows	=	e
Form	=	rectangular
Type	=	real single precision

2.3.53.5 PAT (MATRIX)

Description

$[P_a^t]$ - Equivalent load vector for mode acceleration in a transient analysis problem.

Matrix Trailer

Number of columns	-	number of output times multiplied by 3
Number of rows	-	d
Form	-	rectangular
Type	-	real single precision

2.3.53.6 UDV2T (MATRIX)

Description

$[u_d^{ta}]$ - Mode accelerated displacement vectors for a transient analysis problem.

Matrix Trailer

Number of columns	=	number of output times multiplied by 3
Number of rows	=	d
Form	=	rectangular
Type	=	real single precision

2.3.54 Data Blocks Output from Module BMG

2.3.54.1 BDPØØL (TABLE)

Description

Hydroelastic boundary matrix tables.

Table Format

Same format as the MATPØØL data block DMIG card images.

Notes: The names of the matrices are KBFL and ABFL

Table Trailer

IFP format, 6 words containing 96 pointer bits for use by subroutines PRELØC and LØCATE.

2.3.55 Data Blocks Output from Module PLTTRAN

2.3.55.1 SIP (TABLE)

Description

Same format as data block SIL. If fluid points are present each fluid point, i, will cause the next SIL value to have a value:

$$SIL(i+1) = SIL(i) + 1$$

The SIP data will be:

$$SIP(i+1) = SIP(i) + 6$$

where i is a fluid point.

2.3.55.2 BGPDP (TABLE)

Description

Same format as data block BGPDT except fluid points have the value -2 in the fields corresponding to coordinate system identification numbers.

2.4 EXECUTIVE TABLE DESCRIPTIONS

The following is an alphabetical index of Executive table descriptions.

2.4.1 Executive Tables Which are Permanently Core Resident

2.4.1.1 XFIAT (Permanent File Allocation Table)

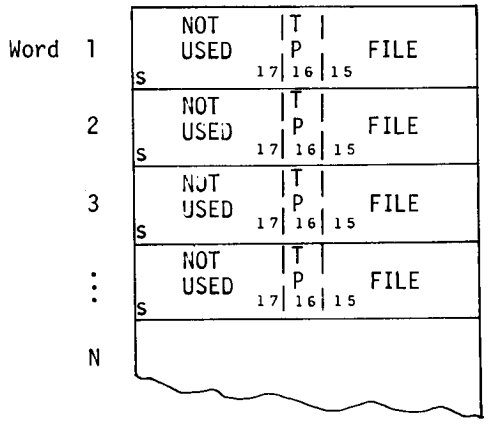
Description

A NASTRAN resident memory table containing the physical file identification for the permanent files (PØØL, ØPTP, etc.).

Created in Module

The physical file identifications are output by GNFIAT (generate FIAT).

Table Format



Word	Item	Description
1-N	TP	Tape Flag (1 bit) - set if physical file (FILE) is a magnetic tape.
	FILE	File ID (15 bits) - unique integer identification for a physical file.

Notes

1. The number of entries (N) is dictated by the integer value in PFIST (see FIST Executive Table Description - 2.4.1.3)
2. The XFIAT table is located in the named common block /XXFIAT/.

2.4.1.2 FIAT (File Allocation Table).

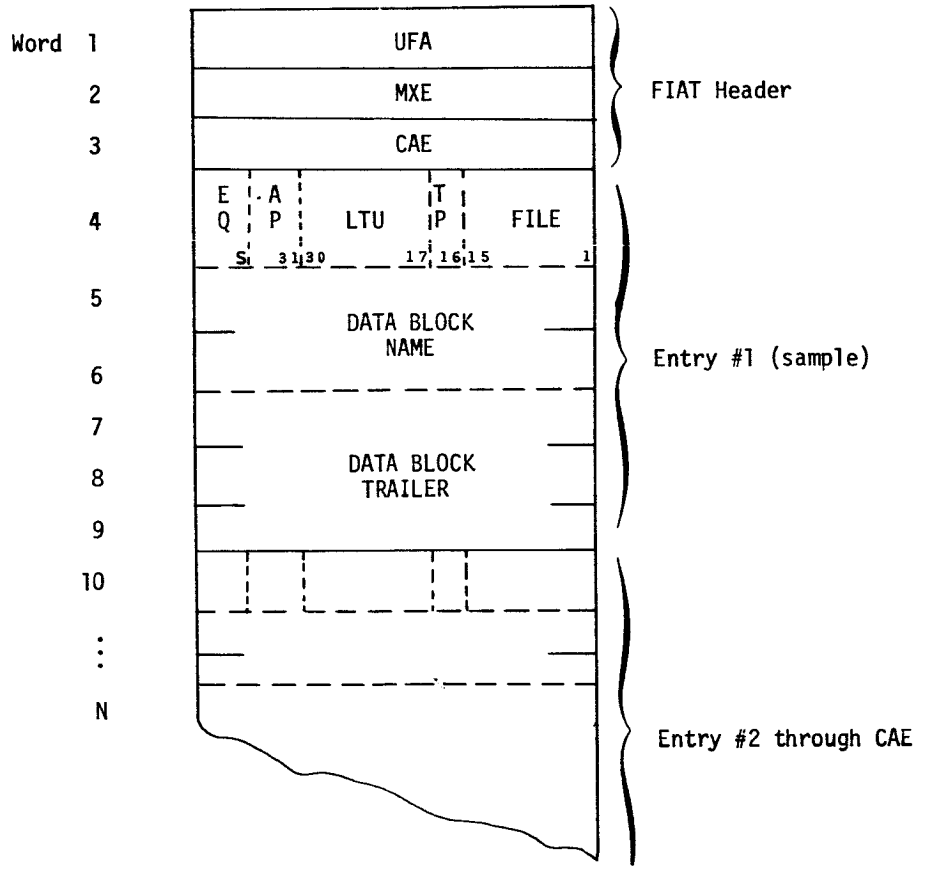
Description

A NASTRAN resident memory table containing the data block name vs. physical file ID. for a segment of DMAP modules.

Created in Module

The physical files available for the system/computer configuration are output by GNFIAT (generate FIAT). The data block names and other data block information are output by XSFA, Executive Segment File Allocator.

Table Format



Word	Item	Description
1	UFA	Unique files available - this integer indicates the number of unique file entries in the FIAT.
2	MXE	Maximum entries - this integer shows the total entry size of the dimensioned FIAT table; the amount of memory reserved (N) = 6 x MXE + 3.
3	CAE	Current active entries - this integer designates the portion of FIAT currently containing valid data; UFA ≤ CAE ≤ MXE.

Words 4 through 9 describe a sample 6-word entry:

4	EQ	Equivalence flag (1 bit) - 0 bit, file not equivalenced. 1 bit, file equivalenced.
	AP	Append flag (1 bit) - set if append is specified for data block in DMAP sequence by a FILE DMAP instruction.
	LTU	Last time used (14 bit integer) - record number of ØSCAR entry for last use of data block.
	TP	Tape flag (1 bit) - set if physical file (FILE) is a magnetic tape.
	FILE	File ID (15 bits) - unique identification for a physical file.
5,6	NAME	Data block name - 8 characters (4 characters/word).
7,8,9	TRAILER	Data block trailer - storage for 6-16 bit data block trailer words.

Words 10 through N contain repeated 6-word entries.

Trailer Information

Trailer information for each data block is stored in and received from the FIAT by WRTTRL (write trailer) and RDTRL (read trailer).

Note

The FIAT table is located in the named common block /XFIAT/.

2.4.1.3 FIST (File Status Table)

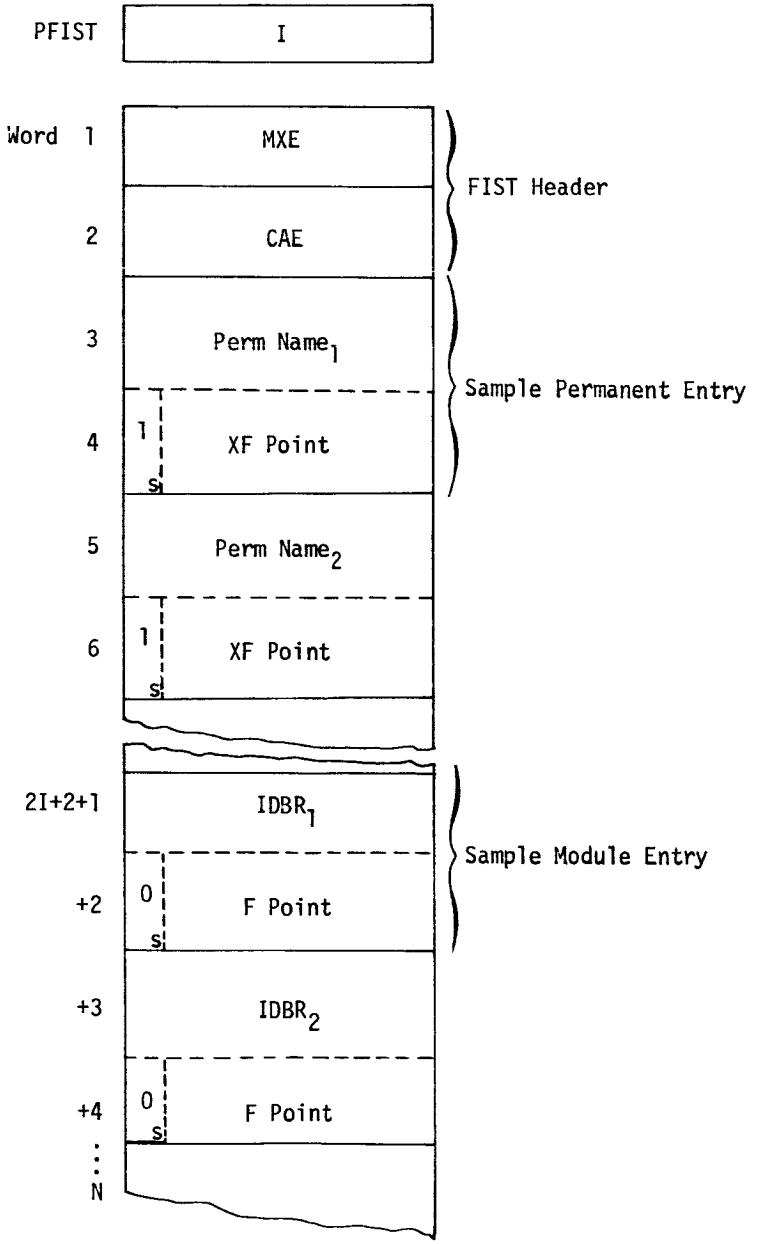
Description

A NASTRAN resident memory table containing the internal data block reference (IDBR) numbers vs. FIAT table pointers for a particular module; also, the permanent file reference names vs. XFIAT table pointers.

Created in Module

The module entries are generated prior to each module execution by subroutines GNFIST (Generate FIST). The permanent entries are initialized at system assembly.

Table Format



Word	Item	Description
PFIST	I	Integer number of permanent FIST entries.
1	MXE	Maximum entries - this integer shows the total entry size of the dimensioned FIST table; the amount of memory reserved (N) = 2 * MXE + 2.
2	CAE	Current active entries - this integer designates the portion of FIST currently containing valid data; I ≤ CAE ≤ MXE.
Words 3 and 4 describe a sample 2-word permanent entry:		
3	Perm Name	A permanent file reference name - 4 characters BCD (e.g., PØØL, ØPTP, PLT1, etc.).
4	XF Point	Points to the XFIAT position containing the file ID for this permanent file.
Words 2I+2+1 and +2 describe a sample 2-word module entry.		
+1	IDBR	An internal data block reference number (GINØ file number) - integer (e.g., 104, 206, 301, etc.).
+2	F Point	Points to the FIAT position containing the file ID for this module entry.

Notes

1. XFIAT pointer values contain an S bit equal to 1, while FIAT pointer values contain an S bit equal to 0.
2. Permanent entries remain static throughout a run, while module entries are changed by GNFIST prior to each module call.
3. FIAT and XFIAT position pointers are indexes into the respective tables considering the first word of the table as position 0.
4. The FIST table is located in the named common block /XFIST/.
   The PFIST entry is located in the named common block /XPFIST/.

2.4.1.4 DPL (Data Pool Dictionary)

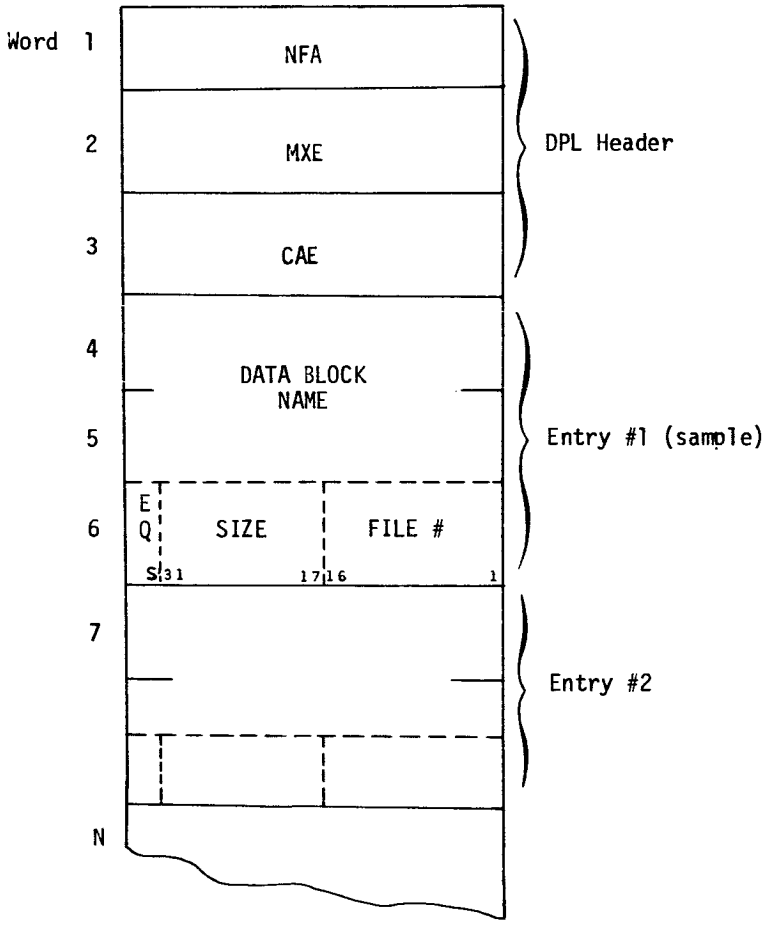
Description

A NASTRAN resident memory table describing the current contents and status of the Data Pool.

Created in Module

Data Pool, and therefore Dictionary entries, are created by pooling from SFA (Segment File Allocator), housekeeping operations by DPH (Data Pool Housekeeper) and restart initialization by GPI (General Problem Initialization), and IFP (Input File Processor) when writing DMI and DTI information (see section 2.3.2).

Table Format



Word	Item	Description
1	NFA	Next file available - the next Data Pool File number (integer) available for output.
2	MXE	Maximum entries - this integer shows the total entry size of the dimensioned DPL table; the amount of memory reserved (N) = 3 * MXE + 3.
3	CAE	Current active entries - this integer designates the portion of the DPL currently containing valid data; $0 \leq CAE \leq MXE$.

Words 4 through 6 describe a sample 3-word entry.

4,5	NAME	Data block name - 8 characters (4 characters/word).
6	EQ	Equivalence flag (1 bit) - 0 bit, file not equivalenced. 1 bit, file equivalenced.
	SIZE	Size of the pooled data block - number of words/10.
	FILE#	The file number (integer) showing the relative position of the data block file of the pool.

Note

The DPL table is located in the labeled common block /XDPL/.

2.4.1.5 CEITBL (Control Entry Information Table)

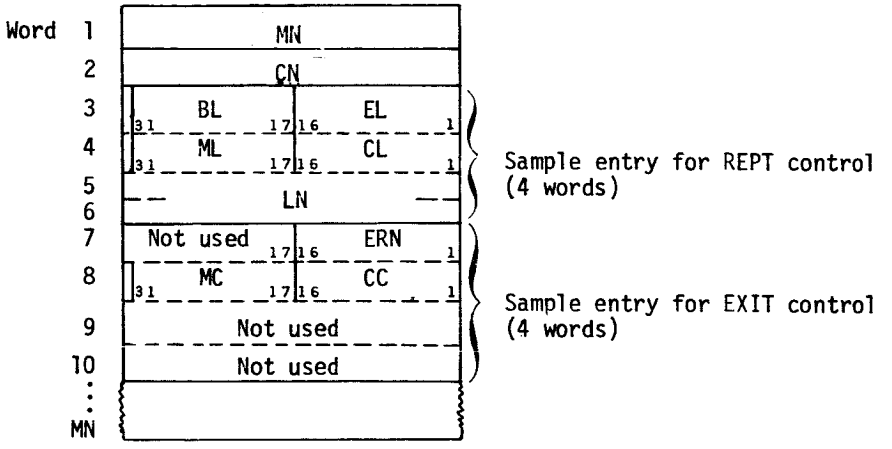
Description

CEITBL controls the REPT and EXIT DMAP module execution.

Created In Module

XGPI.

Table Format



Word	Item	Description
1	MN	Maximum number of words in table (integer).
2	CN	Current number of words being used (integer).
3	BL EL	ØSCAR record number where loop begins (integer). ØSCAR record number where loop ends (integer).
4	ML CL	Maximum loop count as specified in REPT instruction (integer). Current loop count, that is, the number of times loop has been repeated (integer).
5,6	LN	Location name specified in REPT instruction (BCD).
7	ERN	EXIT ØSCAR record number (integer).
8	MC CC	Maximum count specified in EXIT instruction. Current count of number of times EXIT instruction not executed.
9,10		These two words are zeroed.

Notes

CEITBL is located in named common block /XCEITB/.

2.4.1.6 VPS (Variable Parameter Set Table)

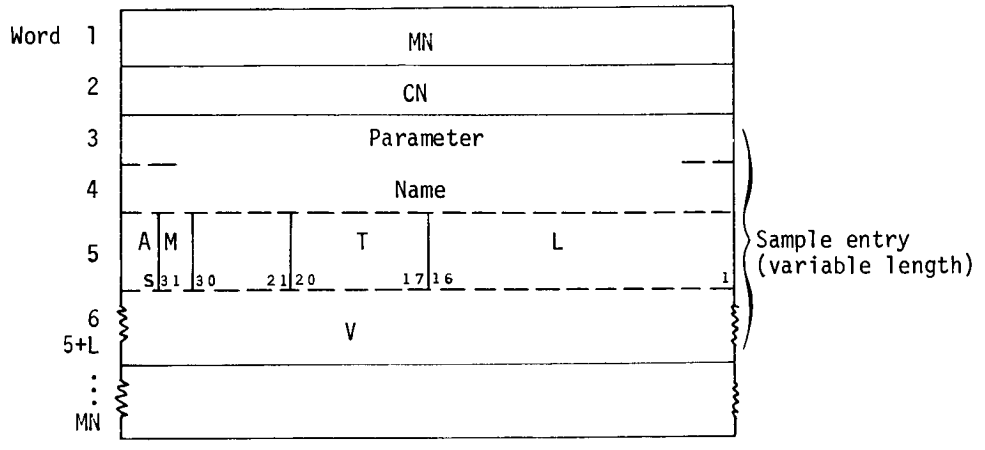
Description

The VPS table contains the values of all variable parameters referenced by DMAP modules in a DMAP program. It is the means for transferring variable parameter values from one module to another.

Created in Module

XGPI.

Table Format



Word	Item	Description
1	MN	Maximum number of words in VPS (integer).
2	CN	Current number of words being used (integer).
3,4	Name	BCD name of variable parameter.
5	A	Assigned flag. A = 1 indicates value from DMAP instruction has been entered in VPS.
	M	Modified flag. M = 1 indicates parameter was modified by bulk data PARAM card on restart.
	T	Type code for parameter (integer).
	L	Length in words of item V (integer).
6 thru 5+L	V	Value of parameter.

Notes

1. Items A, M and T (word 5 of sample entry) are used only by the XGPI module and are cleared prior to exiting XGPI.

2. Type code and corresponding word length.

T	L
1 = integer	1
2 = real, S.P.	1
3 = BCD	2
4 = real, D.P.	2
5 = complex, S.P.	2
6 = complex, D.P.	4

3. The VPS table is located in the named common block /XVPS/.

2.4.1.7 TAPID (Problem Tape Identification Table)

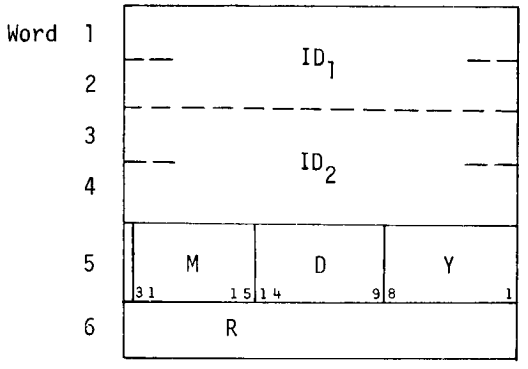
Description

TAPID contains Problem Tape identification information.

Created in Module

XCSA.

Table Format



Word	Item	Description
1,2	ID_1	First BCD field on ID Executive Control card.
3,4	ID_2	Second BCD field on ID Executive Control card.
5	M,D,Y	The date - integers - month, day, year.
6	R	Reel number of Problem Tape (integer).

Notes

1. TAPID is written on Problem Tape as single record field. It is always the first file on the Problem Tape.
2. ØTAPID has same format as TAPID. ØTAPID is the ID information from an Old Problem Tape being used for restarting problem.
3. TAPID and ØTAPID are located in named common block /STAPID/.

2.4.1.8 SYSTEM (NASTRAN System Parameters).

Description

A NASTRAN resident memory table containing various machine dependent, operating system and NASTRAN parameters. The length of the table is defined by one of the table items.

Created in Module

Most items are initialized by the NASTRAN block data program, SEMDBD. Several machine dependent items are set by subroutine BTSTRP.

Table Format

The sequential table description follows:

Word	Symbol	Description	Initially Set by
1	SYSBUF	Number of words in a GINØ buffer	BTSTRP
2	ØUTTAP	FØRTRAN logical unit for output	BTSTRP
3	NØGØ	Flag defining status during Preface	SEMDBD
4	INTP	FØRTRAN logical unit for input	BTSTRP
5	MPC	Multipoint constraint set ID	SEMDBD
6	SPC	Single-point constraint set ID	SEMDBD
7	METHØD	Eigenvalue extraction method	SEMDBD
8	LØAD	First record pointer in Case Control data block	SEMDBD
9	NLPP	Number of lines per page of printed output	BTSTRP
10	MTEMP	Material temperature set ID	SEMDBD
11	NPAGES	Current page count	SEMDBD
12	NLINES	Number of lines on current page	SEMDBD
13	TLINES	Total number of lines printed for problem	SEMDBD
14	MXLINS	Maximum number of printed lines permitted	SEMDBD
15	DATE(1)	Today's date - integer month 1-12	SEMDBD
16	DATE(2)	Today's date - integer day 1-31	SEMDBD
17	DATE(3)	Today's date - integer year (XX)	SEMDBD
18	TIMEZ	Time of problem start - seconds after midnite	SEMDBD
19	ECHØF	Bulk data output request type	SEMDBD
20	PLØTF	Structural plot request flag	SEMDBD
21	APPRCH	Approach type flag (2 = DISPL, 3 = DMAP)	SEMDBD
22	MACH	Computing machine code number (2 = 360, 3 = 1108, 4 = 6600)	BTSTRP
23	LSYSTM	Length of this table	SEMDBD
24	EDTUMF	User master file edit flag	SEMDBD
25	SWITCH	Logical sense switch bits set by a DIAG Executive Control Deck card	SEMDBD
26	CPPGCT	XCHK module page count	SEMDBD
27	MN	Used only in a conical shell problem. The lower order 16 bits contain N, the number of harmonics; the next higher order 16 bits contain M, the number of rings.	SEMDBD
28	ICØNFG	Machine configuration - subset of MACH code number	SEMDBD
29	MAXFIL	Maximum number of files to be added to FIAT	SEMDBD
30	MAXØPN	Maximum number of files to be opened simultaneously	SEMDBD
31	KØN360	Number of memory words to be released for ØS (360 only)	SEMDBD
32	TIMEW	Initial problem start time (integer seconds after midnite)	SEMDBD
33	ØFPFLG	ØFP operate flag - set nonzero when ØFP operates	SEMDBD

Word	Symbol	Description	Initially Set by
34	NBRCBU	Length of FET + circular buffer (CDC 6600 only)	SEMDBD
35	NBRMST	Length of master index (CDC 6600 only)	SEMDBD
36	NBRSUB	Length of subindex (CDC 6600 only)	SEMDBD
37	KSEMTR	Input Data Transliteration Flag (IBM 360 only)	SEMDBD
38	QO	Hydroelastic Problem Flag	SEMDBD
39	NBPC	Number of bits per character	BTSTRP
40	NBPW	Number of bits per word	BTSTRP
41	NCPW	Number of characters per word	BTSTRP
42	SYSDAT(1)	System Generation Date - Month	TTLPGE
43	SYSDAT(2)	System Generation Date - Day	TTLPGE
44	SYSDAT(3)	System Generation Date - Year	TTLPGE
45	TAPFLG	Permanent File Tape Flag	SEMDBD
46	ADUMEL(1)	Dummy Element Flag - DUM1	SEMDBD
47	ADUMEL(2)	Dummy Element Flag - DUM2	SEMDBD
48	ADUMEL(3)	Dummy Element Flag - DUM3	SEMDBD
49	ADUMEL(4)	Dummy Element Flag - DUM4	SEMDBD
50	ADUMEL(5)	Dummy Element Flag - DUM5	SEMDBD
51	ADUMEL(6)	Dummy Element Flag - DUM6	SEMDBD
52	ADUMEL(7)	Dummy Element Flag - DUM7	SEMDBD
53	ADUMEL(8)	Dummy Element Flag - DUM8	SEMDBD
54	ADUMEL(9)	Dummy Element Flag - DUM9	SEMDBD
55	IPREC	Precision Flag	SEMDBD
56	ITHRML	Heat Transfer Flag	SEMDBD
57	Unused		
58	Unused		
59	Unused		
60	Unused		
61	Unused		
62	Unused		
63	Unused		
64	Unused		
65	Unused		

2.4.1.9 XLINK (Link Specification Table - Non-resident Edit)

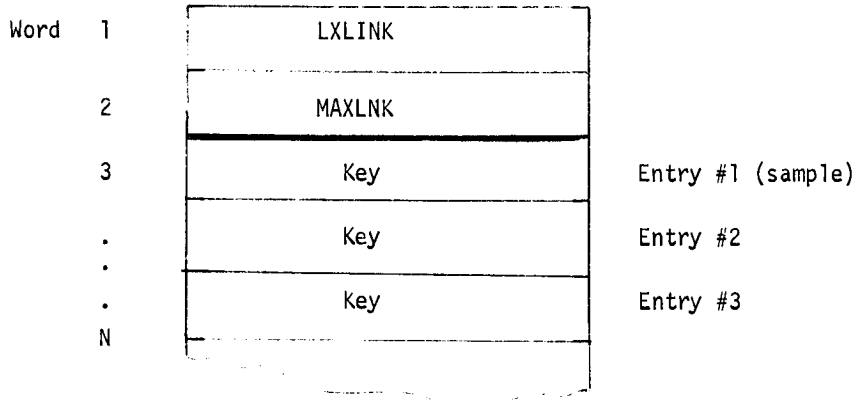
Description

This Link Specification Table (see also 2.4.2.7) contains an entry corresponding to each DMAP module within the MPL (2.4.2.2) table. These entries are indexed by MPL position and are thus ordered the same as the MPL entries. Each entry contains a key indicating the links in which the module resides.

Created in Module

XLINK data is created from the LNKSPC (2.4.2.7) and MPL (2.4.2.2) tables by the XGPIBS subroutine within the XGPI (4.7) module.

Table Format



Word	Item	Description
1	LXLINK	Length of table (number of entries)
2	MAXLNK	Maximum permissable link number
3,N	Key	Link residence key for the corresponding MPL entry

The content of this Key word is identical to the Key word within LNKSPC (2.4.2.7) for the machine type currently operating. See section 2.4.2.7 for an explanation of the content.

Notes

1. The XLINK table must contain an entry in the same order for each module that is in the MPL (2.4.2.2) table.
2. XLINK table is located in /XLINK/.

2.4.2 Executive Tables Not Permanently Core Resident

2.4.2.1 ØSCAR (Operation Sequence Control Array)

Description

The Operation Sequence Control Array (ØSCAR) controls the sequence of modules executed and aids in communicating data between modules.

The ØSCAR is generated from a DMAP instruction sequence supplied by the user or selected from the Rigid Format library. In general, an ØSCAR entry is a DMAP statement which has been translated to a more readily usable form for internal use.

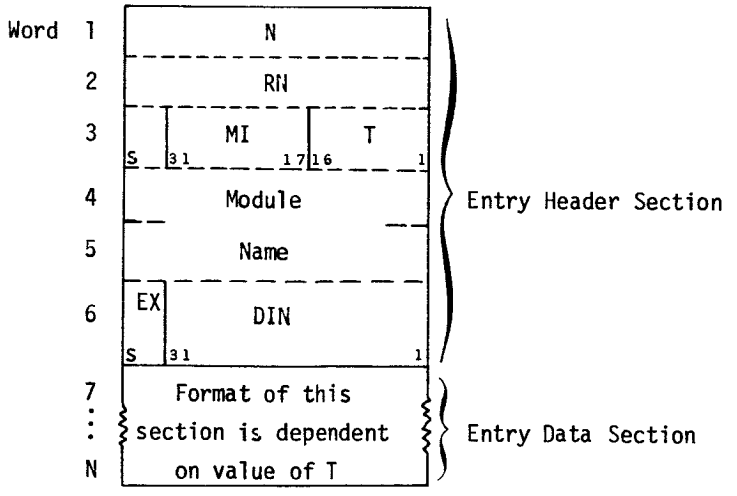
The four ØSCAR entry format types are:

1. Type 1 or F (functional) format is used for all functional modules except output processors.
2. Type 2 or Ø (output) format is used for output processors.
3. Type 3 or C (control) format is used for REPT, JUMP, CØND and END DMAP instructions.
4. Type 4 or E (executive) format is used for SAVE, CHKPNT, PURGE and EQUIV DMAP instructions.

Created in Module

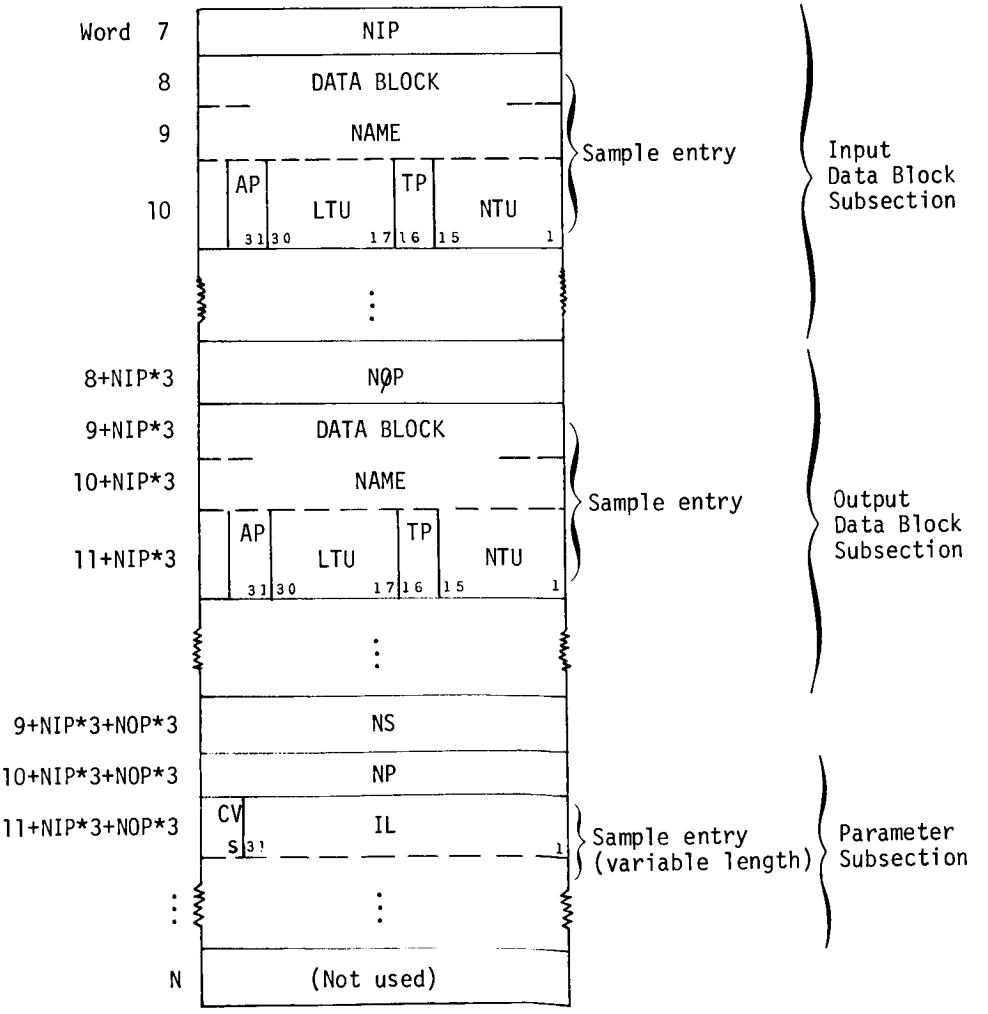
XGPI.

Table Format



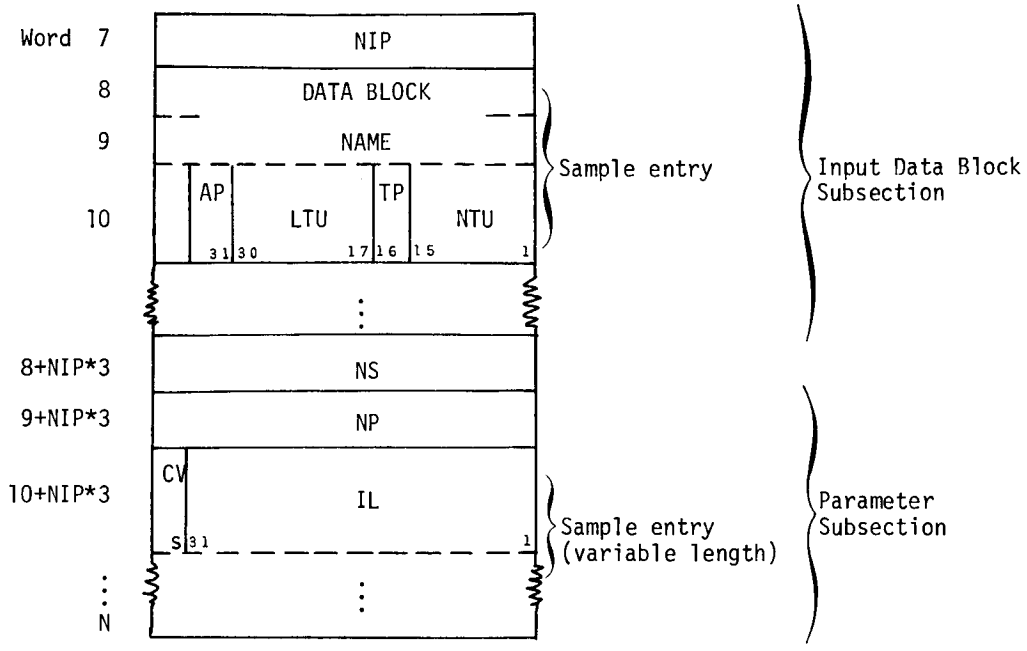
Word	Item	Description
1	N	Integer - number of words in entry.
2	RN	Integer - record number of entry in ØSCAR table.
3	MI	Integer - module index number assigned according to module's position in MPL and used to access the module's link specifications in /XLINK/.
	T	Integer - format type code (1, 2, 3, or 4) for data section of entry.
4,5	Name	BCD - module name is same as DMAP instruction name except when T = 4.
6	EX	Execute flag. EX = 1 indicates module is to be executed.
	DIN	Integer - DMAP instruction number which generated this entry.

Data Section Format for Type 1 or F Format:



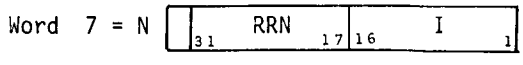
Word	Item	Description
7	NIP	Integer - number of data blocks input to module as specified in MPL.
8,9	NAME	BCD - name of first input data block specified in DMAP instruction or zero if none specified.
10	AP	Append flag used by subroutine XSFA and set by XØSGEN if APPEND is specified for data block in a FILE DMAP instruction.
	LTU	Integer - last time used. ØSCAR record number of entry after which data block will no longer be saved.
	TP	Tape flag used by subroutine XSFA and set by XØSGEN if tape is specified for data block in a FILE DMAP instruction.
	NTU	Integer - next time used. ØSCAR record number of entry where data block is next referenced.
8 + NIP*3	NØP	Integer - number of data blocks output from module as specified in MPL.
9 + NIP*3, 10 + NIP*3	NAME	BCD - name of first output data block specified in DMAP instruction or zero if none specified.
11 + NIP*3	AP,LTU, TP,NTU	Same descriptions as word 10.
9 + NIP*3 + NØP*3	NS	Integer - number of scratch data blocks used by module as specified in MPL.
10 + NIP*3 + NØP*3	NP	Integer - number of parameters used by module as specified in MPL.
11 + NIP*3 + NØP*3	CV	Constant/variable flag. Flag indicates meaning of IL.
	IL	Integer - VPS index/length of constant. If CV = 0 the parameter is a constant whose value is stored in the next IL words (i.e., words 12 + NIP*3 + NØP*3 through 11 + NIP*3 + NØP*3 + IL). If CV = 1 the parameter is a variable whose value is stored in the VPS table. IL points to the value in VPS.

Data Section Format for Type 2 or 0 Format:



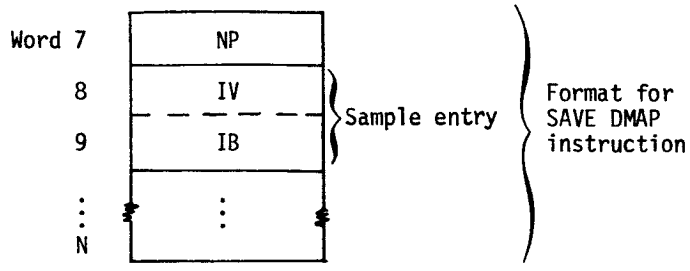
Type 1 format description is applicable to type 2 format above.

Data Section Format for Type 3 or C Format:

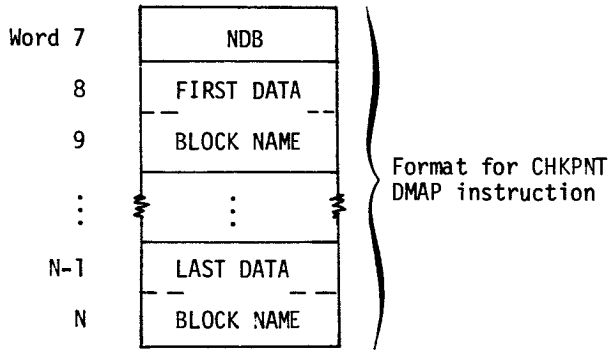


Word	Item	Description
N	RRN	Integer - re-entry record number. Indicates ØSCAR record to jump to for JUMP, REPT and CØND DMAP instructions. Not applicable for EXIT so RRN = 0.
	I	Integer - index into XCEITBL for REPT or EXIT DMAP instruction. Pointer to parameter value in XVPS table if CØND DMAP instruction. Not applicable for JUMP so I = 0.

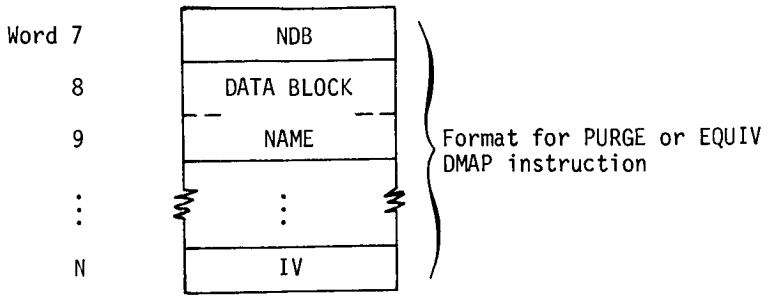
Data Section Formats for Type 4 or E Formats:



Word	Item	Description
7	NP	Integer - number of parameter values to be saved (i.e. number of entries).
8	IV	Integer - pointer to parameter value in VPS.
9	IB	Integer - pointer to parameter value in blank common.



Word	Item	Description
7	NDB	Integer - number of data blocks names in list.
8 thru N	NAMES	BCD - list of data blocks to be checkpointed.



Word	Item	Description
7	NDB	Integer - number of data block names in first group. There may be one or more groups.
8,9	NAME	BCD - name of first data block in first group.
N	IV	Integer - pointer to parameter value in VPS table.

Notes

1. ØSCAR is located in named common block /XGPI1/ while module XGPI is generating it.
2. After generating ØSCAR and prior to exiting XGPI the ØSCAR is written on the Data Pool File. The ØSCAR file header ID is XØSCAR.

2.4.2.2 MPL (Module Property List)

Description

The Module Properties List contains information needed by the module XGPI to correctly generate ØSCAR table entries for executable DMAP instructions and/or to determine whether or not the DMAP instructions adhere to the calling sequence described in section 4, Module Functional Descriptions.

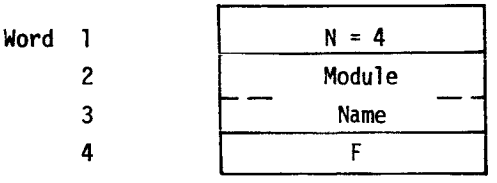
Created in Module

XGPI (Block Data Program XMPLBD).

Table Format

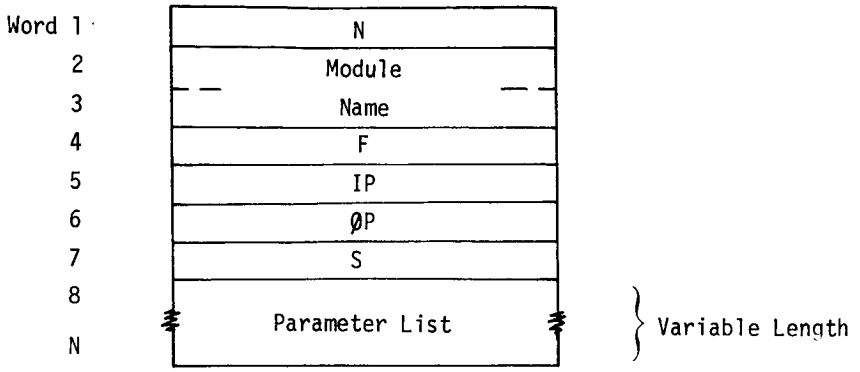
There are two formats used in the MPL, one for Declarative (FILE, BEGIN, LABEL), Executive (CHKPNT, EQUIV, PURGE, SAVE) and Control (REPT, JUMP, CØND, EXIT, END) DMAP modules and the other for functional modules. All entries in the MPL are integer except for module names which are BCD and BCD parameter values.

Format for Declarative, Executive and Control Modules:



Word	Item	Description
1	N	Number of words in entry.
2,3	Name	Name of DMAP module.
4	F	ØSCAR format type code 3 = Control module (C format) 4 = Executive module (E format) 5 = Declarative module (D format)

Format for Functional Modules:



Word	Item	Description
1-3		Same as format for Declarative, Executive and Control modules.
4	F	F = 1 implies module has input and output data blocks F = 2 implies module has no output data blocks, e.g., ØFP, SETVAL etc.
5	IP	Number of input data blocks.
6	ØP	Number of output data blocks.
7	S	Number of scratch data blocks.
8-N		Parameter List (omit if no parameters).

The parameter list for a module contains the types of all parameters residing in blank common that are referenced by the module. The order of the parameters in the MPL entry must coincide with the order of the parameters in blank common. Space must be allowed for a default value if the parameter type code is positive. The space following a positive type code will contain the default value if the type code is integer or BCD, otherwise the space will contain an index into another table which contains the default value.

Type Code	Space Needed for Default Values
1 = integer	1 word
2 = real, single precision	1 word
3 = BCD	2 words
4 = real, double precision	2 words
5 = complex, single precision	2 words
6 = complex, double precision	4 words

An example of all possible entries in a parameter list follows. Note that for each parameter only the first index word will appear in the XMPLBD Block Data subprogram.

	Word		
1	8	=	Integer type code.
-3	9	=	Integer default value.
-1	10	=	Integer type code (no default value).
2	11	=	Real, S.P. type code.
1	12	=	Index into table containing a real S.P. default value.
-2	13	=	Real, S.P. type code (no default value).
3	14	=	BCD type code.
ABCD	15	=	BCD default value (2 words).
EFGH	16		
-3	17	=	BCD type code (no default value).
4	18	=	Real, D.P. type code.
1	19	=	Index into table containing a real D.P. default value.
1	20		Note index is in both words.
-4	21	=	Real, D.P. type code (no default value).
5	22	=	Complex, S.P. type code.
2	23	=	Index into table containing a complex S.P. default value.
2	24		
-5	25	=	Complex, S.P. type code (no default value).
6	26	=	Complex, D.P. type code.
3	27	=	Index into table containing the real part of the complex D.P. default value.
3	28		
4	29	=	Index into table containing the imaginary part of the complex D.P. default value.
4	30		
-6	31	=	Complex, D.P. type code (no default value).

Notes

1. MPL table is located in named common block /XGPI2/.
2. The default value table is located in named common block /XGPI2X/.

2.4.2.3 XPTDIC (Problem Tape Dictionary)

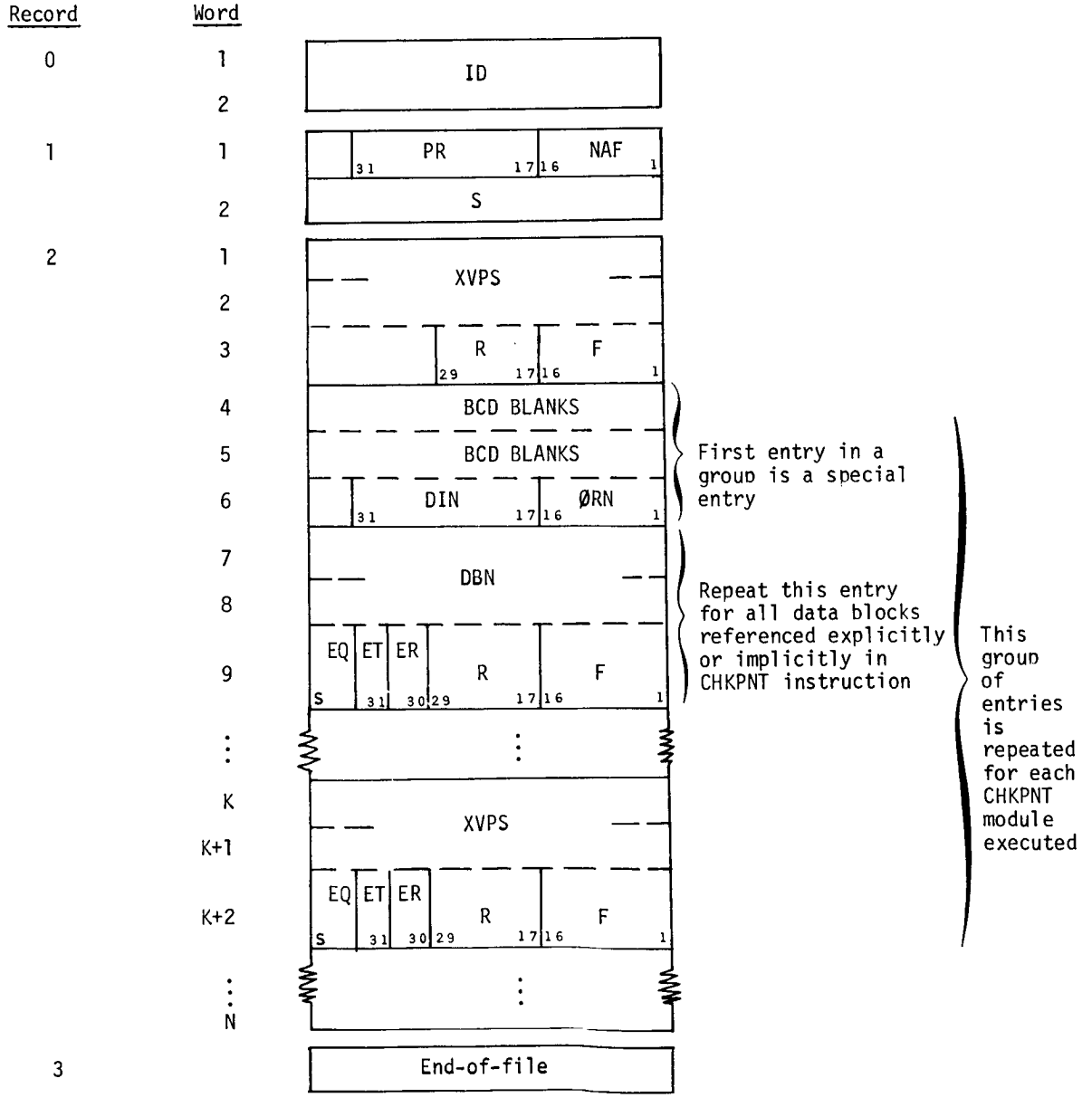
Description

XPTDIC is the Problem Tape Dictionary of data blocks checkpointed plus other information needed to restart a problem.

Created in Modules

XGPI, CHKPNT and XCEI.

Table Format



Record	Word	Item	Description
0	1,2	ID	Header record containing name XPTDIC (BCD).
1	1	PR	Present reel number of Problem Tape. Reels are numbered sequentially beginning with Reel 1.
		NAF	Next available file number on present reel. Files are numbered sequentially beginning with file 1.
	2	S	Sequence number of last restart dictionary card punched out.
2	1,2	XVPS	BCD name XVPS. The file corresponding to this entry contains named common blocks /XVPS/ and /XCEITB/.
	3	R,F	Reel number and file number where the file corresponding to this entry is located. For this entry the reel number must be one.
	4,5	(blanks)	BCD blanks indicate special entry.
	6	DIN	DMAP instruction number of DMAP instruction following CHKPNT module (i.e., re-entry point).
		ØRN	ØSCAR record number of CHKPNT module being executed.
	7,8	DBN	Data block name (BCD) of data block being checkpointed.
	9	EQ	Equivalence flag. EQ = 1 indicates data block is equivalenced to another data block.
		ET	End of tape flag. ET = 1 indicates that data block is split across two reels of problem tape.
		ER	End of logical record flag. ER = 1 indicates that the complete logical record was written out prior to changing reels when ET = 1.
		R,F	Reel number and file number where the file corresponding to this entry is located. For purged or not-generated data blocks, R = 0 and F = 0.
	K, K+1	XVPS	BCD name XVPS. The file corresponding to this entry contains named common blocks /XVPS/, /XCEITB/ and /SYSTEM/.
	K+2	EQ,ET, ER,R,F	See word 9 for descriptions.

Notes

1. All entries are integer unless otherwise noted.
2. The XPTDIC table is always the last file on the Problem Tape.
3. XGPI generates records 0, 1 and the first entry of record 2. CHKPNT modules add entries to record 3. XCEI drops entries from record 2 when a REPT DMAP instruction transfers control to the top of a DMAP loop.
4. XCSA also creates a XPTDIC table when problem is being restarted. This special XPTDIC table is created from the restart dictionary and its format is essentially the same as described above except that there are no special entries.

2.4.2.4 PVT (Parameter Value Table)

Description

The Parameter Value Table contains the parameter names and values of all parameters input by means of the PARAM bulk data card.

Created in Module

IFP.

Table Format

Record	Word	Item	
0	1,2	Header record contains name PVT (BCD).	
1	1,2	Name of parameter (BCD)	repeat for all parameters on PARAM cards.
	3	Type code for parameter value	
	4	Value of parameter. Type codes	
	⋮	and corresponding lengths, L, of	
	3+L	values are given in table below.	
	⋮		

Notes

Type Code	Meaning of Code	Corresponding Length in Words
1	Integer	1
2	Real, single precision	1
3	BCD	2
4	Real, double precision	2
5	Complex, single precision	2
6	Complex, double precision	4

1. IFP does not create PVT if no PARAM cards exist in the Bulk Data Deck.
2. PVT is written on the Problem Tape as 2 or more records (a header record and 1 record for each PARAM card).
3. The PVT table is located in named common block /XPVT/.

2.4.2.5 XCSA (Executive Control Table)

Description

Executive control table derived from the Executive Control Deck.

Created in Module

XCSA.

Table Format

Record	Word	Item	
0	1	BCD word XCSA - header ID.	
	2,3	BCD word SØL	Dictionary of contents of records to follow. Does not need to be in this order, nor is MED always present.
	4,5	BCD word DMAP	
	6,7	BCD word MED	
1	1	Approach code	SØL record
	2	Start code	
	3,4	Alter parameters	
	5	Solution number	
	6	Subset number	
2	1	RD table (packed DMAP program) or user generated DMAP program (18 words per card image).	DMAP record (BCD information)
	:		
	N		
3	1	Number of DMAP instructions	MED record included only if approach calls for a Rigid Format
	2	Number of words per ISl table entry.	
	3	ISl table (Module Execution Decision Table).	
	:		
	L	Number of entries in JNM table.	
	L+1	JNM table (File Name Table)	
	:		
	M	Number of entries in INM table	
	M+1	INM table (Card Name Table)	
	:		
4		End-of-file	

Notes

1. Data block XCSA is written on the Problem Tape.
2. A more detailed description of tables ISl, JNM and INM is given in the Module Functional Description for module XCSA, section 4.2.

2.4.2.6 XALTER (Executive Alter Table)

Description

XALTER is generated from the ALTER data in the Executive Control Deck.

Created in Module

XCSA.

Table Format

Record	Word	Item	
0	1,2	BCD word XALTER - header record	
1	1,2	Numbers of DMAP instructions to be altered. (Integers).	Repeat 1 or more times until EØF encountered.
2	1 : 18	Card image (BCD)	Zero or more of these records. Repeat until next 2 word record encountered.
:			
N		End-of-file	

Notes

XALTER data block is written on the Problem Tape.

2.4.2.7 LNKSPC (Link Specification Table - Resident Base)

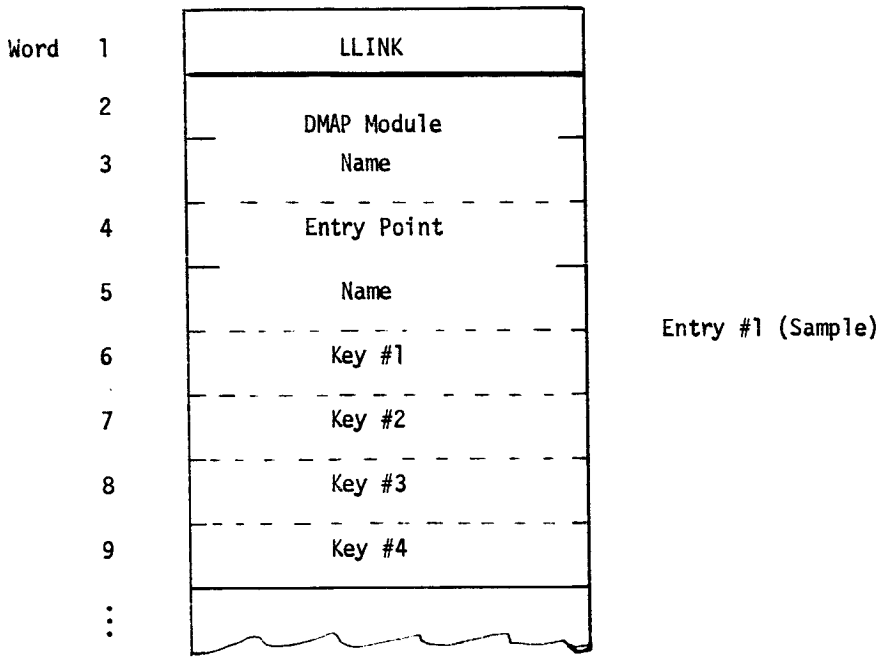
Description

This Link Specification Table (see also 2.4.1.9) contains an entry for each executable DMAP module available within the NASTRAN system. Each entry contains: a) the DMAP module name, b) the module's subroutine entry point name and c) a key indicating the links in which the module resides for each of four machine types.

Created in Module

LNKSPC data is stored by the XBSBD Block Data subprogram in module XGPI (4.7).

Table Format



Word	Item	Description
1	LLINK	Length of table in words (excluding word 1)
2,3	DMAP Module Name	DMAP name-8 characters (4 characters/word)
4,5	Entry Point Name	Entry name-8 characters (4 characters/word)
6	Key #1	Link residence key for machine type #1
7	Key #2	Link residence key for machine type #2
8	Key #3	Link residence key for machine type #3
9	Key #4	Link residence key for machine type #4

The machine type code number is the same as that defined in the MACH word of the SYSTEM (2.4.1.8) table. Each bit within the Key word specifies a link number that is to contain that module. Bits are numbered from right to left; the right most (least significant) bit specifies that the module is to reside in link 1, etc. For example, if a particular Key contained 26 (binary 011010), only links 2, 4 and 5 would contain the specified module.

Notes

1. The LNKSPC table must contain an entry for each executable module that is in the MPL (2.4.2.2) table.

2. The LNKSPC table is located in /XLKSPC/.

2.4.2.8 IFPXO (Modified Restart Table)

Description

IFPXO records the types of changes to the input data which were made during a restart. In addition, it classifies each type of change as to substantive (solution affecting) or nonsubstantive (output only affecting). The basic data is stored in packed format, 31 bits to the word. The use of this array in restart and its companion /IFPX1/ is described in section 1.10.

Created in Module(s)

IFP1, XSØRT and IFP and read by XGPI.

Table Format

Word	Item	
1	N	Number of pairs (I,L) to follow.
2	I1	Pointer to first word in /IFPXO/ that is used to flag modified bulk data.
3	L1	Number of words reserved for modified bulk data flags.
4	I2	Pointer to first word in /IFPXO/ that is used to flag modified Case Control data.
5	L2	Number of words reserved for modified Case Control data flags.
6	I3	Not used.
7	L3	
8 through 18	IB	Array containing flags which specify what input has been modified for restart (the meaning of each bit can be determined from /IFPX1/. (See section 2.4.2.9).
19 through 29		Array which specifies which bits in the IB array can initiate a modified restart.

2.4.2.9 IFPX1 (Master Card Name Table)

Description

IFPX1 contains mnemonics for the various card types (and data types) which can be significant for restart. It is actually a key into common block IFPX0 (see section 2.4.2.8). The use of this array is described in section 1.10.

Created in Module

Modules IFP1, XSØRT, IFP and XGPI read this array.

Table Format

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
1		310	Number of Card Types	
2	1	GRID		
4	2	GRDSET		
6	3	BEAMØR		No
8	4	SEQGP		
10	5	CØRD1R		
12	6	CØRD1C		
14	7	CØRD1S		
16	8	CØRD2R		
18	9	CØRD2C		
20	10	CØRD2S		
22	11	PLØTEL	Yes	
24	12	SPC1		
26	13	SPCADD		
28	14	SUPØRT		
30	15	ØMIT		
32	16	SPC		
34	17	MPC		
36	18	FØRCE		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
38	19	MØMENT		
40	20	FØRCE1		
42	21	MØMENT1		
44	22	FØRCE2		
46	23	MØMENT2		
48	24	PLØAD		
50	25	SLØAD		
52	26	GRAV		
54	27	TEMP		
56	28	GENEL		
58	29	PRØD		
60	30	PTUBE		
62	31	PVISC		
64	32(word 2)	PBEAM		No
66	33	PTRIA1		
68	34	PTRIA2		
70	35	PTRBSC		
72	36	PTRPLT		
74	37	PTRMEM		
76	38	PQUAD1		
78	39	PQUAD2		
80	40	PQDPLT		
82	41	PQDMEM		
84	42	PSHEAR		
86	43	PTWIST		
88	44	PMASS		
90	45	PDAMP		
92	46	PELAS		
94	47	CØNRØD		
96	48	CRØD		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
98	49	CTUBE		
100	50	CVISC		
102	51	CBEAM		No
104	52	CTRIA1		
106	53	CTRIA2		
108	54	CTRBSC		
110	55	CTRPLT		
112	56	CTRMEM		
114	57	CQUAD1		
116	58	CQUAD2		
118	59	CQDPLT		
120	60	CQDMEM		
122	61	CSHEAR		
124	62	CTWIST		
126	63(word 3)	CØNM1		
128	64	CØNM2		
130	65	CMASS1		
132	66	CMASS2		
134	64	CMASS3		
136	68	CMASS4		
138	69	CDAMP1		
140	70	CDAMP2		
142	71	CDAMP3		
144	72	CDAMP4		
146	73	CELAS1		
148	74	CELAS2		
150	75	CELAS3		
152	76	CELAS4		
154	77	MAT1		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
156	78	MAT2		
158	79	CTRIARG		
160	80	CTRAPRG		
162	81	DEFØRM		
164	82	PARAM	Yes	
166	83	MPCADD		
168	84	LØAD		
170	85	EIGR		
172	86	EIGB		
174	87	EIGC		
176	88	REACT		
178	89		Yes	
180	90	MATS1		
182	91	MATT1		
184	92	ØMIT1		
186	93	TABLEM1		
188	94(word 4)	TABLEM2		
190	95	TABLEM3		
192	96	TABLEM4		
194	97	TABLES1		
196	98	TEMPD		
198	99	TABLES2		No
200	100	TABLES3		No
202	101	TABLES4		
204	102	MATT2		
206	103	MATS2		No
208	104	CTØRDRG		
210	105	SPØINT		
212	106	SEQD		FØRCE
214	107	SEQDBFE		FØRCE

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
216	108	QDSEP		FØRCE
218	109	SPQUAD1		FØRCE
220	110	SPQUAD2		FØRCE
222	111	SPQDMEM		FØRCE
224	112	SPQDPLT		FØRCE
226	113	ZI		FØRCE
228	114	CTRIA3		FØRCE
230	115	PTRIA3		FØRCE
232	116	SETRBFE		FØRCE
234	117	VECDN		FØRCE
236	118	VECGP		FØRCE
238	119	DMI		
240	120	DMIG		
242	121	PTØRDRG		
244	122	MAT3		
246	123	DLØAD		
248	124	EPØINT		
250	125(word 5)	FREQ1		
252	126	FREQ		
254	127	NØLIN1		
256	128	NØLIN2		
258	129	NØLIN3		
260	130	NØLIN4		
262	131	RLØAD1		
264	132	RLØAD2		
266	133	TABLED1		
268	134	TABLED2		
270	135	SEQEP		
272	136	TF		
274	137	TIC		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
276	138	TLØAD1		
278	139	TLØAD2		
280	140	TABLED3		
282	141	TABLED4		
284	142	TSTEP		
286	143	DSFACT		
288	144	AXIC		
290	145	RINGAX		
292	146	CCØNEAX		
294	147	PCØNEAX		
296	148	SPCAX		
298	149	MPCAX		
300	150	ØMITAX		
302	151	SUPAX		
304	152	PØINTAX		
306	153	SECTAX		
308	154	PRESAX		
310	155	TEMPAX		
312	156(word 6)	FØRCEAX		
314	157	MØMAX		
316	158	EIGP		
318	159	MASSC		
320	160	EDFIR		FØRCE
322	161	DFØRM		FØRCE
324	162	TABDMP1		
326	163	TABDMP2		
328	164	TABDMP3		
330	165	TABDMP4		
332	166	FREQ2		
334	167	CQUAD3		FØRCE

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
336	168	PQUAD3		FØRCE
338	169	SPQUAD3		FØRCE
340	170	SETR		FØRCE
342	171	SPTRIA1		FØRCE
344	172	SPTRIA2		FØRCE
346	173	SPTRMEM		FØRCE
348	174	SPTRBSC		FØRCE
350	175	SPTRPLT		FØRCE
352	176	SECL		FØRCE
354	177	SECP		FØRCE
356	178	SEPTRIA3		FØRCE
358	179	BARØR		
360	180	CBAR		
362	181	PBAR		
364	182	DAREA		
366	183	DELAY		
368	184	DPHASE		
370	185	PLFACT		
372	186	CGENEL		FØRCE
374	187	PGENEL		FØRCE
376	188	ELDELE		FØRCE
378	189	MATT3		
380	190	RFØRCE		
382	191	TABRND1		
384	192	TABRND2		
386	193	TABRND3		
388	194	TABRND4		
390	195	RANDPS		
392	196	RANDT1		
394	197	RANDT2		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
396	198	PLØAD1		
398	199	PLØAD2		
400	200	DTI		
402-598	201-299	Not used		
600	300	CØUPMASS		
602	301	GRDPNT	Yes	
604	302	WTMASS	Yes	
606	303	IRES	Yes	
608	304	LFREQ		
610	305	HFREQ		
612	306	LMØDES		
614	307	G		
616	308	W3		
618	309	W4		
620	310	MØDACC		
622	311	MPC$		
624	312	SPC$		
626	313	LØAD$		
628	314	METHØD$		
630	315	DEFØRM$		
632	316	TEMPLD$		
634	317	TEMPMT$		
636	318	IC$		
638	319	AØUT$	Yes	
640	320	LØØP$		
642	321	LØØP1$		
644	322	DLØAD$		
646	323	FREQ$		
648	324	TF$		

Word No. In IFPX1	Bit No. In IFPX0	Contents	Output Only (PMR)	Supported
650	325	PLØT$	Yes	
652	326	TSTEP$		
654	327	PØUT$	Yes	
656	328	TEMPMX$		
658	329	DSCØ$		
660	330	K2PP$		
662	331	M2PP$		
664	332	B2PP$		
666	333	CMETHØD$		
668	334	SDAMP$		
670	335	INERTIA$		FØRCE
672	336	NLFØRCE$		
674	337	XYØUT$	Yes	
676	338	DELETE$		FØRCE
678	339	RANDØM$		
680	346	AXYØUT$	Yes	
682	341	NØLØØP$ Not Used		

2.5 MISCELLANEOUS TABLE DESCRIPTIONS.

The following is an alphabetical index of miscellaneous table descriptions.

2.5.1 Miscellaneous Tables Which Are Permanently Core Resident.

2.5.1.1 ØSCENT (ØSCAR Entry)

Description

A 200 word storage array containing the ØSCAR entry (record) currently being processed.

Created in Module

The entry is read from the ØSCAR and stored in ØSCENT by the XSEMi (section 3.3.7) subroutine. Other executive routines that require details of the current entry will search ØSCENT.

Table Format

The ØSCENT format is identical to the ØSCAR (section 2.4.2.1) entry it currently contains.

2.5.1.2 ØUTPUT (Output headings)

Description

A storage array containing problem title, subtitle, label and various headings required by the PAGE (section 3.4.24) routine to properly annotate the NASTRAN output.

Created in Module

The title, subtitle and label are taken from Case Control Deck cards and stored in ØUTPUT by IFP1 (section 4.3). Other heading lines may be stored by output modules prior to calling PAGE.

Table Format

ØUTPUT contains sufficient space for seven 128 character lines. The first three lines contain the title, subtitle, and label. The subsequent three lines contain local headings, and the final line contains the plotter ID. Since 4 characters occupy each computer word, the ØUTPUT array requires 224 words of storage.

2.5.1.3 STIME (Solution Time)

Description

A storage cell containg the user's estimated solution time.

Created in Module

The estimated solution time is taken from a Executive Control Deck card and stored into STIME by XCSA (section 4.2)

Table Format

STIME consists of a single cell containing the estimated time in integer seconds.

2.5.1.4 XMDMSK (Executive Module Decision Mask)

Description

Contains the 155 bit master module execution mask (see section 1.10) and a cell indicating checkpoint status.

Created in Module

The 155 bit master module execution mask is generated and used by XGPI (section 4.7). The checkpoint status set on (YES) by XCSA (section 4.2) by the presence of a CHKPNT = YES card in the Executive Control Deck.

Table Format

The 155 bit mask occupies the low order 31 bits of the first five words of XMDMSK. The sixth word is the checkpoint status (flag).

2.5.1.5 MSGX (Message Queue)

Description

A queue table to hold four word NASTRAN information and error messages between the time they are generated by a module and printed by the message writer, MSGWRT (section 3.4.26).

Created in Module

Messages may be generated by any NASTRAN module through a call to MESAGE (section 3.4.25).

Table Format

Word 1	-	Number of messages queued.
Word 2	-	Maximum number of messages queue can hold
Word 3-6	-	Four word message entry (typical)
Word 6-end	-	Additional four word message entries

2.5.1.6 DESCRP (Matrix Description)

Description

A storage block used by subroutine INTPK (section 3.5.3) to buffer the matrix unpacking procedure. This buffering reduces the number of I/Ø accesses to the particular matrix data block.

Created in Module

DESCRP is filled and used exclusively by INTPK

Table Format

An array with the first word defining the length of the array.

2.5.1.7 TWØ (Powers of Two)

Description

A 32 word array with each word (starting with 1 in the 32nd word) containing the next power of two.

Created in Module

The 32 integer values are defined within the NASTRAN system block data program (SEMDBD).

Table Format

Word 32 - 1
Word 31 - 2
Word 30 - 4
Word 29 - 8
etc.

2.5.1.8 NAMES (Symbolic Names)

Description

A series of symbolic names identified with their NASTRAN numeric equivalents. Defines values for GINØ file options, arithmetic types and matrix forms.

Created in Module

The values are defined within the NASTRAN system block data program (SEMDBD).

Table Format

Word	SYMBØL	VALUE	Word	SYMBØL	VALUE	Word	SYMBØL	VALUE
1	RD	= 2	7	EØFNRW	= 3	13	RECT	= 2
2	RDREW	= 0	8	RSP	= 1	14	DIAG	= 3
3	WRT	= 3	9	RDP	= 2	15	UPPER	= 4
4	WRTREW	= 1	10	CSP	= 3	16	LOWER	= 5
5	REW	= 1	11	CDP	= 4	17	SYM	= 6
6	NØREW	= 2	12	SQUARE	= 1	18	RØW	= 7
						19	IDENT	= 8

2.5.1.9 TYPE (Number Types)

Description

A series of properties are defined as a function of a number type. The type may be Real Single Precision (RSP-1), Real Double Precision (RDP-2), Complex Single Precision (CSP-3), or Complex Double Precision (CDP-4). The properties that may be returned include precision (single, double), number of words, and real or complex.

Created in Module

The properties are defined within the NASTRAN system block data program (SEMDBD).

Table Format

Word	Property (Values)	Type		
1	1	Precision (RSP)		
2	2	Precision (RDP)		
3	1	Precision (CSP)	Words (RSP)	
4	2	Precision (CDP)	Words (RDP)	
5	2		Words (CSP)	
6	4		Words (CDP)	
7	1			Real/Complex (RSP)
8	1			(RDP)
9	2			(CSP)
10	2			(CDP)

Example

Assume the number of words required to contain a Complex Single Precision (CSP-3) is desired. The third item in the Words array is indexed and found to contain a 2 (words).

2.5.2 Miscellaneous Tables Not Permanently Core Resident

2.5.2.1 /GPTA1/

Purpose

To describe connection and property characteristics of each element. /GPTA1/ is used in modules GP1, GP2, GP3, TA1, SMA1, SMA2, DSMG1, SDR2, PLØT, and SSG1, and is initialized by the block data program GPTABD and subroutine DELSET.

Description

Word	Type	Item	
1	I	Number of entries (i.e., elements) in table	
2	I	Pointer to first word of last entry in table	
3	I	Number of words per entry in table	
4-5	B	Name of element (e.g., RØD)	repeated for each element
6	I	Internal element identification number	
7-8	I	ECT record ID and trailer bit for LØCATE	
9	I	Number of words per entry on ECT	
10-11	I	EPT record ID and trailer bit for LØCATE	
12	I	Number of words per entry on EPT	
13	I	Number of grid points per element	
14	I	+1 : Scalar element with grid point and component code 0 : Not a scalar element -1 : Scalar element with scalar points only	
15	I	Number of words per entry on EST	
16	I	Position of first grid point in ECT entry	
17	I	Temperature data	
18	I	Temperature data count	
19	I	2 Hollerith symbols if element is plottable	
20	I	Number of words SDR2 passes from Phase 1 element routines to Phase 2 element routines	
21	I	Count of words SDR2 outputs for real stresses	
22	I	Count of words SDR2 outputs for real forces	
23	I	Pointer into an SDR2D table for combining of real stresses to form complex stress outputs	
24	I	Pointer into an SDR2D table for combining of real forces to form complex force outputs	

Word	Type	Item
25	I	SMA1 element overlay limb
26	I	SMA2 element overlay limb
27	I	SMA3 element overlay limb

2.5.2.2 BITPØS.

Purpose

To provide pointers into USET and USETD words for interpreting the nested vector sets in NASTRAN.

Description

Word	Item	
1	UM	Bit number
2	UO	Bit number
3	UR	Bit number
4	USG	Bit number
5	USB	Bit number
6	UL	Bit number
7	UA	Bit number
8	UF	Bit number
9	US	Bit number
10	UN	Bit number
11	UG	Bit number
12	UE	Bit number
13	UP	Bit number
14	UNE	Bit number
15	UFE	Bit number
16	UD	Bit number

Note

All words are integer.

2.5.2.3 PLTDAT

Purpose

To define plotter-dependent parameters.

Description

This table is defined in the PLØTBD block data subprogram. The table is divided into N+2 20-word sections, where N = number of plotters acceptable by the NASTRAN plotting software. Sections 3 to N+2 are the only sections initialized, because each contains values which are dependent upon the plotter hardware. Section 1 contains values which may vary within the limits of the hardware, and Section 2 is simply a duplicate of one of the last N sections corresponding to the plotter of interest.

Section 2 must be filled in by the module writer. The format of Sections 2 to N+2 is as follows:

Word	Type	Name	Description
1-2	R	XYMAX	Maximum x and y coordinate values acceptable by the plotter.
3	R	CNTSIN	Number of plotter counts/inch on paper.
4-5	R	CNTCHR	Number of plotter counts per character in the x and y directions.
6	R	MAXLEN	Maximum length of a line segment.
7	I	NPENS	Maximum number of pens or line density available on the plotter.
8-9	R	ØRIGIN	For incremental plotters, the current pen position relative to the lower left corner of the plot. Otherwise, the location of the lower left corner of the plotter relative to its true physical origin.
10	I	PLTYPE	+1, +2, or +3 if the plotter is a microfilm, table or drum plotter, respectively, with typing capability. -1, -2, or -3 if the plotter is a microfilm, table or drum plotter, respectively, with no typing capability (i.e., all characters must be drawn).
11	B	PLTAPE	PLT1 if an even parity plot tape is to be generated for this plotter. PLT2 if an odd parity plot tape is to be generated for this plotter.
12	I	PBFSIZ	Plot tape physical record size (number of characters)
13	I	EØF	0 if an end-of-file is to be written after every plot. 1 if no end-of-file is to be written on the plot tape.
14-20			Undefined

Section 1 must also be filled in by the module writer. However, unlike Section 2, some of the parameters may vary from plot to plot, as long as they remain within the limitations imposed by the plotter hardware. The format of Section 1 is as follows.

Word	Type	Name	Description
1	I	MØDEL	Plotter model index
2	I	PLØTER	Plotter index
3-6	R	REG	Plotter region (x_{min}, y_{min}, x_{max}, y_{max}) in which the current picture is being drawn. These values must be some fraction (between 0 and 1) of words 7 and 8 (AXYMAX).
7-8	R	AXYMAX	Size of the paper used (x,y), less the borders, in plotter units.
9-10	R	XYEDGE	Size of the borders (x,y) in plotter units.
11	I	CAMNUM	Current selected camera. This word need not be filled in, because it is set and used as a communication between the SELCAM and SKPFRM subroutines.
12-20			Undefined

Usage

Sections 1 and 2 are normally setup by the FNDPLT subroutine, except for the plotter region values (REG). These values must be setup by the module writer himself. It is essential that both these sections be correctly setup, because they are referenced by the entire NASTRAN plotter software package.

If Sections 1 and 2 are correctly setup by the module writer, he need not subsequently worry about such things as compensating for paper margins or different physical plotter origins. He need only assume that the plotter origin is located at the lower left corner of the paper where the left and bottom borders intersect. The NASTRAN plotter software will automatically compensate for the borders and the physical origin.

2.5.2.4 CHAR94

Purpose

To provide a table of characters used to generate plot tapes as if the computer were always an IBM 7094. This table however is independent of the actual computer used.

Description

This is a 240 word table defined in the PLØTBD block data subprogram. It is divided into four equal sections of 60 words each. Each entry in each section has a parallel entry in the other three sections.

Section I is a string of all the Hollerith characters acceptable by the plot modules of the form 1Hx, where x is a Hollerith character.

Section II contains the integer equivalents of the IBM 7094 internal binary characters in the same order as Section I. However, near the end of this section are integers representing various additional characters not in Section I. These additional characters cannot be expressed in the form 1Hx and are used for special plotter commands. Each entry in this table is a right-adjusted two-digit integer with leading zeroes.

Section III contains the integer equivalents of the IBM 7094 BCD characters as they would appear on an even parity tape written on an IBM 7094, in the same order and form as in Section II.

Section IV contains the integer equivalents of the CDC display character codes so as to produce an even parity BCD plot tape as if written on an IBM 7094, in the same order and form as in Section II.

The sequence of characters in each section is as follows:

0	1	2	3	4	5	6	7	8	9
A	B	C	D	E	F	G	H	I	J
K	L	M	N	Ø	P	Q	R	S	T
U	V	W	X	Y	Z	(	)	+	-
*	/	=	.	,	$	'	b		

character 49 = end of record mark

character 50 = end of file mark

characters 51-53 = special characters.

characters 54-60 = 0

Note

In Section I, characters 49-60 = 0.

Usage

Section I is basically used for calculating an index into the other two sections by comparing an arbitrary Hollerith character with each character in Section I until a match is found. Once this is done, the index is used to extract the corresponding entry from either Section II or III, depending on whether an odd or even parity plot tape is being generated. If the computer is an IBM 7094, only Section II is used, and if the computer is a CDC 6600 and an even parity plot tape is being generated, Section IV is used instead of Section III.

2.5.2.5 XXPARM

Purpose

To define the plot tape buffer size, the camera to be used, the number of blank frames of film to be inserted between plots, the plotter model name, and the paper size to be used on table plotters.

Description

This table is defined as follows in the PLØTBD block data subprogram.

Word	Type	Name	Description
1	I	BUFSIZ	Plot tape buffer size
2	I	CAMERA	Plotter camera to be used (appropriate only on a microfilm plotter).
3	I	BFRAMS	Number of blank frames of film to be inserted between plots (appropriate only on a microfilm plotter).
4-5	I, or B	PLTMDL	Plotter model identification.
8-9	R	PAPSIZ	Width and height of the paper to be used (appropriate only on table plotters).

Usage

The initial values of these variables are as follows:

BUFSIZ = must be set by the module writer

CAMERA = 2 (paper output only)

BFRAMS = 1

PLTMDL = 4020, 0 (integer)

PAPSIZ = 8.5, 11.0

This table's actual size is 152 words. The remainder of the table is initialized for the structural plotter module, PLØT, but may be used by the programmer for anything he desires in other plotting modules.

2.5.2.6 SYMBLS

Purpose

To provide a table of indices into the CHAR94 and CHRDRW tables used to type or draw predefined plotter symbols.

Description

The table is defined in the PLØTBD block data subprogram. There is room for up to 20 indices for each plotter. However, the same number of indices must be defined for each plotter. The format of the table is as follows:

Word	Type	Description
0	I	Number of symbols defined for each plotter (currently = 9).
1-20	I	Symbol indices for plotter 1.
21-40	I	Symbol indices for plotter 2.
41-60	I	Symbol indices for plotter 3.
⋮	⋮	⋮

There are as many groups of symbol indices as there are available plotters. The symbols defined for each plotter are as follows:

Symbol 1 = x
Symbol 2 = *
Symbol 3 = +
Symbol 4 = -
Symbol 5 = · (dot, not a period).
Symbol 6 = circle
Symbol 7 = square
Symbol 8 = diamond
Symbol 9 = triangle

Should any of these symbols not be available on a plotter, a substitution of another symbol must be made.

Usage

This table is used by the SYMBØL subroutine.

2.5.2.7 CHRDRW

Purpose

To define the combination of lines needed to draw alphanumeric characters and symbols.

Description

This table is defined in the PLØTBD block data subprogram. The table is divided into two sections. Section I is a list of indices into Section II, used to locate the data needed to draw characters. The first 48 indices in Section I correspond to the 48 characters listed in Section I of the CHAR94 table. The last 7 indices are used for drawing the special characters listed in the SYMBLS table. If an index is negative, it is an index into Section I instead of Section II. This occurs when a duplicate character exists (e.g., a zero, the letter "Ø", and the symbol for a circle).

Section II of this table defines the (integer) coordinates of the starting and ending points of the straight lines to be drawn in order to draw a character or symbol. In general, the necessary straight lines are contiguous, so that the end point of one line is the starting point of the next, etc. In some cases, this is either impractical or impossible (e.g., *, +, =, etc.). In such a situation, the starting point of a line is negative, meaning that it is not to be connected to the end point of the preceding line.

The characters defined in Section II are based upon 6x6 square characters. The values in this section are simply integer coordinates within a 6x6 square.

The format of this table is as follows:

Word	Type	Name	Description
0	I	LSTCHR	Name of characters and symbols referenced in Section I (=52).
1-60	I	CHRIND	Section I - "LSTCHR" indices into Section II.
61-760	I	CHR	Section II = (x,y) pairs defining the lineal representation of 6x6 square characters.

Usage

This table is used by the DRWCHR subroutine.

3.1 INTRODUCTION

Section 3 contains descriptions of subroutines not an integral part of a module. Those subroutines which are an integral part of a module are discussed in section 4, Module Functional Descriptions. Section 3.2 contains an alphabetical index of entry points of routines documented in section 3. A similar index of entry points documented in section 4 can be found in section 4.1.3.

Subroutine descriptions have been partitioned into 3 classifications: executive, utility and matrix subroutine descriptions, documented in sections 3.3, 3.4, and 3.5 respectively.

Descriptions of the plotting utility routines (e.g., AXIS, section 3.4.40; AXISi, section 3.4.41) refer to plotters by number or the letter "i", and to plotter models by number only. The correspondence of these numbers to plotter hardware is given in Table 1. Further details can be found in section 4 of the User's Manual.

Table 1. Correspondence Between External and Internal Plotter and Model Names and Numbers.

External plotter name	External model name	Internal plotter number	Internal model number
BL	STE,30	1	1
	LTE,30		
EAI	3500,30	2	1
	3500,45	8	1
SC	4020,0	3	1
CALCØMP	765,205	5	4
	765,210	4	4
	765,105	5	5
	765,110	4	5
	763,205	7	4
	763,210	6	4
	763,105	7	5
	763,110	6	5
	565,205	5	2
	565,210	4	2
	565,105	5	3
	565,110	4	3
	565,305	5	1
	565,310	4	1
	563,205	7	2
	563,210	6	2
	563,105	7	3
	563,110	6	3
	563,305	7	1
	563,310	6	1
DD	80,B	9	1
NASTRAN	M,0	10	+1
	T,0	11	+2
	D,0	11	+3
	M,1	10	-1
	T,1	11	-2
	D,1	11	-3

where:

BL = Benson Lehner
EAI = Electronic Associates Inc.
SC = Stromberg Carlson

Table 1. Correspondence Between External and Internal Plotter and Model Names and Numbers (Cont'd).

CALCØMP	= California Computing
DD	= Data Display
NASTRAN	= NASTRAN General Purpose Plotter

3.2 ALPHABETICAL INDEX OF ENTRY POINTS FOR SUBROUTINE DESCRIPTIONS.

ALPHABETICAL INDEX OF ENTRY POINTS FOR SUBROUTINE DESCRIPTIONS

Section Number	Entry Point	Subroutine Description	Page Number
3.4.26	MSGWRT	MSGWRT	3.4-40
3.5.15	ØNETWØ	DECØMP	3.5-54
3.4.2	ØPEN	ØPEN	3.4-3
3.4.13	ØPNCØR	ØPNCØR	3.4-20
3.4.1	ØRF	MAPFNS	3.4-1
3.5.2	PACK	PACK	3.5-5
3.4.24	PAGE	PAGE	3.4-38
3.4.24	PAGE1	PAGE	3.4-38
3.4.24	PAGE2	PAGE	3.4-38
3.5.6	PARTN	PARTN - MERGE	3.5-13
3.4.22	PEXIT	PEXIT	3.4-36
3.4.70	PHDMIA	PHDMIA	3.4-118
3.4.70	PHDMIB	PHDMIA	3.4-118
3.4.70	PHDMIC	PHDMIA	3.4-118
3.4.70	PHDMID	PHDMIA	3.4-118
3.4.63	PLAMAT	PLAMAT	3.4-106
3.4.67	PLTSET	PLTSET	3.4-113
3.4.30	PRELØC	PRELØC	3.4-44
3.4.36	PREMAT	PREMAT	3.4-55
3.4.39	PRETAB	PRETAB	3.4-67
3.4.37	PRETRD	PRETRD	3.4-64
3.4.38	PRETRS	PRETRS	3.4-66
3.4.49	PRINT	PRINT	3.4-81
3.4.20	RCARD	RCARD	3.4-32
3.5.15	RCØRE	DECØMP	3.5-58
3.4.13	RDCØR	ØPNCØR	3.4-20
3.4.50	RDMØDE	RDMØDX	3.4-83
3.4.50	RDMØDX	RDMØDX	3.4-83
3.4.50	RDMØDY	RDMØDX	3.4-83
3.4.16	RDTRL	WRTTRL	3.4-24

ALPHABETICAL INDEX OF ENTRY POINTS FOR SUBROUTINE DESCRIPTIONS

ALPHABETICAL INDEX OF ENTRY POINTS FOR SUBROUTINE DESCRIPTIONS

3.3 EXECUTIVE SUBROUTINE DESCRIPTIONS.

3.3.1 XSEM1 (Executive Sequence Monitor, Preface).

3.3.1.1 Entry Point: XSEM1.

3.3.1.2 Purpose

To initiate the execution of the NASTRAN Preface.

3.3.1.3 Calling Sequence

CALL XSEM1

3.3.1.4 Method

Subroutine BTSTRP is called to initialize machine dependent data, and then subroutine SEMINT is called to execute the program Preface (i.e. input file processors and DMAP program compiler). After initiating the problem, modules are called as directed by the ØSCAR until a module is encountered in the ØSCAR that does not reside in link 1 at which time XSEM1 calls subroutine ENDSYS to load a new link.

3.3.1.5 Design Requirements

XSEM1 must reside in the core resident portion of link 1. Link 1 is not re-entrant which means that once the program leaves link 1 it can never transfer control back to link 1. Functional DMAP modules can not reside in link 1. Open core is used for a GINØ buffer with named common block /ESFA/ defining the beginning of open core. See the second paragraph of the design requirements section of the subroutine description XSEMi (see section 3.3.7) for details on files, data blocks, and common blocks necessary for operation.

3.3.2 BTSTRP (Bootstrap Generator).

3.3.2.1 Entry Point: BTSTRP.

3.3.2.2 Purpose

Determines the machine type and initializes the machine dependent constants and masks within the NASTRAN system block data program (SEMDBD).

3.3.2.3 Calling Sequence

CALL BTSTRP

3.3.2.4 Method

The machine type (IBM 7094, IBM S/360, Univac 1108, CDC 6600) is determined by inspection of the machine binary word length and the known methods of representing negative integers (sign and magnitude or ones/twos complement) using the following algorithm:

1. If the ones complement (CØMPLF see section 3.4.1) of -1 is greater than 2, the machine is the IBM 7094. If not, the machine is an IBM S/360, Univac 1108 or CDC 6600. (i.e., only the sign and magnitude representation of -1 on the 7094 will yield a large (> 2) positive value when complemented.)

2. Shift (RSHIFT see section 3.4.1) a binary machine word of all 1's to the right thirty-two binary places. Compare the resulting value to 15. If the value is less than fifteen, the machine is the 32 bit IBM S/360; equal to fifteen, the 36 bit Univac 1108; and greater than fifteen, the 60 bit CDC 6600.

Once the machine type is known, the proper constants and masks are selected from assembled tables.

3.3.2.5 Design Requirements

This subroutine must be modified if it is to operate with other than the four machine types listed above.

3.3.3 SEMINT (Sequence Monitor Initialization).

3.3.3.1 Entry Point: SEMINT.

3.3.3.2 Purpose

To execute the Preface of a NASTRAN problem solution.

3.3.3.3 Calling Sequence

```
CALL SEMINT
```

3.3.3.4 Method

The first card of the NASTRAN data deck is read from the system input file and its image stored in blank CØMMØN. XRCARD is called to convert the card. If the name of the card is NASTRAN, the card is echoed and keywords are identified and appropriate words of /SYSTEM/ are reset to the input values. If an unidentified keyword is detected, or the card has a format error, a message is printed and the NØGØ flag is turned on. The first word of blank CØMMØN is set to one if the card was a NASTRAN card, to zero otherwise. Then GNFIAT is called to generate the initial FIAT. XCSA is called to read and process the Executive Control Deck. IFP1 is called to read and process the Case Control Deck. XSØRT is called to read and sort the Bulk Data Deck. If bulk data is present, IFP is called to process it. If the problem is a conical shell problem, IFP3 is called to further process the bulk data. If the current run is to prepare a User's Master File, UMFEDT is called and control is returned to XSØRT for each new problem to be written on the UMF. Otherwise, XGPI is called to perform General Problem Initialization and then return is made to XSEM1 signifying completion of the Preface.

3.3.3.5 Design Requirements

If the NASTRAN card is present, it must be the first card of the data deck.

3.3.3.6 Diagnostic Messages

```
UNIDENTIFIED NASTRAN KEYWØRD _____.  ACCEPTABLE KEYWØRDS FØLLØW--
     BUFFSIZE
     CØNFIG
     MAXFILES
     MAXØPEN
     SYSTEM
```

Self-explanatory.

NASTRAN CARD DØES NØT HAVE CØRRECT FØRMAT.

Typical errors include non-integer values or continuation of the card following an = sign.

See section 6.3.1 for further details on the NASTRAN card.

3.3.4 GNFIAT (Generate FIAT).

3.3.4.1 Entry Point: GNFIAT.

3.3.4.2 Purpose

Determines the number of logical files available within the computer hardware and software configuration and places an entry for each into FIAT or XFIAT.

3.3.4.3 Calling Sequence

CALL GNFIAT

GNFIAT must be called once and only once as the first call from the preface.

3.3.4.4 Method

Each computer configuration has its own independent subroutine to accomplish the necessary functions of GNFIAT. The subroutine interrogates unit blocks, data definition cards, file tables, etc. to determine the number of logical files available within the configuration. As each logical file is sensed, it is determined whether the file has been assigned to a physical magnetic tape or some bulk storage device such as disk or drum. Each file has a logical name and/or number for identification. These file ID's are stored in FIAT, XFIAT or both depending on several factors. As the file ID is stored, a physical tape flag is set where appropriate. The factors that determine FIAT vs. XFIAT storage are as follows: 1) the first PFIST (see section 2.4 for a description of the FIST) files sensed are always entered into XFIAT, 2) except for the first file (always the PØØL), all of the first PFIST files without tape flags are also entered into FIAT, and 3) all other files are entered into FIAT only.

3.3.4.5 Design Requirements

Since GNFIAT routines are computer hardware/software dependent, operational requirements may differ at various times. See appropriate commented assembly listing if difficulties or error codes are encountered.

3.3.5 ENDSYS (End-of-Link).

3.3.5.1 Entry Points: ENDSYS, BGNSYS.

3.3.5.2 Purpose

For ENDSYS, to save various NASTRAN core-resident Executive Tables on a scratch file for use in communicating with the next link requested.

For BGNSYS, to restore the NASTRAN Executive Tables saved by ENDSYS and to position the ØSCAR at the correct entry to be executed in the resident link.

3.3.5.3 Calling Sequences

CALL ENDSYS(LINK,X,REWFLG)

LINK - BCD name of the link. The naming convention is: NSO1 = link 1, NSO2 = link 2, etc.

X - Dependent on machine type. For the IBM 7094 only, X (6 BCD characters) specifies the unit where the links are stored. Not used on other machines.

REWFLG = 0 indicates LINK is ahead of current link (i.e. we are going from link N to link N + K, K > 0). IBM 7094 only; not used on other machines.

REWFLG = 1 indicates LINK is behind current link (i.e. we are going from link N to link N + K, K < 0). IBM 7094 only; not used on other machines.

CALL BGNSYS.

3.3.5.4 Method

For ENDSYS, a search is made for an empty file and when found the Executive Tables are written (saved) on it. A pointer to the save file is saved in blank common or written on a system file for use by BGNSYS when the new link is loaded. Subroutine SEARCH is then called to load the requested link.

BGNSYS is called after a new link is loaded. The pointer to the save file containing the Executive Tables is obtained from either blank common or a system file, and the Executive Tables are reloaded into core. The ØSCAR is positioned at the correct entry to be executed, and a RETURN is made to the calling routine.

3.3.5.5 Design Requirements

Program links are usually considered to be physically separate programs, essentially independent of one another except for the fact that the operating system executive (not the NASTRAN executive) provides a means by which control can be transferred from one link to another when requested by the user. The means by which the operating system executive transfers control from one link to another is dependent upon the machine and the system being used. For some future machines there may be no means for building physically separate links so the links become logical subsets of one huge program.

No matter how the links are formed it is necessary, when transferring from one link to another, that all file assignments be preserved as well as their status (i.e. don't rewind the tapes).

Open core is used for GINØ buffer area and the beginning of open core is defined by named common block /ESFA/.

If no save file is available or if any of the Executive Tables to be written exceeds 900 words, the job is terminated.

3.3.6 SEARCH (Search, Load, and Execute Link).

3.3.6.1 Entry Point: SEARCH.

3.3.6.2 Purpose

SEARCH locates (searches for) a particular link of the NASTRAN system on the Link Storage File, loads the link into the computer memory and transfers execution control to the link entry point XSEMi, i = 2,3,....

3.3.6.3 Calling Sequence

CALL SEARCH(LKNAM,LKFIL,REW)

LKNAM = 4 character symbolic name of link, i.e., NSO1, NSO2 for link 1, link 2, etc.

LKFIL = symbolic name of the Link Storage File (IBM 7094 only)

REW = set non-zero to position a sequential Link Storage File to its beginning (IBM 7094 only)

3.3.6.4 Method

SEARCH is machine dependent. It interfaces with the machine operating system to provide a multi-link capability. Each link is a somewhat arbitrary part of the complete NASTRAN system. The division into links was necessary only because of the size limitation for program complexes imposed by the various operating systems. The linking technique for each machine is discussed in section 5 of the Programmer's Manual.

3.3.6.5 Design Requirements

Only the IBM 7094 system requires the Link Storage File to be named (LKFIL) and, since it is sequential, provides the capability of rewinding it following a SEARCH call. All other systems provide random access (disk, drum) Link Storage Files.

3.3.6.6 Diagnostic Messages

Individual SEARCH subroutines may abnormally terminate due to hardware malfunction. See appropriate commented assembly listing if difficulties or error codes are encountered.

3.3.7 XSEMi (Link i Main Program, i = 2,3, ...

3.3.7.1 Entry Point: XSEMi.

3.3.7.2 Purpose

To get the next module to be executed from the ØSCAR, initialize the module and call it if it is in link i, or transfer to the link in which module resides if it is not in link i.

3.3.7.3 Calling Sequence

Example: CALL XSEM2, where XSEM2 is the entry point of link 2

3.3.7.4 Method

Subroutine BTSTRP is called to initialize machine dependent data, and then subroutine BGNSYS is called to reload Executive Tables saved from the previous link.

The next ØSCAR entry is read into core and processed. If the entry is for a functional module, subroutine GNFIST is called to link files with input, output and scratch data blocks needed by the module. Variable parameter values needed by the module are transferred to blank common from table VPS which resides in named common block /XVPS/. Constant values in the ØSCAR entry parameter section are transferred to blank common.

The link specification table in named common block /XLINK/ is examined to see if the module resides in this link. If it does, the module is called. Upon returning from the module, the diagnostic message queue is checked and message writer MSGWRT is called if there are messages queued. Begin and end execution times are printed out for functional modules.

The next ØSCAR entry is read and the process is repeated until a module is encountered which does not reside in this link, at which time subroutine ENDSYS is called to initiate loading of the link containing the module.

3.3.7.5 Design Requirements

XSEMi must reside in the core resident portion of link i. Link i is re-entrant which means program control can be transferred to this link as often as needed. Open core is used for a GINØ buffer with named common block /ESFA/ defining the beginning of open core. An ØSCAR entry cannot be greater than 200 words.

Files, data blocks and named common blocks needed by XSEMi are listed below, along with type of access required (i.e. fetch and/or store data) and reasons for use.

1. Data Pool File - fetch. Contains XØSCAR data block.
2. XØSCAR - fetch. Contains ØSCAR entry to be processed.
3. Common /XLINK/ - fetch. Contains link specification table.
4. Common /XFIST/ - store. Initialized prior to calling GNFIST.
5. Common /XPFIST/ - fetch. Contains parameter needed to initialize FIST table.
6. Common /ØSCENT/ - fetch. Contains ØSCAR entry to be processed.
7. Common /ESFA/ - store. Defines beginning of open core area used by GINØ buffer.
8. Common /XVPS/ - fetch. Contains variable parameter values needed to initialize module to be executed.
9. Common /MSGX/ - fetch. Contains diagnostic message queue.
10. Common /SEM/ - fetch. Contains BCD names of links NS01, NS02, ...

3.3.7.6 Diagnostic Messages

A message is written if the module to be executed required more files than are available. The job is then terminated.

3.3.8 XSEMXX (Sequence Monitor - Deck Generator).

3.3.8.1 Entry Point: XSEMXX.

3.3.8.2 Purpose

To provide a model from which all other XSEMi (i = link number) subroutines except XSEM1 can be made.

See section 6.11, which discusses how to generate a link driver subroutine.

3.3.9 GNFIST (Generate FIST)

3.3.9.1 Entry Point: GNFIST.

3.3.9.2 Purpose

To set up the proper linkage between data blocks and the files they reside on in preparation for executing the functional module requiring the data blocks.

3.3.9.3 Calling Sequence

CALL GNFIST(DBN,FISTNM,MØDNØ)

DBN - Data block name (Two word BCD array - 8 characters total)

FISTNM - Data block identification (GINØ file number) used by functional module (integer).

MØDNØ - ØSCAR record number of functional module to be executed (integer). MØDNØ indicates to the calling routine what action was taken by GNFIST.

MØDNØ > 0, data block assigned a file or it was purged.

MØDNØ = 0, fatal error detected.

MØDNØ < 0, data block not assigned a file, GNFIST called Executive Segment File Allocator (XSFA)

3.3.9.4 Method

If the data block is purged, GNFIST returns to the calling routine with MØDNØ > 0. A data block is purged if it is an input which has not been generated or its status is purged or DBN = 0.

If an input data block resides on the Data Pool File and needs to be unpooled, GNFIST calls the file allocator (XSFA) to unpool all inputs to the module which reside on the Data Pool File that need to be unpooled. GNFIST then returns to the calling routine with MØDNØ < 0. The other condition under which XSFA is called is if a file has not been allocated to a non-purged output data block or scratch data block needed by the module.

A file is allocated to a data block when the data block name appears in the FIAT table, located in named common block /XFIAT/, as unpurged. Input, output and scratch data blocks which have been assigned to a file and are required by the functional module, have their FISTNM's entered

in the FIST table which is located in named common block /XFIST/. FIST entries are linked to the DBN's in the FIAT table which in turn links the data block to a file. This completes the linking of functional module data blocks to their files.

Output data blocks cannot reside on the Data Pool File, so GNFIST checks for this and if found, the DBN and all DBN's equivalenced to it are deleted from the DPL table located in named common /XDPL/.

3.3.9.5 Design Requirements

GNFIST resides in the core resident portion of a link. It does not use open core and the only restriction is that the FIST table be large enough to hold all FISTNM's for a module.

The named common blocks needed by GNFIST are listed below, along with type of access required (i.e. fetch and/or store data) and reasons for use.

1. CØMMØN/XFIST/ - Store.

   Used to store FISTNM's and link FISTNM's with their corresponding DBN's in FIAT.

2. CØMMØN/XFIAT/ - Fetch and store.

   Used to determine status of DBN's. The FIAT table is altered if unpooling of input data blocks is necessary.

3. CØMMØN/XDPL/ - Fetch and store.

   Used to determine status of input DBN's and is altered if output DBN's appear in it.

4. CØMMØN/ØSCENT/ - Fetch.

   Contains ØSCAR entry for functional module to be executed. Used to alter FIAT when input DBN's need to be unpooled.

3.3.9.6 Diagnostic Messages

GNFIST detects overflow in FIST table and sends message to terminate job.

3.3.10 XEØT (End-of-Tape).

3.3.10.1 Entry Point: XEØT.

3.3.10.2 Purpose

To prepare and send to the computer operator, messages instructing him what to do when end-of-tape has been encountered on the Old Problem Tape (ØPTP) or the New Problem Tape (NPTP).

3.3.10.3 Calling Sequence

CALL XEØT(ID,ØREEL,NREEL,BUF)

ID - BCD name NPTP or ØPTP

ØREEL - Number of reel to be dismounted - integer.

NREEL - Number of new reel to be mounted - integer.

BUF - GINØ buffer used by NPTP or ØPTP.

3.3.10.4 Method

A check is made to see if tape has multi-reel capability. If not, a fatal message is issued and job is terminated. The operator messages are generated and issued and the old reel is rewound and unloaded. A check is made to see if correct new reel has been mounted and then a return is made to calling program.

3.3.10.5 Design Requirements

XEØT must be accessible to routines XGPI and XCHK.

3.3.10.6 Diagnostic Messages

A message is issued if tape does not have multi-reel capability.

3.3.11 SSWTCH (Sense Switches)

3.3.11.1 Entry Point: SSWTCH.

3.3.11.2 Purpose

To indicate to the calling routine whether or not a specified sense switch is set.

3.3.11.3 Calling Sequence

```
CALL SSWTCH(SS,F)
```

SS - Sense switch number - integer. $1 \leq SS \leq 31$.

F - Flag indicating status of SS

F = 0 if SS not on

F = 1 if SS is on

3.3.11.4 Method

Named common block /SYSTEM/ contains the word which contains the sense switch settings. Bit 1 of the word corresponds to sense switch 1, bit 2 corresponds to sense switch 2, etc. If the bit corresponding to SS is on then F = 1, if not then F = 0.

Note that sense switches are set by the user via the DIAG card in the Executive Control Deck and not through physical sense switches set by the computer operator.

The following sense switches are currently in use:

Switch	
1	Dump core when subroutine DUMP or PDUMP is called. This will cause a core dump on any nonpreface fatal error.
2	Print the FIAT after each call to XSFA.
3	Print the Data Pool Dictionary after each call to XSFA.
4	Print the ØSCAR at the end of XGPI.
5	Type a message to signify the beginning of each module on the operator's console.
6	Type a message to signify the ending of each module on the operator's console.
7	Print eigenvalue extraction diagnostics for real inverse power and real and complex determinant methods.

Switch	
8	Print matrix trailers as the matrices are generated.
9	Not used.
10	Use alternate nonlinear loading in TRD. (Replace $\{N_{n+1}\}$ by $\frac{1}{3}\{N_{n+1} + N_n + N_{n-1}\}$)
11	Print all active row and column possibilities for the decomposition algorithm.
12	Print eigenvalue extraction diagnostics for complex inverse power.
13	Print open core length.
14	Print the Rigid Format (NASTRAN SOURCE PROGRAM COMPILATION) for all non-Restart runs.
15	Trace GINØ ØPEN/CLØSE operations on CDC 6000 series.
16	Trace real inverse power eigenvalue extraction operations.
17	Punch the DMAP sequence that is compiled.
18	Not used.
19	Print data for MPYAD method selection.
20	Generate de-bug printout (For NASTRAN programmers who include CALL BUG in their subroutines).
21	Print GP4 set definition.
22	Print GP4 degree of freedom definition.
23-26	Not used.
27	Input File Processor (IFP) table dump.
28	Punch out the link specification table - deck XBSBD.
29	Process link specification table update deck.
30	Punch out alters to XSEMi decks.
31	Print link specification table.

For a further explanation of switches 28-31 see Section 6.11 in the Programmer's Manual.

3.3.11.5 Design Requirements

SSWTCH resides in the core resident portion of a link.

3.3.12 CØNMSG (Console Message Writer).

3.3.12.1 Entry Point: CØNMSG

3.3.12.2 Purpose

Writes the current time and a NASTRAN system message onto the system output device and (if the computer configuration permits) onto the on-line operator's console device.

3.3.12.3 Calling Sequence

```
CALL CØNMSG(MSG,CNT,YN)
```

MSG - Array name containing message.

CNT - Number of 4-character words in message (integer).

YN - 1 = yes, 0 = no. Print on-line device if yes and available.

3.3.12.4 Method

A computer real-time and/or job clock is interrogated. The number of message words indicated is sent to the system output device (usually printer) along with the clock reading(s). If the computer configuration permits and the yes/no switch is set yes, the same clock reading(s) and message is sent to the operator's console device (usually typewriter).

3.3.12.5 Design Requirements

Only the left-most four characters from each computer word are extracted and sent to the output device(s).

3.3.13 TTLPGE (Title Page Writer).

3.3.13.1 Entry Point: TTLPGE

3.3.13.2 Purpose

To print on the system output file title page information as follows:

- the NASTRAN symbol
- the machine type and model
- the system generation date
- the level identification
    - major level number (corresponds to the basic archive Source Library)
    - minor level number (corresponds to the object library for a machine type)
    - local level number
    - variations of a local level
- the Rigid Format series identification, including modifications, if any

3.3.13.3 Calling Sequence

```
CALL TTLPGE (K)
```

3.3.13.4 Method

TTLPGE is called as the first executable statement in the Preface driver SEMINT following transliteration (IBM 360, 370 only) and reading of the NASTRAN card (if any).

The variable K is stored as a local variable in subroutine SEMINT and may be set at execution time by the user on the NASTRAN data card by

```
NASTRAN TITLEØPT = k
```

where the default value for k is 1 as defined by a DATA statement in subroutine SEMINT. The action taken by TTLPGE depends on the integer option parameter K (whose value is k) as shown below.

k	TTLPGE action
<0	Print one (1) copy of an abbreviated title page
=0	Supress any title page printout
1	Print one (1) copy of the full title page
2	Print two (2) copies of the full title page
3	Print a single copy of a locally annotated title page
>3	Supress any title page printout

Whenever changes are incorporated into NASTRAN, the TTLPGE routine should be updated to reflect these changes. This is particularly important when official updates are made since runs may only be identifiable by the information contained in this printout. The basic identification of a given version of NASTRAN is called the Level number, a code of the form

i.j.k

where i is the current major level number, j is the minor level number and k is local level number.

The major level corresponds to a complete recompilation of the entire system on each machine from a single archive source library maintained for all machines. It is through this mechanism that the machine-independent nature of the NASTRAN code is guaranteed. Major levels of NASTRAN will probably only be issued at intervals of once a year or longer due to the expense involved.

Minor levels correspond to changes that are made on one given type of machine, say the CDC 6000 machines. These changes are reflected in the object library for the given machine class, and may be reflected in the source by either alters to the basic source library or by an updated source library. Minor levels will probably be issued every few months for each machine class as alters to the basic or previous source library.

Local levels are reserved for locally made changes and provides a mechanism for the local NASTRAN system programmer to keep track of several versions of NASTRAN that may exist at his installation. This would probably consist of a digit or a digit and a typed letter (e.g., Level 15.1.2A).

The Rigid Format series is designated by a letter. Minor modifications will be identified by a digit (e.g., Rigid Format Series M.2). It is anticipated that new series of Rigid Formats will only be available concurrently with major levels of the program.

3.3.14 SEMTRN (Transliterator) (IBM 360-370 only)

3.3.14.1 Entry Point: SEMTRN

3.3.14.2 Purpose

To read the system input stream and convert EBCDIC characters to BCD.

3.3.14.3 Calling Sequence

```
CALL SEMTRN (KIN, KØUT)
```

3.3.14.4 Method

An I/Ø activity is done using FØRTRAN. One eighty (80) column card image at a time is read from FØRTRAN unit KIN, transliterated, and written out on FØRTRAN unit KØUT. FØRTRAN unit KØUT is rewound before writing and before returning. FØRTRAN unit KIN is not rewound before reading and is not manipulated further once an end-of-file condition is detected. Any EBCDIC characters other than the standard NASTRAN set defined on page 2.1-2 (6/1/72) of the User's Manual are transliterated to the blank character. BCD punched characters are transliterated into themselves. Thus, for the standard character set, either BCD, EBCDIC or mixed BCD and EBCDIC may be used on the IBM 360-370 computer systems. It should be emphasized that decks containing EBCDIC characters will not run on the other NASTRAN computers.

3.3.14.5 Design Requirements

The FØRTRAN unit KØUT must be defined in the JCL and sufficient space must be allocated to hold the transliterated input stream. The actual unit numbers used are defined by the calling program (SEMINT) and are currently set to KIN = 5 and KØUT = 1. If the 2314 disk facility is used for KØUT, the space can be estimated by

$$\text{No. Tracks} = \frac{\text{No. Cards}}{91}$$

if full track blocking is used. This is accomplished by specifying the DCB as

```
DCB = (RECFM=FB, LRECL=80, BLKSIZE=7280) .
```

The transliteration is effected by using the character read in as an index into a 256 byte table containing the desired BCD representations. In this way, no look-up expense is involved.

3.3.15 RETURN (Return)

3.3.15.1 Entry Point: RETURN

3.3.15.2 Purpose:

To allow inclusion of calls to non-existing decks. Linkage Editor data changes are required to use this capability.

3.3.15.3 Calling Sequence

```
CALL RETURN
```

3.3.15.4 Method

The only executable statement is a RETURN to the calling program.

3.3.15.5 Design Requirements

RETURN should be located in LINK 0 or in the root segment.

3.3.15.6 Diagnostic Messages

None.

3.4 UTILITY SUBROUTINE DESCRIPTIONS.

3.4.1 MAPFNS (Machine Word Functions).

3.4.1.1 Entry Points: LSHIFT, RSHIFT, ANDF, ØRF, XØRF, CØMPLF, CØRSZ, CØRWDS.

3.4.1.2 Purpose

To perform basic computer word manipulations by standard binary digit (bit) operations. The manipulations are performed over the complete memory word length for the particular hardware. Also, to determine the size of open core (CØRSZ) and the absolute difference between locations in core (CØRWDS).

3.4.1.3 Calling Sequence

All machine word functions are executed as FØRTRAN integer function subroutines with integer arguments.

3.4.1.4 Method

The method employed within each function will be described following the separate function examples.

3.4.1.5 Entries

K = LSHIFT (I,N)

The entire bit structure of word I is shifted left N places and the resulting word replaces word K. Word I is unchanged. High-order bits shifted out are lost. Zeros are supplied to vacated low-order positions. The shift is logical; no special provision is made for the sign position.

K = RSHIFT (I,N)

The entire bit structure of word I is shifted right N places and the resulting word replaces word K. Word I is unchanged. Low-order bits shifted out are lost. Zeros are supplied to vacated high-order positions. The shift is logical; no special provision is made for the sign position.

K = ANDF (I,J)

A logical product of the bits within word I and word J is formed and stored into word K. Words I and J are unchanged.

K = ØRF (I,J)

A logical sum of the bits within word I and word J is formed and stored into word K. Words I and J are unchanged.

K = XØRF (I,J)

The modulo-two sum (exclusive or) of the bits within word I and word J is formed and stored into word K. Words I and J are unchanged.

K = CØMPLF (I)

The ones complement of the bits within word I is formed and stored into word K. Word I is unchanged.

K = CØRSZ (I,J)

The size of open core is computed and stored in location K through this function. Location I is normally the address of a labeled common cell defining the beginning of a particular open core area. Location J is normally the address of blank common (usually thought to be the end of a particular open core area). On computer memory configurations where blank common does not define the end of open core, CØRSZ ignores location J and substitutes a correct end value. The arguments I and J may be interchanged without affecting results.

K = CØRWDS (I,J)

The absolute difference plus 1 between the addresses of locations I and J is computed and stored into word K. Words I and J are unchanged.

3.4.1.6 Design Requirements

MAPFNS is written in assembly language.

3.4.2 ØPEN (Initiate Activity on a File).

3.4.2.1 Entry Point: ØPEN.

3.4.2.2 Purpose

To initiate activity on the requested file.

3.4.2.3 Calling Sequence

CALL ØPEN($n,NAME,BUFF,ØP)

n - FØRTRAN statement number defining the return to be taken in the event NAME is not in the FIST (i.e. the data block is purged).

NAME - GINØ file name of the data block which is to be read or written(see section 1.6.4.1).

BUFF - An array whose dimension equals the contents of the first word of /SYSTEM/ which will be used by GINØ while the file is open.

ØP = {0, open file to read with rewind
1, open file to write with rewind
2, open file to read without rewind
3, open file to write without rewind

3.4.2.4 Method

ØPEN stores parameters in /GINØX/ and then calls XGINØ which searches the FIST for a name match and picks up from the FIAT the unit to which the data block is assigned. The position of the buffer is determined relative to /XNSTRN/.

This index is saved in the BUFADD array in /GINØX/. BUFADD is searched to determine if any other buffer overlaps the buffer currently assigned. GINØ is called to initiate activity for the file.

3.4.2.5 Design Requirements

The address of the buffer assigned must be greater than the address of /XNSTRN/.

3.4.2.6 Diagnostic Messages

The following system fatal errors may be issued by ØPEN:

3006

3012

3040

3.4.3 WRITE (Write Data in a Logical Record).

3.4.3.1 Entry Point: WRITE.

3.4.3.2 Purpose

To write a logical record, or portion of a logical record, on the requested file.

3.4.3.3 Calling Sequence

CALL WRITE(NAME,BLØCK,N,EØR)

NAME - GINØ file name of the data block which is to be written (see section 1.6.4.1).

BLØCK- An array of dimension ≥ N containing the data words to be written.

N - The number of words to be written - integer - input.

EØR = { 0, the N words to be written by this call do not end the logical record, i.e. subsequent WRITE calls will provide additional data to be written in the current logical record.
1, the N words to be written by this call end the logical record.

3.4.3.4 Method

WRITE stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to perform the actual processing of the call.

3.4.4 CLØSE (Terminate Activity on a File).

3.4.4.1 Entry Point: CLØSE.

3.4.4.2 Purpose

To terminate activity on the requested file.

3.4.4.3 Calling Sequence

CALL CLØSE(NAME,ØP)

NAME - GINØ file name of the data block to be closed (see section 1.6.4.1).

ØP
- 1, if file was opened to write, write end-of-file and rewind.
  If file was opened to read, rewind only.
- 2, close file at current file position (no end-of-file, no rewind).
- 3, if file was opened to write, write end-of-file and position file in front of end-of-file mark.
  If file was opened to read, same as ØP = 2.

If the requested file is not in the FIST or is not currently open, a normal return is given and no operation takes place.

If the file was opened for output and the last logical record has not been written, it is written prior to honoring the ØP request.

The buffer assigned when the file was opened is released and is available to the user on return.

3.4.4.4 Method

CLØSE stores parameters in /GINØX/ and then calls XGINØ. If XGINØ returns indicating the file is not in the FIST or not open, an immediate return is given to the user. Otherwise XGINØ calls GINØ to process the call.

3.4.5 READ (Read Data From a Logical Record).

3.4.5.1 Entry Point: READ.

3.4.5.2 Purpose

To read the contents of a logical record, or portion of a logical record, from the requested file.

3.4.5.3 Calling Sequence

CALL READ($$n_1$$,$$n_2$$,NAME,BLØCK,N,EØR,M)

$$n_1$$ - FØRTRAN statement number defining the return to be taken in the event an end-of-file is encountered by this READ operation.

$$n_2$$ - FØRTRAN statement number defining the return to be taken at the end of the READ operation whenever the end-of-logical-record is encountered prior to transmitting the requested number of data words.

NAME - GINØ file name of the data block which is to be read (see section 1.6.4.1).

BLØCK - An array of dimension ≥ N, where the words read will be stored.

N - { N > 0: The number of words to be read and stored at BLØCK - integer - input.
N ≤ 0: The number of words to be skipped, i.e., read but not stored at BLØCK.
Integer - input.

EØR - { 0, subsequent calls to READ for the current logical record are expected.
1, the current call is the last call for the current logical record. The file will be positioned to the beginning of the next logical record before returning.

M - If return to $$n_2$$ is given, the number of words actually read is stored in M. In no other case are the contents of M changed.

Whenever return to $$n_2$$ is given, the file is positioned to the beginning of the next logical record regardless of the setting of EØR.

A return to $$n_1$$ is possible only when a call to READ is given when the file is positioned at the beginning of a logical record.

3.4.5.4 Method

READ stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to perform the actual processing of the call.

3.4.6 FWDREC (Forward Space One Logical Record).

3.4.6.1 Entry Point: FWDREC.

3.4.6.2 Purpose

To position the requested file forward one logical record.

3.4.6.3 Calling Sequence

CALL FWDREC($n,NAME)

n - FØRTRAN statement number defining the return to be taken in the event an end-of-file is encountered.

NAME - GINØ file name of data block to be positioned forward (see section 1.6.4.1).

This call will always position the file to the beginning of the next logical record unless an end-of-file is encountered.

3.4.6.4 Method

FWDREC stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to process the call.

3.4.7 BCKREC (Backspace One Logical Record).

3.4.7.1 Entry Point: BCKREC.

3.4.7.2 Purpose

To position the requested file backward one logical record.

3.4.7.3 Calling Sequence

CALL BCKREC (NAME)

NAME - GINØ file name of data block to be positioned backward (see section 1.6.4.1).

If the file is positioned in the middle of a logical record, the file is repositioned to the beginning of that record. Otherwise, the file is positioned to the beginning of the previous logical record.

If the file is positioned at the beginning of file, no operation occurs and a normal return is given.

3.4.7.4 Method

BCKREC stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to process the call.

3.4.8 REWIND (Position File to the Load Point).

3.4.8.1 Entry Point: REWIND

3.4.8.2 Purpose

To rewind the requested file.

3.4.8.3 Calling Sequence

```
CALL REWIND(NAME)
```

NAME - GINØ file name of the data block to be rewound (see section 1.6.4.1).

Rewind given for an output file has the effect of erasing any data which has been written on the file.

3.4.8.4 Method

REWIND stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to process the call.

3.4.9 EØF (Write an End-of-File).

3.4.9.1 Entry Point: EØF.

3.4.9.2 Purpose

To write an end-of-file on the requested file.

3.4.9.3 Calling Sequence

CALL EØF(NAME)

NAME - GINØ file name of data block on which end-of-file is to be written (see section 1.6.4.1.)

The file must be open to write at the time of this call.

3.4.9.4 Method

EØF stores parameters in /GINØX/ and then calls XGINØ which in turn calls GINØ to process the call.

3.4.10 SKPFIL (Skip Files Forward or Backward).

3.4.10.1 Entry Point: SKPFIL.

3.4.10.2 Purpose

To position the requested file forward or backward a stated number of files.

3.4.10.3 Calling Sequence

CALL SKPFIL(NAME,N)

NAME - GINØ file name of the data block to be repositioned (see section 1.6.4.1).

N - The number of files to be skipped. N > 0 means forward skip, N < 0 means backward skip, N = 0 means no operation - integer - input.

Notes:

1. Following a forward skip, the file is positioned at the beginning of the first logical record (i.e. immediately after the end-of-file mark).

2. Following a backward skip, the file is positioned immediately in front of the end-of-file mark (or at the beginning-of-unit).

3. Request to skip backward from the beginning-of-unit is ignored and the file remains positioned at the beginning-of-unit.

4. SKPFIL backward on a file opened to write has the effect of "erasing" file(s) written.

3.4.10.4 Method

SKPFIL stores parameters in /GINØX/ and calls XGINØ which in turn calls GINØ to process the call.

3.4.11 XGINØ (GINØ Utility Routine).

3.4.11.1 Entry Point: XGINØ.

3.4.11.2 Purpose

To convert the GINØ file name to a unit number, retrieve the buffer assigned to the file and call GINØ.

3.4.11.3 Calling Sequence

CALL XGINØ(n_1,n_2,A,M)

CØMMØN/GINØX/LGINØX,FILEX,EØR,ØP,ENTRY,LSTNAM,N,NAME,NTAPE,XYZ(2),UNITAB(75),BUFADD(75)

ENTRY = { 1, call from subroutine ØPEN
2, call from subroutine WRITE
3, call from subroutine READ
4, call from subroutine CLØSE
5, call from subroutine BCKREC
6, call from subroutine FWDREC
7, call from subroutine SKPFIL
8, call from subroutine EØF
9, call from subroutine REWIND } integer - input

NAME - GINØ file name of data block for which activity is requested - integer - input.

FILEX - Unit number to which NAME is assigned - integer - output.

LSTNAM - On entry to XGINØ, GINØ name from previous call. On exit from XGINØ, LSTNAM = NAME - integer - input and output.

NTAPE = { 0, file does not reside on tape
1, file resides on tape } integer - output.

n_1 - { if ENTRY = 1 or 4, FØRTRAN statement number defining return in the event NAME is not in FIST.
if ENTRY = 3 or 6, FØRTRAN statement number defining return in the event an end-of-file is encountered.

n_2 - If ENTRY = 3, FØRTRAN statement number defining end-of-logical-record prior to completion of requested read.

A - If ENTRY = 2 or 3, A is the user block (from/to) which data words are written/read.

M - If ENTRY = 3 and return to n_2 is given, M = number of words read - integer - output.

3.4.11.4 Method

The FIST is searched for a name match. If found, the pointer to FIAT is used to pick up the unit number and tape flag. If not found, a non-standard return is given (ENTRY = 1 or 4) or a fatal message is generated. The address of the buffer assigned to the file is picked up and GINØ is called to execute the requested operation.

3.4.11.5 Design Requirements

XGINØ is designed as an integral part of the GINØ collection of routines for use only by ØPEN, READ, WRITE, etc.

The BUFADD table must be initialized to zero prior to the first call in a NASTRAN execution.

3.4.11.6 Diagnostic Messages

The following system fatal errors may be issued by XGINØ:

3010

3021

3.4.12 GINØ (General Input/Output Routine).

3.4.12.1 Entry Point: GINØ.

3.4.12.2 Purpose

To provide general purpose Input/Output services to higher level routines (READ, WRITE, etc.) in the NASTRAN program.

3.4.12.3 Calling Sequence

CALL GINØ(n_1,n_2,BUFF,A,M)

CØMMØN/GINØX/LGINØX,FILEX,EØR,ØP,ENTRY,LSTNAM,N,NAME,NTAPE,XYZ(2),UNITAB(75),BUFADD(75)

ENTRY = { 1, ØPEN Operation; 2, WRITE Operation; 3, READ Operation; 4, CLØSE Operation; 5, BCKREC Operation; 6, FWDREC Operation; 7, SKPFIL Operation; 8, EØF Operation; 9, REWIND Operation } Input, integer

FILEX - Unit number of file - integer - input.

EØR - End-of-record flag (see READ, WRITE) - integer - input.

ØP - Operation code (see ØPEN, CLØSE) - integer - input.

N - Number of words to write/read or number of files to skip (see WRITE, READ, SKPFIL) - integer - input.

BUFF - Address of buffer assigned to FILEX.

n_1 - FØRTRAN statement number defining return in the event an end-of-file is encountered (READ and FWDREC operations only).

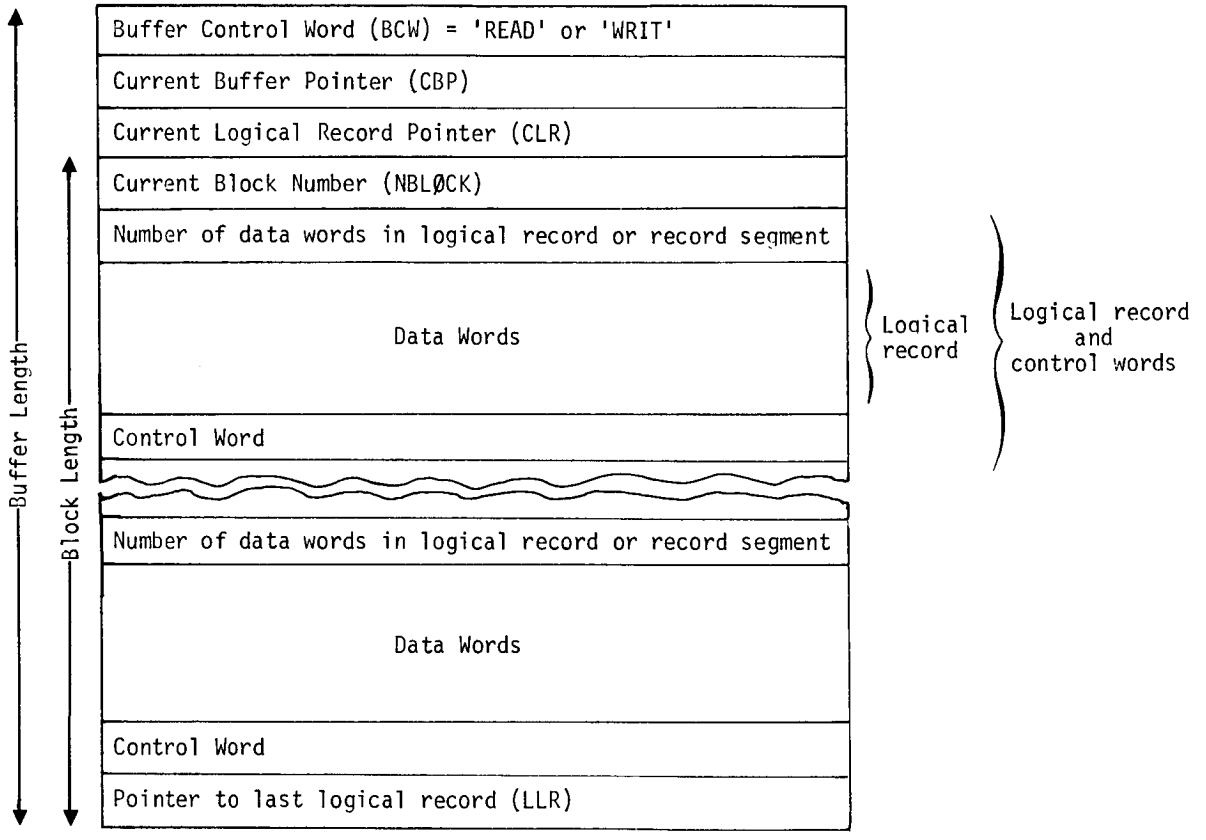
n_2 - FØRTRAN statement number defining return in the event an end-of-record is encountered prior to transmitting the requested number of words (READ operations only).

A - User block (see WRITE, READ).

M - Number of words actually read if end-of-record encountered and return to n_2 is given (see READ) - integer - output.

3.4.12.4 Method

GINØ blocks all logical records into fixed length physical records (blocks) for writing and reading. A description of the GINØ buffer follows:



Control word = 4*K + 2*F2 + F1 where

F1 = 1 indicates continued record

F2 = 0 indicates last segment of continued record

if F1 = 0, K = number of words in logical record

if F2 = 1, K = 65536*(Block No.) + CLR of 1st segment of logical record

Processing of each operation takes place as follows:

1. ØPEN. If a rewind is requested, the file is rewound and the first three words of the buffer are initialized followed by a return. Otherwise, the current file position is retrieved from UNITAB. If the file is logically between blocks, action occurs as above. Otherwise, the next block is read and the pointer to the current logical record is restored. If the block read is not the expected block, a recovery attempt is made.

2. WRITE. For the first call to write in a logical record, NBLØCK and CLR are saved in UNITAB. User data is transferred to the buffer. If the buffer is filled, a control word indicating continuation is placed, the block is written and the logical record is continued in the next block. After data transfer to the buffer, EØR is tested. If on, a control word is placed in the buffer and pointers are moved to the beginning of a new logical record.

3. READ. If the buffer is empty, the next block on the file is read. If positioned at the beginning of a logical record, a test for logical end-of-file is made. If on, return to n_1 is given. Otherwise data is transferred from the buffer to the user area. If the logical end-of-record is encountered before the requested number of words have been transmitted, M is set with the number of words read, and return to n_2 is given. If the logical record is continued to the next block, the next block is read. After the transfer of data is complete, EØR is tested. If on, pointers are moved to the beginning of the next logical record.

4. CLØSE. If the file was opened to read, ØP is tested. If ØP = 1, the file is rewound. If ØP ≠ 1, the file is backspaced one block unless the file is logically between blocks. In either case, the logical position of the file (NBLØCK and CLR) is saved in UNITAB, BCW is set to zero and return is made. If the file was opened to write and CBP ≠ CLR, control words for the last logical record are stored in the buffer. If ØP = 1 or 3, a logical end-of-file is placed. The current block is written on the file. If ØP = 1, the file is rewound, otherwise the file is backspaced one block. The logical position of the file is saved in UNITAB, BCW is set to zero and return is made.

5. BCKREC. If the buffer in core is empty, the file is backspaced one block, the block is read and LLR is used to set the pointers to the last logical record in the block. If the file is logically positioned in the middle of a logical record, pointers are reset to the beginning of a logical record. If the file is positioned at the beginning of a logical record, pointers are reset to the beginning of the previous logical record.

6. FWDREC. N is set to zero and EØR to 1 and the code in the READ portion of GINØ is used to position the file at the beginning of the next logical record.

7. SKPFIL. If a forward skip is requested, logical records are skipped until a logical end-of-file is encountered. This is repeated until the number of requested files has been skipped.

If a backward skip is requested, the code in the BCKREC portion of GINØ is used to position backwards one logical record. A test for load point is made. If yes, return is made. Otherwise, a logical end-of-file test is made. If no, the BCKREC is repeated. If yes, a test for number of requested files is made. If yes, return is given. Otherwise, the process is repeated.

8. EØF. If the file was not opened to write, an error message is generated. If CBP ≠ CLR, control words are placed to "close" the last logical record. A logical end-of-file is placed in the buffer. Return is made.

9. REWIND. The file is rewound, pointers are reset and return is given.

3.4.12.5 Design Requirements

1. GINØ is designed as an integral part of the GINØ collection of routines and is to be called only by XGINØ.

2. Since GINØ "remembers" the position of files when they are closed, any activity on a file outside of GINØ will likely be fatal.

3. Because of the packing used in the control word, the following maximums apply:

Max. number of blocks written on one file = $2^k - 1$ where k = number of bits in the computer word - 18.

Max. buffer size = 65535 words.

4. The actual contents of the GINØ buffer are machine dependent. See Section 5 for details.

3.4.12.6 Diagnostic Messages

The following system fatal messages may be issued by GINØ:

3009

3029

3048

3049

3.4.12.7 Information Message

GINØ RECØVERY ATTEMPT ØN DATA BLØCK _____. EXPECTED BLØCK NØ. = _____. ACTUAL BLØCK NØ. = _____.

This message is issued prior to Message 3049. GINØ attempts to reposition the file. If the attempt fails, Message 3049 is issued, otherwise the problem proceeds.

3.4.13 ØPNCØR (Transmit Logical Records To/From Core Storage).

3.4.13.1 Entry Points: ØPNCØR, WRTCØR, RDCØR.

3.4.13.2 Purpose

To simulate the GINØ WRITE and READ calls providing the capability to write logical records of data in core storage and read logical records from core storage.

3.4.13.3 Calling Sequence

CALL ØPNCØR(BLØCK)

BLØCK - An array whose dimension is sufficient to hold a logical record to be written or read.

CALL WRTCØR(BLØCK,A,N,EØR)

BLØCK - The array where the logical record is to be written.

A - An array containing the data words to be written.

N - The number of data words to be written from A.

EØR - $\begin{cases} = 0, \text{ additional data will be written in the logical record via subsequent calls to WRTCØR.} \\ \neq 0, \text{ the current call is that last call for the current logical record.} \end{cases}$

CALL RDCØR($\$n_1$,$\$n_2$,BLØCK,A,N,EØR,M)

n_1 - FØRTRAN statement number defining the return taken in the event an end-of-file is encountered. This return is not possible from RDCØR but is provided in the calling sequence for compatibility with READ.

n_2 - FØRTRAN statement number defining the return taken in the event that the number of words requested to be read is not available in the record. In this case, M words are read and transmitted and the value M is returned to the user.

BLØCK - The array where the logical record is stored.

A - An array where the requested data words from the record will be stored.

N - The number of data words to be read.

EØR - $\begin{cases} = 0, \text{ more data is to be read from the record via subsequent calls to RDCØR.} \\ \neq 0, \text{ the current call is the last call for the current logical record. Any remaining words in the logical record are to be skipped.} \end{cases}$

M - The number of words actually read in the event return to n_2 is taken.

The number of words available at BLØCK must be equal to (or greater than) the number of words in the logical record plus two.

ØPNCØR initializes a word pointer stored at BLØCK(1) to 1 and has no other function. The user may desire to perform this function himself with the statement BLØCK(1) = 1. This function must be accomplished prior to the first call to WRTCØR or RDCØR for each logical record.

3.4.13.4 Method

ØPNCØR. BLØCK(1) is set to one and return is made.

WRTCØR. The current pointer stored at BLØCK(1) is picked up. N words are transmitted from A to BLØCK beginning at the current pointer plus one. If EØR = 0, the new pointer is stored and return made. Otherwise, an end-of-record flag is stored in BLØCK following the last word written. The pointer (pointing to the flag) is stored and return made.

RDCØR. The current pointer is picked up from BLØCK(1). Words are transmitted from BLØCK beginning at the current pointer plus one to A until (1) the end-of-record flag is encountered in which case the actual number of words transmitted is stored in M and RETURN 2 is given, or (2) N words have been transmitted. If EØR = 0, the new pointer is stored and return is made. If EØR ≠ 0, BLØCK is searched until the flag is found, the pointer (pointing immediately prior to the flag) is saved and return is made.

3.4.13.5 Design Requirements

The flag value must be unique. Its value = (-16777215) must not be one of the data words written.

3.4.14 GØPEN (Short Form for Subroutine ØPEN With Header Record Processing).

3.4.14.1 Entry Point: GØPEN.

3.4.14.2 Purpose

To provide a short form (without the non-standard return of subroutine ØPEN) for opening a GINØ file, and to write a two-word header record if the data block is opened as output with rewind or to skip the header record if the data block is opened as input with rewind.

3.4.14.3 Calling Sequence

```
CALL GØPEN(FILE,BUFFER,ØPT)
```

where:

FILE = GINØ file name (see section 1.6.4.1).

BUFFER = GINØ buffer location.

ØPT = any of the open options permitted by subroutine ØPEN (see section 3.4.2).

3.4.14.4 Method

Open the file (subroutine ØPEN). If ØPT = input with rewind (0), skip the first record of the data block. If ØPT = output with rewind (1), write the two word BCD name of the data block as returned by subroutine FNAME.

3.4.14.5 Design Requirements

The data block must exist (must not be purged). If ØPT = input with rewind (0), the first record of the data block must be at least two words long. Subroutines used: ØPEN, READ, WRITE, FNAME, MESAGE.

3.4.14.6 Diagnostic Messages

If the data block is purged or if an end-of-file or end-of-record condition is encountered when reading the data block, subroutine MESAGE will be called with internal message numbers 1, 2, or 3, respectively (external message numbers are 3001, 3002 and 3003).

3.4.15 FREAD (Short Form for Subroutine READ).

3.4.15.1 Entry Point: FREAD.

3.4.15.2 Purpose

To provide a short form (without the non-standard returns of subroutine READ) of reading a GINØ file.

3.4.15.3 Calling Sequence

```
CALL FREAD(FILE,BLØCK,N,EØR)
```

where:

FILE = GINØ file name (see section 1.6.4.1).

BLØCK= array into which N items are to be read.

N = number of items to be read.

EØR = any end of record option permitted by subroutine READ (see section 3.4.5).

3.4.15.4 Method

Read the N items from FILE into BLØCK. If subroutine READ returns an end-of-file or end-of-record condition, subroutine MESAGE is called with a fatal error condition.

3.4.15.5 Design Requirements

In addition to those imposed by READ, there must be N items remaining in the record to be read. Subroutines used: READ, MESAGE.

3.4.15.6 Diagnostic Messages

Subroutine MESAGE may be called with internal message number 2 or 3 (external message numbers 3002,3003).

3.4.16 WRTTRL (Write Trailer).

3.4.16.1 Entry Points: WRTTRL, RDTRL.

3.4.16.2 Purpose

WRTTRL will pack six words of trailer information into three words and store them in the FIAT.

RDTRL will retrieve and unpack the trailer information.

3.4.16.3 Calling Sequence

CALL WRTTRL(FILBLK)

FILBLK(1) - GINØ file name (see section 1.6.4.1).

FILBLK(2-7) - Trailer information to be stored.

CALL RDTRL(FILBLK)

FILBLK(1) - GINØ file name.

FILBLK(2-7) - Storage space for trailer information.

3.4.16.4 Method

The index into the FIAT for the specified file is located in the FIST. The three packed words are stored in or retrieved from the FIAT. The information is also stored for all files equivalenced to the GINØ file name. For RDTRL, if the file is purged, FILBLK(1) is set negative. If the file is a matrix, word 7 is converted to a density (10000 = 100% dense). Matrix trailers can be displayed as they are written by activating DIAG 8.

3.4.16.5 Design Requirements

Each word of trailer information is assumed to be a positive integer less than $2^{16}-1$. Trailers may not be written on GINØ files 101-199.

3.4.16.6 Diagnostic Messages

If the file did not exist in the FIST when WRTTRL was called, fatal error 3011 occurs.

3.4.17 FNAME (File Name).

3.4.17.1 Entry Point: FNAME.

3.4.17.2 Purpose

Given a GINØ file name, FNAME returns the two BCD words which describe the data block.

3.4.17.3 Calling Sequence

CALL FNAME(FILE,NAME)

FILE - GINØ file name (see section 1.6.4.1).

NAME(2) - Storage for the two BCD words.

3.4.17.4 Method

The GINØ file name is first located in the FIST. The index in the FIST is used to find the BCD descriptors in the FIAT. If the file does not exist in the FIST, "^(NØNE)^" is returned as the two words, ^ indicating a BCD blank.

3.4.18 CLSTAB (Close a GINØ File and Write a Non-zero Trailer).

3.4.18.1 Entry Point: CLSTAB.

3.4.18.2 Purpose

To close a GINØ file and generate a table trailer by calling WRTTRL.

3.4.18.3 Calling Sequence

CALL CLSTAB(FILE,ØPT)

where:

FILE = GINØ file number - integer - input.

ØPT = any close option permitted by subroutine CLØSE (see section 3.4.4) - integer - input.

3.4.18.4 Method

CALL CLØSE(FILE,ØPT)

Generate the table control block, ITABCB:

```
ITABCB(1) = FILE
ITABCB(7) = 1
DØ 10 I   = 2,6
10 ITABCB(I) = 0
```

CALL WRTTRL (ITABCB).

3.4.18.5 Design Requirements

Same as those for subroutines CLØSE and WRTTRL. Subroutines used: CLØSE, WRTTRL.

3.4.19 XRCARD (Executive Free-Field Card Data Conversion Routine)

3.4.19.1 Entry Point: XRCARD.

3.4.19.2 Purpose

To interpret NASTRAN free-field card input data as follows:

1. Identify BCD alpha and numeric data fields as they are converted and placed in the user's buffer;
2. Flag and output special data field delimiters;
3. Convert BCD numeric fields to binary integer or binary floating point;
4. Indicate when the data extends beyond one 72 column card.

3.4.19.3 Calling Sequence

```
CALL XRCARD(ØUTBUF,L,INBUF)
```

Where:

ØUTBUF = The buffer which is to contain the converted card image.

L = The length of ØUTBUF available to XRCARD.

INBUF = The buffer containing the card image to be converted.

3.4.19.4 Method

XRCARD's design is based on the necessity of having to function on a variety of computing machines having a variety of computer word structures, and a variety of differences in hollerith handling imposed by differing FØRTRAN compilers.

XRCARD analyzes the twenty hollerith words input through INBUF as follows:

Data Field Delimiters

Type A:

The following symbols signify the end of an alpha field or numeric field on the card. As these symbols are encountered, they will be flagged and placed in the output buffer to aid the user in identifying the data.

(LEFT PAREN
/ SLASH
= EQUAL

Type B:

The following symbols are identical to those listed above except that the symbol is not flagged or placed in the output buffer:

, COMMA

) RIGHT PAREN

When successive type A or type B delimiters are encountered, a null field indication (two BCD blank words) is output. A null field is generated for each successive delimiter. A null field is also generated when a type A or type B delimiter is followed by a $ indicating the end of data condition.

Type C:

The following symbol is identical to the COMMA except that no null field indication is output when they are encountered in succession.

∧ BLANK

End of Data Indication

There are three means by which end-of-data may be specified on the card:

- The last data field ends in column 72, or is followed by blanks out through column 72;
- $ is encountered, after which comments may be included out to column 80; or
- Continuation cards ending in (, /, = or , will result in a continuation flag (0 mode word).

Format of Output Data

A mode word, N, is placed in the output buffer to distinguish between BCD data and numeric data.

Numeric Mode Word: A new mode word is output each time a numeric field is converted and output. (All numeric mode words are negative).

N = -1 integer data (1 data word)

= -2 floating point single precision (1 data word)

= -4 floating point double precision (2 data words)

N indicates the type of numeric data and where to look for the next mode word.

Alpha Mode Word: When processing alpha data, only one mode word is output for successive alpha fields, i.e., an alpha mode word will never follow another alpha mode word.

N = The number of successive alpha fields encountered on the card. Each alpha field consists of two 4-character computer words (left adjusted). Thus N can be used to compute the location of the next mode word.

The type A delimiters are output as alpha data and are 'covered' by the alpha mode word. Since data output in the alpha mode must consists of two words a type A delimiter will appear as:

Word 1 = Delimiter flag, all bits of the word are on.

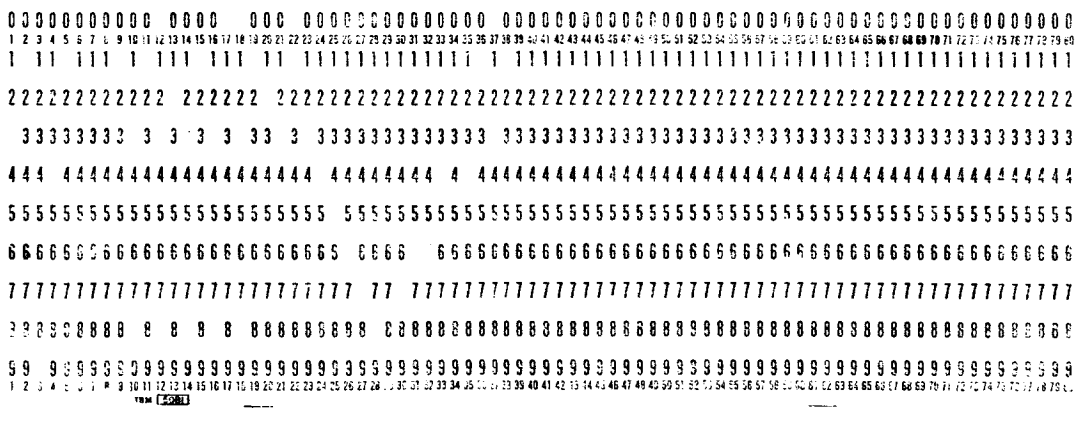
Word 2 = BCD delimiter, left adjusted, followed by BCD blanks.

End-of-Data: The end-of-data flag is placed last in the output buffer and appears in place of an expected mode word. There are two end-of-data flags:

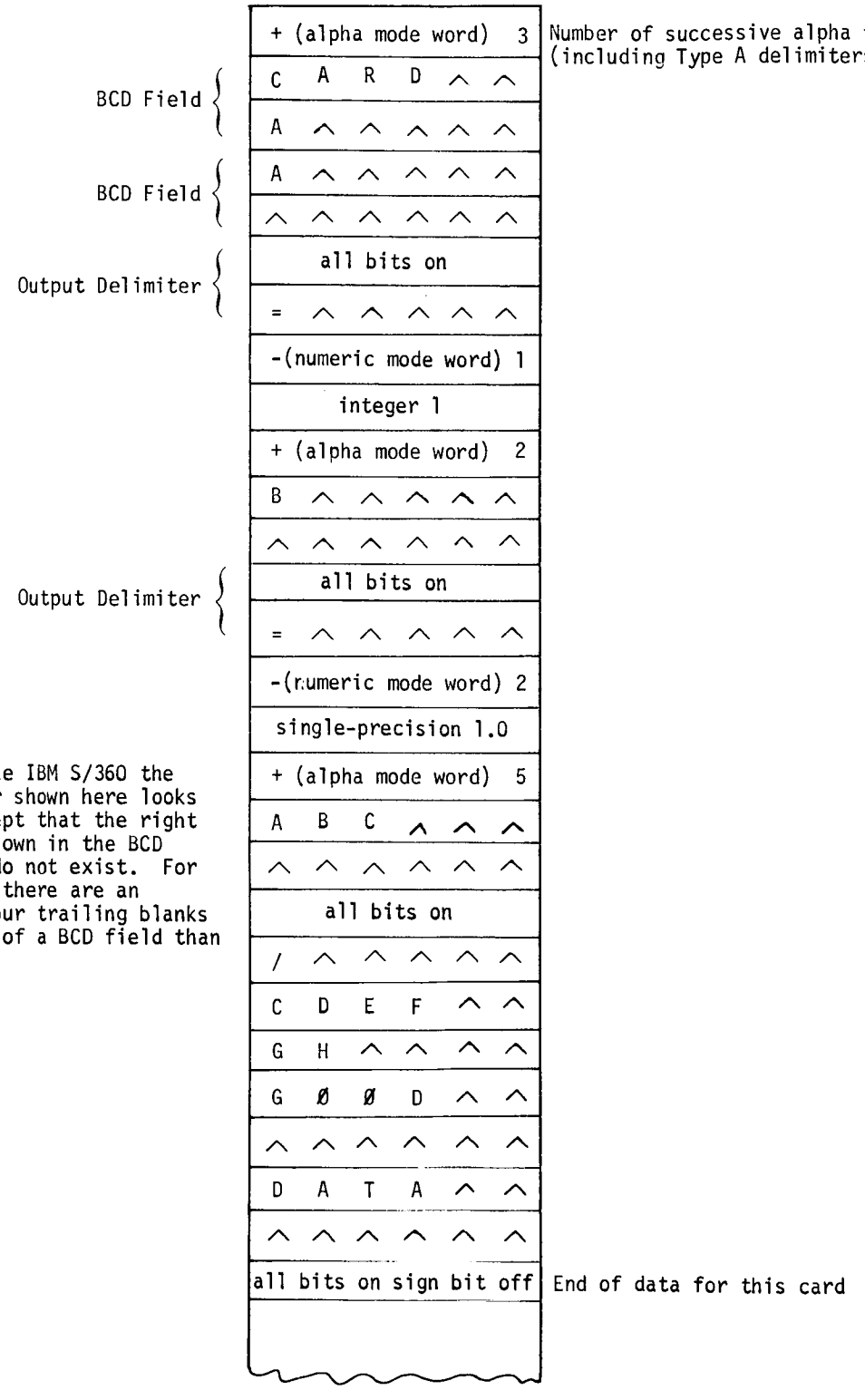
- A word with all bits off, indicating that more data is to follow on a continuation card.
- A word with all bits on except for the sign, indicating that no more data is to follow for this card type.

Sample Input Card

```
CARDA   A=1,B=1.0,ABC/CDEFGH GOOD DATA
```



Resulting Output Buffer for IBM 7094 or Univac 1108



NOTE: For the IBM S/360 the output buffer shown here looks the same except that the right two blanks shown in the BCD fields here do not exist. For the CDC 6600 there are an additional four trailing blanks in each word of a BCD field than shown here.

^ Indicates blank.

3.4.19.5 Design Requirements

An alpha field must be eight characters or less. Long alpha fields will be truncated to eight characters.

All data must be placed in card columns 1-72.

A data field may not be split between two cards.

The specification of all numeric data fields must conform to FØRTRAN IV standards.

If an error condition is encountered, e.g., data bad, XRCARD will write a message, turn on the NØGØ flag in /SYSTEM/, set the first word of ØUTBUF = 0, and make a normal return to the calling program.

3.4.20 RCARD (Fixed Field Card Data Conversion Routine).

3.4.20.1 Entry Point: RCARD.

3.4.20.2 Purpose

To interpret NASTRAN fixed-field (bulk data) card input as follows:

- Identify BCD alpha and numeric data fields as they are converted and placed in the users buffer; and

- Convert BCD numeric fields to binary integer or binary floating point.

3.4.20.3 Calling Sequence

CALL RCARD(ØUTBUF,FRMTBF,NFLAG,INBUF)

Where:

ØUTBUF = The buffer which is to contain the converted card image.

FRMTBF = A buffer which contains identification flags for the converted data in ØUTBUF.

NFLAG = Contains number of words returned in ØUTBUF.

INBUF = The buffer containing the card image to be converted.

Definition of Data Identification Flags Placed in FRMTBF

0 = output for a blank data field.

1 = output for an integer field.

2 = output for a floating point field.

3 = output for a BCD field.

4 = output for a double precision floating point field.

-1 = error.

3.4.20.4 Method

RCARD's design is based on the necessity of having to function on a variety of computing machines having a variety of computer word structures, and a variety of differences in Hollerith handling imposed by differing FØRTRAN compilers.

Twenty 4-Hollerith words are received by RCARD on any particular call to RCARD. RCARD first determines from field 1 (words 1 and 2) if the data card is a continuation card, and whether the

fields are single (2 words each) or double (4 words each) in length. Fields 2 through 9 (for single field cards) or 2 through 5 (for double field cards) are then considered one at a time. No consideration is made for the last field of any card (words 19 and 20).

3.4.20.5 Design Requirements

1. All BCD fields must begin with an alphabetic character.

2. All BCD fields are defined to be eight characters in length. Names with less than eight characters will be filled with BCD blanks.

3. When placed in the user output buffer, each BCD field will be divided into two four-character words (left adjusted) and stored in two successive locations of the output buffer. The remainder of the words is filled with BCD blanks.

4. Special characters are not to be used as part of a BCD field except for * and + in field 1 (column 1) which indicate a double field or single field (respectively) continuation card.

5. The data fields will be stored successively in the users output buffer as they are encountered in scanning the card image from left to right. The number of output core locations required per field type varies:

   a. Integer field = 1 core word (right adjusted).

   b. BCD field = 2 core words.

   c. Real single precision = 1 core word.

   d. Real double precision = 2 core words.

   e. Blank field = 1 core word (integer 0).

6. The card type field (field 1) of a continuation card will not be passed along to the user. Two zero words will replace the ID field in the output buffer. Thus the user can easily distinguish the difference between a continuation card and a new card type.

7. A check for bulk data card types SEQGP and SEQEP is made by RCARD. Fields 3, 5, 7, and 9 of these card types are processed by a special conversion.

The input within these special fields will be similar to the Dewey decimal notation and consists of a multiple digit integer and up to three single digit sub-integers; e.g., (354.1.2) and (267.5). The special fields will be converted to a single integer by dropping any decimal points and appending a number of zeros equal to three minus the number of decimal points in the original number; e.g., (354120) and (267500).

8. RCARD does not know the length of the users output buffer, therefore, no check is made for exceeding the length of the buffer. However, the number of data words placed in the output buffer will be specified in NFLAG.

9. Field 10 will not be passed along to the user.

3.4.20.6 Diagnostic Messages

Fields appearing to be incorrect to RCARD will cause a diagnostic to be written on the system output file followed by a card format heading, a card image echo, and an underlining of the field in question. Also, the /SYSTEM/ NØGØ flag is set .TRUE., a zero is placed in the output buffer for the field, and a -1 is placed in the format buffer for the field. RCARD will print diagnostics for all fields appearing incorrect and make a normal return.

3.4.21 TAPBIT (Tape Bit Test).

3.4.21.1 Entry Point: TAPBIT.

3.4.21.2 Purpose

To examine the tape bit for a permanent GINØ file to determine the existence of a physical tape for that file.

3.4.21.3 Calling Sequence

```
IF (TAPBIT(FILE)) GØ TØ ...
```

FILE is the GINØ file name (one of 'PØØL', 'ØPTP, 'NPTP', 'UMF ', 'NUMF', 'PLT1', 'PLT2', 'INPT').

3.4.21.4 Method

The permanent FIST is searched and the tape bit in the corresponding FIAT entry is examined. If the bit is on (indicating the presence of a physical tape), TAPBIT will be set .TRUE.. Otherwise it will be set .FALSE..

3.4.21.5 Design Requirements

The type of TAPBIT must be declared LØGICAL.

3.4.21.6 Diagnostic Messages

A fatal call to MESAGE occurs if a GINØ file name other than those listed is used.

3.4.22 PEXIT (Problem Exit).

3.4.22.1 Entry Point: PEXIT.

3.4.22.2 Purpose

To terminate the program.

3.4.22.3 Calling Sequence

CALL PEXIT.

3.4.22.4 Method

The diagnostic message queue is checked and if not empty the message writer MSGWRT is called. If the checkpoint flag is set a card is punched indicating the end of the restart checkpoint dictionary. The system output buffers are flushed and then the job is terminated.

3.4.22.5 Design Requirements

PEXIT must have access to the FØRTRAN I/Ø routines.

PEXIT should not be called by module writers. Termination should be via a call to MESAGE (i.e., CALL MESAGE(-61,0, NAME)).

3.4.23 TMTØGØ (Time-To-Go).

3.4.23.1 Entry Point: TMTØGØ.

3.4.23.2 Purpose

Computes the running time remaining for this NASTRAN problem.

3.4.23.3 Calling Sequence

CALL TMTØGØ (TIME)

TIME = Remaining time in integer seconds.

3.4.23.4 Method

During NASTRAN problem initialization, one system cell is set to the problem starting time (PSTART) while another is set to the maximum running time (MXTIME) contained on the Executive Control Deck TIME card. TIME-TØ-GØ is then found by reading the clock (NØW) and solving the following:

TIME-TØ-GØ = MXTIME - (NØW - PSTART).

The CPU clock is utilized on all machines except the IBM 7094 where none is available.

3.4.24 PAGE (Page Heading).

3.4.24.1 Entry Points: PAGE, PAGE1, PAGE2

3.4.24.2 Purpose

To provide a standard page heading for NASTRAN output.

3.4.24.3 Calling Sequence

```
CALL PAGE
CALL PAGE1
CALL PAGE2(N)

CØMMØN/SYSTEM/XXX,ØTPE,SPACE(6),IPAGE,LINE,ITLINE,MAXLIN,DATE(3)
```

ØTPE - System output unit - integer.

IPAGE - Current page number - increased by 1 on each call to PAGE.

LINE - Number of data lines on previous page - LINE is set to zero by PAGE.

ITLINE - Total number of lines of printout in run - ITLINE = ITLINE + LINE.

MAXLIN - Maximum number of data lines allowed - if ITLINE > MAXLIN, PEXIT will be called.

DATE(3)- Today's date: month, day, year - integer.

N - Number of lines to be written - integer - input.

```
CØMMØN/ØUTPUT/TITLE(32),SUBTIT(32),LABEL(32),HEAD1(32),HEAD2(32),HEAD3(32)
```

3.4.24.4 Method

PAGE writes a standard 6 line heading from TITLE, SUBTIT, LABEL, HEAD1, HEAD2, HEAD3.

PAGE1 writes only the first 3 lines of a standard header.

PAGE2 restores the page if N lines will not fit on the current page.

3.4.24.5 Design Requirements

ITLINE must be less than MAXLIN. PAGE must have access to the FØRTRAN I/Ø routines.

3.4.25 MESAGE (Message).

3.4.25.1 Entry Point: MESAGE.

3.4.25.2 Purpose

To queue nonfatal messages during the execution of a module; and for fatal messages give a core dump (CALL PDUMP), print the message queue (CALL MSGWRT), and call PEXIT.

3.4.25.3 Calling Sequence

CALL MESAGE(NØ,PARM,NAME)

Where

NØ = Internal message number. NØ positive defines the message as nonfatal; NØ negative defines the message as fatal.

PARM = Parameter used in the printed message (usually the GINØ file number)

NAME(2) = Two words used in the printed message (usually two BCD words containing the name of the subroutine calling MESAGE).

3.4.25.4 Method

Non-fatal messages are queued in common block /MSGX/ until the maximum number is reached. All non-fatal messages after this are lost. When a fatal message is encountered, it is queued and appropriate action taken to terminate the run.

3.4.25.5 Design Requirements

The size of common block /MSGX/ limits the number of messages stored.

3.4.26 MSGWRT (Message Writer).

3.4.26.1 Entry Point: MSGWRT.

3.4.26.2 Purpose

To print NASTRAN error messages on the system output file.

3.4.26.3 Calling Sequence

```
CALL MSGWRT

COMMON/MSGX/N,M,MSG(4,10)
```

where:

N - is the total number of messages to be printed.

M - maximum number of messages that can be queued by subroutine MESAGE in the array MSG.

MSG - array where message parameters are queued.

MSG(1,I) - the internal message number of the I^{th} message.

MSG(2,I) - if $|MSG(1,I)| \neq 30$, MSG(2,I) is a GINO file number.
If $|MSG(1,I)| = 30$, then MSG(2,I) is an internal message number and USRMSG is called.

MSG(3,I), MSG(4,I) = parameters for the I^{th} message.

3.4.26.4 Method

The internal message number, M(1,I), if not equal to 30 in absolute value, is used by MSGWRT to print out the error message along with external message number, which is 3000 plus the internal message number. If the internal message number, M(1,I), is 30, subroutine USRMSG is called.

3.4.26.5 Design Requirements

External message numbers output by MSGWRT at present are 3001 through 3057.

MSGWRT is called only by MESAGE.

3.4.27 USRMSG (User Message Writer).

3.4.27.1 Entry Point: USRMSG.

3.4.27.2 Purpose

To print most NASTRAN user error messsges on the system output file.

3.4.27.3 Calling Sequence

```
CALL USRMSG(I)

COMMON/MSGX/N,M,MSG(4,10)
```

where:

I - Pointer into the MSG array.

N - Not used in USRMSG.

M - Not used in USRMSG.

MSG(1,I) - If |MSG(1,I)| = 30, MSGWRT will call USRMSG.

MSG(2,I) - Used by USRMSG as the internal message number.

MSG(3,I), MSG(4,I) - Parameters for the I^{th} message.

3.4.27.4 Method

USRMSG will print appropriate error message along with external message number, which is 2000 plus internal message number.

3.4.27.5 Design Requirements

External message numbers output by USRMSG at present are: 2001--2140.

USRMSG is called only by MSGWRT.

3.4.28 MATDUM (Matrix Dump (Print) Routine).

3.4.28.1 Entry Point: MATDUM.

3.4.28.2 Purpose

To print a general NASTRAN matrix.

3.4.28.3 Calling Sequence

CALL MATDUM(FILEA)

FILEA - Seven-word array (matrix control block) - integer

Word

1 GINØ name

2 Number of columns

3 Number of rows

4 Form of matrix

5 Type of matrix

6 Maximum number of non-zero terms in any column

7 Undefined

3.4.28.4 Method

The non-zero terms of each column are unpacked and printed.

If the matrix control block does not contain legal values the table printer (see section 3.4.29) is called.

3.4.28.5 Design Requirements

Open core at /TABPRX/.

MATDUM must hold the non-zero band of the matrix in this area.

Subroutine TABPRT and the FØRTRAN I/Ø routines must be available to MATDUM.

3.4.29 TABPRT (Table Printer).

3.4.29.1 Entry Point: TABPRT.

3.4.29.2 Purpose

To print any NASTRAN Data Block (especially tables).

3.4.29.3 Calling Sequence

CALL TABPRT(FILEN)

FILEN - GINØ name of data block - integer - input.

3.4.29.4 Method

Each word is read, identified as to type -- integer, BCD, or real number and printed 10 characters per word, 10 numbers per line. Note that the identification method varies from machine to machine and is not 100% certain, i.e., certain words may be misidentified.

3.4.29.5 Design Requirements

Open core at /TABPRX/.

Double precision numbers will not be correctly interpreted on the Univac 1108.

3.4.30 PRELØC (Position Data Block to Requested Record).

3.4.30.1 Entry Points: PRELØC, LØCATE.

3.4.30.2 Purpose

To provide a convenient means of locating data records in data blocks output by the Input File Processor (IFP).

3.4.30.3 Calling Sequence

CALL PRELØC($n,BUFF,NAME)

n - FØRTRAN statement number defining return taken in the event NAME is not in the FIST (i.e., data block is purged).

BUFF - An array whose dimension equals the contents of the first word of /SYSTEM/ plus one. Used as a GINØ buffer by PRELØC and LØCATE.

NAME - GINØ file name of data block to be read (integer).

CALL LØCATE($n,BUFF,ID,IDX)

n - FØRTRAN statement number defining return taken in the event that the requested record (defined by ID) is not present in the data block.

BUFF - The same BUFF assigned when PRELØC was called.

ID - The address of a two-word array. The first word is the integer record identification and the second word is the bit position in the trailer for the data block where the presence or absence of the record is defined.

IDX - The contents of the third word of the record found will be stored in IDX (internal card number generated by IFP).

Notes:

1. If the data block is not purged, PRELØC will open the file and skip the header record.

2. If the requested record is not present (as determined by the appropriate trailer bit), no I/Ø activity will occur. Otherwise, LØCATE will position the file to read the first data entry of the requested record (i.e., after the 3-word header for the record). See 2.3.2 for format of records and trailer.

3. If the user does not read all data in a record and he wishes to use LØCATE to find another record, he should use FWDREC to skip the remainder of the current record prior to calling LØCATE.

4. For optimum efficiency in processing a data block, the user should call LØCATE in the order in which the records appear on the data block, i.e. NASTRAN collating order.

3.4.30.4 Method

PRELØC stores NAME in BUFF(1) and then calls ØPEN using BUFF(2) as the buffer address. If the data block is purged, the non-standard return is given to the user. Otherwise, FWDREC is called to skip the header record and return is made to the user. LØCATE calls RDTRL to read the data block trailer. The bit position identified by ID(2) is tested using ANDF. If zero, the non-standard return is given. Otherwise, three words from the file are read. If the first word equals ID(1), IDX is set to the third word and return is made. Otherwise, the first word is saved and the remainder of the record is skipped. The first three words of each successive record are read and the test for match on first word is made until (1) an end-of-file occurs in which case the file is rewound, the header record skipped and the process is continued, (2) a match is found in which case IDX is set and return is given or (3) a match with the first record read is found in which case the record is skipped, a warning message is queued and the non-standard return is given.

3.4.30.5 Diagnostic Messages

The following messages may be issued by PRELØC:

2072

3002

3003

3.4.31 SØRT (Sort a Table).

3.4.31.1 Entry Point: SØRT.

3.4.31.2 Purpose

To sort a core contained table, or to sort a logical record from a specified input file, on a specified keyword in each entry.

3.4.31.3 Calling Sequences

To sort a core contained table:

CALL SØRT(0,0,NWDS,KEYWD,TABLE,NTABLE)

NWDS - The number of words in each entry of the table. Restriction: NWDS ≤ 20.

KEYWD - The word position within each entry on which the sort is to take place.

TABLE - Address where the table is stored.

NTABLE - Total number of words in the table (NTABLE must be an integral multiple of NWDS).

To sort a logical record:

CØMMØN/SETUP/NFILE(6),BUF

CALL SØRT(INPFL,ØUTFL,NWDS,KEYWD,BLØCK,NBLØCK)

NFILE - The first three words must be set by the user prior to CALL SØRT with the GINØ file names of three scratch files for use by SØRT. Upon return to the user, NFILE(6) will contain the GINØ file name of the file containing the sorted record.

BUF - If INPFL = ØUTFL, then BUF points to an area in BLØCK where a GINØ buffer is available for SØRT, i.e., BLØCK(BUF) is the buffer address. Restriction: BUF > NBLØCK.

INPFL - GINØ file name of data block containing the logical record to be sorted.

ØUTFL - GINØ file name of data block where the sorted record is to be written. If ØUTFL = 0, the sorted record will remain on NFILE(6).

NWDS - The number of words in each entry of the record. Restriction: NWDS ≤ 20.

KEYWD - Defined as above.

BLØCK - An area in core to be used by SØRT to perform the sort phase.

NBLØCK - The number of computer words available at BLØCK.

Notes:

1. INPFL must be opened and positioned to the logical record by the user prior to entry to SØRT. The file is not closed by SØRT.

2. If ØUTFL ≠ 0, this file must be opened and positioned by the user prior to entry to SØRT. The file is not closed by SØRT.

3. If INPFL = ØUTFL, the file is closed by SØRT, opened to write with rewind, and the sorted logical record is written as the first logical record on the file. The file is not closed by SØRT.

4. NFILE(6) is always closed with rewind.

3.4.31.4 Method

1. CØRE SØRT. The method used is a shuttle exchange or bubble sort which is optimum for data which is nearly in sort. The method is as follows:

a. The key words of two successive entries are compared. If currently in sort, the process is repeated. If not,

b. A search toward the beginning of the table is made to determine the position of the out-of-sort entry.

c. From this position, the table is shifted one entry and the out-of-sort entry is inserted at its proper position.

d. If the last pair of entries have not been analyzed, the process returns to step (a). Otherwise the sort is complete.

2. FILE SØRT. One GINØ buffer is allocated at the end of BLØCK and a scratch file is opened to write. As many entries as can be held in the remaining core in BLØCK are read and sorted using the algorithm above. The sorted data is written as a logical record on the scratch file. This process is repeated until all data in the input record has been read and the sorted

strings written on the scratch file. If only one such sort was required, the sort is complete except for copying onto ØUTFL if requested. Otherwise, an optimum distribution of sorted records on two scratch files is computed using a Fibonacci sequence. The sorted strings are redistributed between two scratch files and the merge phase is entered. The two scratch files are read one entry at a time, merged, and new sorted entries written on a third scratch file. Note that, using the Fibonacci sequence, one of the files containing sorted strings will have a greater number of strings (records) than the other. On each pass in the merge phase, the merge occurs until the file with fewer strings is exhausted. At this point, the merged file becomes the file with the larger number of sorted strings, the previous larger file becomes the file with the fewer strings, and the previous file with fewer strings (which was exhausted) becomes the file onto which the merged strings are written. The process continues until the sort is complete. The resulting sorted record is copied onto ØUTFL if requested.

3.4.31.5 Design Requirements

The number of words per entry may not exceed 20. (A change in the dimension of the local variable TEMP may be made to relax this restriction.)

The amount of core available at BLØCK must be at least one GINØ buffer plus 2*NWDS during the core sort phase and three GINØ buffers plus 2*NWDS during the merge phase.

The core table or logical record to be sorted must contain an integral number of entries.

3.4.31.6 Diagnostic Messages

The following messages may be issued by SØRT:

3001

3002

3008

3.4.32 GMMATD (General Matrix Multiply and Transpose - Double Precision).

3.4.32.1 Entry Point: GMMATD.

3.4.32.2 Purpose

To perform any one of the following matrix operations:

$$[A]\,[B] = [C] \tag{1}$$

$$[A]^T\,[B] = [C] \tag{2}$$

$$[A]\,[B]^T = [C] \tag{3}$$

$$[A]^T\,[B]^T = [C] \tag{4}$$

$$[A]\,[B] + [D] = [C] \tag{5}$$

$$[A]^T\,[B] + [D] = [C] \tag{6}$$

$$[A]\,[B]^T + [D] = [C] \tag{7}$$

$$[A]^T\,[B]^T + [D] = [C] \tag{8}$$

where [A], [B], [C], and [D] are real double precision matrices. This routine is used for small in-core matrices, in non-NASTRAN packed format, in such modules as SMA1, SMA2, SMA3 and DSMG1.

3.4.32.3 Calling Sequence

```
CALL GMMATD(A,IRØWA,ICØLA,MTA,B,IRØWB,ICØLB,MTB,C)
```

A - A real double precision matrix of IRØWA rows and ICØLA columns stored in the singly dimensioned double precision variable A.

N.B. A must be stored by rows. For example, if

$$[A] = \begin{bmatrix} 1.0 & 4.0 \\ 2.0 & 5.0 \\ 3.0 & 6.0 \end{bmatrix},$$

then the matrix must be stored in the FØRTRAN double precision array A as follows:

```
A(1) = 1.0
A(2) = 4.0
A(3) = 2.0
A(4) = 5.0
A(5) = 3.0
```

A(6) = 6.0

(A is input only).

IRØWA - number or rows of [A] - input.

ICØLA - number of columns of [A] - input.

MTA - Flag used to determine if [A] is to be transposed and to determine if the output matrix, [C], is to be zeroed out; that is, to determine if a matrix product only, of the form [A] [B] = [C], will be performed or if a product and (in effect) a sum, of the form [A] [B] + [D] = [C], will be performed.

1. If MTA = 0, then [A] is not transposed and hence either Equation (1) or (3) will be performed, depending upon MTB.

   If MTA = +1 then [A] is transposed and hence either Equation (2) or (4) will be performed, depending upon MTB.

   MTA is input only.

2. If MTA is less than zero, [C] is not zeroed out. Hence the routine, in this case, computes

   $[A][B] + [D] = [C]$ if MTA = -2 and MTB = 0.

   $[A][B]^T + [D] = [C]$ if MTA = -2 and MTB = 1.

   $[A]^T[B] + [D] = [C]$ if MTA = -1 and MTB = 0.

   $[A]^T[B]^T + [D] = [C]$ if MTA = -1 and MTB = 1.

   (see MTB definition below)

   where D is a real double precision matrix of IRØWA rows and ICØLB columns if MTA = -2 and D is ICØLA x ICØLB if MTA = -1. D must be stored row-wise at the location of C by the calling program.

B - real double precision matrix, stored row-wise. See comments for A above - input.

IRØWB - the number or rows of [B] - input.

ICØLB - the number of columns of [B] - input.

MTB - Transpose flag for [B]. If MTB = 0, [B] is not transposed. If MTB = 1, [B] is transposed. Note that MTA and MTB are independent and that only MTA controls whether or not

[C] will be zeroed out. MTB is input only.

C - real double precision matrix. Input (if MTA < 0) and output.

Examples on the use of the routine:

1. If [A] is 3x3 and [B] is 3x1 and [C] = [A] [B] is desired then:

   CALL GMMATD(A,3,3,0,B,3,1,0,C). [C] is 3x1.

2. If [A] is nx1 and [B] is nx1 and the dot product is desired ($[A]^T$ [B]) then:

   CALL GMMATD(A,N,1,1,B,N,1,0,C). [C] is 1x1, a scalar.

3. Compute [C] = $([X]\ [Y])^T$ where [X] is 5x4 and [Y] is 4x7:

   CALL GMMATD(Y,4,7,1,X,5,4,1,C). C is 7x5.

4. Compute D = [A] $[B]^T$ + [C] where [A], [B] and [C] are 3x3:

```
      DO 10 I = 1, 9
   10 D(I) = C(I)
      CALL GMMATD(A,3,3,-2,B,3,3,1,D).
```

3.4.32.4 Method

The first phase of the subroutine sets up integer loop limits which are functions of the two transpose flags. If MTA is not less than zero, the C array is zeroed out. Then the classical mathematical definitions of the above matrix products are carried out.

3.4.32.5 Design Requirements

The orders of the [A] and the [B] matrices in combination with the transpose flags must define a conformable matrix product.

3.4.32.6 Diagnostic Messages

The subroutine examines the tranpose flags in combination with the orders of the matrices to make sure that a conformable matrix product is defined by this input data. This test clearly is made for purposes of calling routine checkout only. No tests are made, nor can they be made, to insure that the calling routine has provided sufficient storage for arrays. If a conformable matrix product is not defined by the input arguments, fatal error message 2021 is printed.

3.4.33 GMMATS (General Matrix Multiply and Transpose - Single Precision).

3.4.33.1 Entry Point: GMMATS.

3.4.33.2 Purpose

To perform any one of the following matrix operations:

$$[A]\,[B] = [C] \tag{1}$$

$$[A]^T\,[B] = [C] \tag{2}$$

$$[A]\,[B]^T = [C] \tag{3}$$

$$[A]^T\,[B]^T = [C] \tag{4}$$

$$[A]\,[B] + [D] = [C] \tag{5}$$

$$[A]^T\,[B] + [D] = [C] \tag{6}$$

$$[A]\,[B]^T + [D] = [C] \tag{7}$$

$$[A]^T\,[B]^T + [D] = [C] \tag{8}$$

where [A], [B], [D] and [C] are real single precision matrices. This routine is used for small in-core matrices in non-NASTRAN packed format in such modules as SDR2 and PLA3 and in the utility routine PREMAT.

3.4.33.3 Calling Sequence

```
CALL GMMATS(A,IRØWA,ICØLA,MTA,B,IRØWB,ICØLB,MTB,C)
```

This routine is exactly the same as subroutine GMMATD except that GMMATD operates on real double precision matrices, while GMMATS operates on real single precision matrices. See subroutine description for GMMATD (see section 3.4.32) for details on subroutine arguments, method, design requirements and diagnostic messages.

3.4.34 INVERD (Double Precision In Core Inverse Routine).

3.4.34.1 Entry Point: INVERD.

3.4.34.2 Purpose

To compute the inverse of a real double precision matrix [A] and on option to solve the matrix equation [A] [X] = [B]. This routine is used to invert small in-core double precision matrices in non-NASTRAN packed format and is used as a utility routine in such modules as SMA1, SMA3 and DSMG1.

3.4.34.3 Calling Sequence

CALL INVERD (NDIM,A,N,B,M,DETERM,ISING,INDEX)

NDIM - The actual row dimension of the doubly subscripted arrays A and B in the calling program - integer - input.

A - The square matrix to be inverted. $[A]^{-1}$ upon return from INVERD is stored at A. Double precision - input and output

N - The order of the matrix being inverted (the size of the upper left hand corner actually being inverted). $N \leq NDIM$ - integer - input.

B - The column(s) of constants in the above equation. If [A] is to be inverted, then B is a dummy argument. The solution matrix [X] is returned at B. Double precision - input and output.

M - The number of columns of constants. If $M \leq 0$, $[A]^{-1}$ is computed - integer - input.

DETERM - The determinant of [A]. Double precision - output.

ISING - Singularity indicator. If [A] is non-singular, ISING is set to 1; if [A] is singular, ISING is set to 2 - integer - output.

INDEX - Doubly subscripted array of row dimension N and column dimension 3 used for the row and column interchanges - integer - internal working storage.

3.4.34.4 Method

The classical Gauss-Jordan method with full row and column interchanges is used. All arithmetic operations are double precision.

3.4.35 INVERS (Single Precision In Core Inverse Routine).

3.4.35.1 Entry Point: INVERS.

3.4.35.2 Purpose

To compute the inverse of a real single precision matrix [A] and on option to solve the matrix equation [A] [X] = [B]. This routine is used to invert small in-core single precision matrices in non-NASTRAN packed format and is used as a utility routine in such modules as SDR2.

3.4.35.3 Calling Sequence

CALL INVERS (NDIM,A,N,B,M,DETERM,ISING,INDEX)

This routine is exactly the same as subroutine INVERD except that INVERD operates on real double precision matrices, while INVERS operates on real single precision matrices. All arithmetic operations are single precision. DETERM is real single precision. See subroutine description for INVERD (see section 3.4.34) for details on subroutine arguments and method.

3.4.36 PREMAT (Material Property Utility).

3.4.36.1 Entry Points: PREMAT, MAT.

3.4.36.2 Purpose

To provide a utility routine for obtaining material properties used by structural element subroutines. The first entry point, PREMAT, is called once by a module for initialization purposes, and then MAT can be called by the module's element subroutines repeatedly to fetch required material properties.

3.4.36.3 Calling Sequence

CALL PREMAT (Z,ZZ,BFR,N1MAT,N2MAT,MPTF,DITF)

Z - Integer array of open core given to the subroutine to store the material properties and the direct input tables - input and output.

ZZ - Same address as Z. Used as real in this routine - input and output.

BFR - A GINØ buffer (plus one cell) used by subroutine PRELØC as a buffer - input only.

N1MAT - The length of open core, the Z array, given to PREMAT and MAT - integer - input only.

N2MAT - The length of open core used by PREMAT and MAT - integer - output only.

MPTF - GINØ file number of the Material Properties Table (MPT) data block - input only.

DITF - GINØ file number of the Direct Input Tables data block. If DITF is negative, the routine assumes that the calling module is a Piecewise Linear Analysis module which implies material properties cannot be temperature dependent and that MATS1 cards are to be read.

PREMAT uses the 10^{th} word of /SYSTEM/ which is the temperature set identification number for material properties chosen by the user in his Case Control Deck. PREMAT also uses /NAMES/ for various GINØ options.

CALL MAT (ELEMID)

ELEMID - Integer element identification number; used only for diagnostic messages (see below) - input and output.

COMMON/MATIN/MATID,INFLAG,TEMP,PLAARG,SINTH,COSTH

MATID - Material property identification number - integer - input.

INFLAG - Integer input flag which determines which sets of input data cards, MAT1, MAT2, or MAT3, the routine will search in order to find MATID. Also INFLAG determines in what format the output will be placed in the MATOUT common block. Currently INFLAG may assume the values 1 through 7 defined as follows:

INFLAG = 1 -- The material properties corresponding to the MATID are output in "MAT1" or isotropic material format (see /MATOUT/ below). One dimensional elements such as ROD, BAR, SHEAR etc. require isotropic materials. If the MATID is not found among all the MAT1 material cards read by PREMAT, a fatal error occurs.

INFLAG = 2 -- If INFLAG = 2, the material properties corresponding to the MATID are output in "MAT2" or anisotropic material format. Two-dimensional elements such as TRMEM, TRIA1, QDPLT, QUAD1 etc. may use isotropic or anisotropic materials. First, the routine will try to find the MATID among the MAT1 cards. If it is found among the MAT1 cards, the variables E (modulus of elasticity), ν (Poisson's ratio) and G (shear modulus) are used to construct the 3x3 symmetric matrix $[G_e]$ needed by two-dimensional elements, and the matrix is stored in /MATOUT/:

$$[G_e] = \begin{bmatrix} \frac{E}{1-\nu^2} & \frac{\nu E}{1-\nu^2} & 0 \\ \frac{\nu E}{1-\nu^2} & \frac{E}{1-\nu^2} & 0 \\ 0 & 0 & G \end{bmatrix}$$

If the MATID is not found among the MAT1 cards, the MAT2 cards are searched. If the MATID is not found among the MAT2 cards a fatal error occurs. If it is found, $[G_m]$, the 3x3 symmetric matrix input on the MAT2 card, is transformed by the matrix equation $[G_e] = [U]^T[G_m][U]$ and $\{\alpha\} = [V]\{\alpha_m\}$, where $\{\alpha_m\}$ is the temperature expansion coefficient vector input on a MAT2 card. [U] and [V] are functions of sin θ and cos θ (see SINTH and CØSTH below).

$$[U] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & \cos\theta\sin\theta \\ \sin^2\theta & \cos^2\theta & -\cos\theta\sin\theta \\ -2\cos\theta\sin\theta & 2\cos\theta\sin\theta & (\cos^2\theta-\sin^2\theta) \end{bmatrix}$$

$$[V] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & -\cos\theta\sin\theta \\ \sin^2\theta & \cos^2\theta & \cos\theta\sin\theta \\ 2\cos\theta\sin\theta & -2\cos\theta\sin\theta & (\cos^2\theta - \sin^2\theta) \end{bmatrix}$$

INFLAG = 3 -- If INFLAG = 3, it implies the inverse of the symmetric 2x2 transverse shear matrix J will be stored in locations 16, 17 and 18 of /MATØUT/. There are two cases: (1) the current MATID is not equal to the most recent MATID, MATIDØ, and (2) the current MATID is equal to the most recent MATID.

1. If the current MATID is not equal to the most recent material identification number (MATIDØ), the MAT1 cards are searched. If the MATID is found among the MAT1 cards, then locations 16,17 and 18 of /MATØUT/ are set to G, 0.0 and G respectively, where G is the shear modulus. If the MATID is not found among the MAT1 cards, the MAT2 cards are searched. If the MATID is not found among the MAT2 cards, a fatal error occurs. If it is found among the MAT2 cards, locations 16, 17 and 18 are set to zero.

2. The current MATID is equal to the most recent MATID. If INFLGØ, the most recent INFLAG is not 2, this is the same as case (1). If it is 2, then (a) if the MATID was found on a MAT1 card, locations 16, 17 and 18

are set to G, 0.0 and G respectively; or (b) if the MATID was found on a MAT2 card, locations 16, 17 and 18 are set to 0.0.

INFLAG = 4 -- If INFLAG is 4, this implies that only the density of the material, RHØ, will be returned in /MATØUT/ and this in the first location. The MATID can be either on a MAT1 or MAT2 card. If the MATID cannot be found among all MAT1 and MAT2 cards, a fatal error occurs.

INFLAG = 5 -- INFLAG = 5 is reserved for use only by module PLA1. This option determines if the MATID is such that E, the modulus of elasticity, is defined as stress dependent by MATS1 and TABLES1 cards. If it is stress dependent, INDSTR, equivalenced to the first word of /MATØUT/, is set to +1. If not stress dependent, INDSTR is set to 0. Only MAT1 cards are admissible for INFLAG = 5.

INFLAG = 6 -- INFLAG = 6 is reserved for use by modules PLA3 and PLA4. The fourth word of /MATIN/, PLAARG (see below), is strain and is used as the independent variable in a table look-up for stress, which is stored in the first word of /MATØUT/. Only MAT1 cards are searched to match the input MATID.

INFLAG = 7 -- INFLAG 7 implies that the material properties corresponding to the MATID will be output in MAT3 or orthotropic material format. Currently only the axisymmetric elements TRIARG, TRAPRG and TØRDRG use this option. If the MATID is found in the MAT1 set, the data are stored in MAT3 format. If not found in the MAT1 set, the MAT3 set is searched. If not found here, a fatal error exists.

INFLAG = 8 -- INFLAG = 8 is used only by two-dimensional element subroutines in modules PLA3 and PLA4. The fourth word of /MATIN/, PLAARG (see below), is stress (σ) and is used as the ordinate in an inverse interpolation table look-up to obtain the abscissa which is strain (ε).

If either: a) the ordinate is in the range of the piecewise linear function defined by the table on a TABLES1 bulk data card, or b) the ordinate is greater than the maximum (which is also the last) ordinate in the table but the slope of the line segment joining the last two points of the table is nonzero, then the second word of /MATØUT/ is set to zero and the abscissa,

obtained by inverse linear interpolation or extrapolation, is stored in the first word of /MATØUT/. If either: a) the ordinate is less than the minimum (which is also the first) ordinate in the table, or b) the ordinate is greater than the maximum ordinate in the table and the slope of the line segment joining the last two points of the table is zero, then the integer "1" is stored in the second word of /MATØUT/ (and the first word of /MATØUT/ is set to zero). Only MAT1 cards are searched to match the input MATID.

TEMP - Average element temperature. Used as the independent variable in a table look-up when it is determined that a material property is temperature dependent. Not used when INFLAG = 5 or 6.

PLAARG - Element strain. Used as the independent variable in a table look-up when E, the modulus of elasticity, is defined as the first derivative of a strain-stress curve. Used only in the Piecewise Linear Analysis Rigid Format and only by modules PLA3 and PLA4.

SINTH - Sine of the material property orientation angle. Used only when INFLAG = 2 and the MATID is found among the MAT2 cards. Used to construct the [U] matrix referenced above.

CØSTH - Cosine of the material property orientation angle. The comments on SINTH, above, also apply here.

CØMMØN/MATØUT/ - (Output Common Block). Length 20 words. Depending upon the values of INFLAG, the output common block is defined variously as follows:

1. MAT1 Format (INFLAG = 1)

Word	Symbol	Definition
1	E	Young's modulus (modulus of elasticity)
2	G	Shear Modulus
3	ν	Poisson's ratio
4	ρ	Density
5	α	Thermal expansion coefficient
6	T_o	Thermal expansion reference temperature
7	g_e	Structural element damping coefficient
8	σ_t	Stress limit for tension
9	σ_c	Stress limit for compression
10	σ_s	Stress limit for shear
11-20	-	Undefined

2. MAT2 Format (INFLAG = 2)

Word	Symbol	Definition
1	G11	The 3x3 symmetric material property matrix
2	G12	
3	G13	
4	G22	
5	G23	
6	G33	
7	RHØY	Density
8	ALPH1	Thermal expansion coefficient vector
9	ALPH2	
10	ALPH12	
11	TØY	Thermal expansion reference temperature
12	GEY	Structural element damping coefficient
13	SIGTY	Stress limit for tension
14	SIGCY	Stress limit for compression
15	SIGSY	Stress limit for shear
16-20	-	Undefined

3. Transverse Shear Inverse Matrix (INFLAG = 3)

Word	Symbol	Definition
1-15	-	Unchanged
16	J11	The 2x2 symmetric inverse of the transverse shear matrix
17	J12	
18	J22	
19-20		Undefined

4. RHØ Only Format (INFLAG = 4)

Word	Symbol	Definition
1	RHØ	Density
2-20	-	Undefined

5. PLA1 Use Only (INFLAG = 5)

Word	Symbol	Definition
1	INDSTR	Stress dependent flag
2-20	-	Undefined

6. Stress Functional Value (INFLAG = 6)

Word	Symbol	Definition
1	PLAANS	Value of stress (σ) as a function of ε (strain)
2-20	-	Undefined

7. MAT3 Format (INFLAG = 7)

Word	Symbol	Definition
1	EX3	Young's Moduli x, y and z directions
2	EY3	
3	EZ3	
4	NUXY3	Poisson's ratios. Coupled strain ratios in the xy, yz, and zx directions
5	NUYZ3	
6	NUZX3	
7	RHØ3	Density
8	GXY3	Shear moduli
9	GYZ3	
10	GZX3	
11	AX3	Thermal expansion coefficients
12	AY3	
13	AZ3	
14	TREF3	Thermal expansion reference temperature
15	GE3	Structural element damping coefficient
16-20	-	Undefined

8. Strain Functional Value (INFLAG = 8)

Word	Symbol	Definition
1	PLAANS	Value of strain (ϵ) as an inverse function of stress (σ)
2	ICELL2	= 0 if the input stress is in the range of the function = 1 if the input stress is outside the range of the function
3-20		Undefined

3.4.36.4 Method

1. PREMAT: All the MAT1, MAT2 and MAT3 cards are read from the MPT data block into open core so that each card is assigned 1 + 3*N words of core where N, a function of the card type, is the number of material property data items on that card type. The first word is the material iden-

tification number and each material property is allocated 3 words: the first the input material property; the second a table (function) number which gives this material property as a function of temperature; the third a table number which gives this material property as a function of stress. Initially words 2 and 3 are set to zero. Although the third word is currently used only for MAT1 cards and for E, the modulus of elasticity, on that card, future development may make use of a more general application of stress dependent material properties. If there are no temperature dependent material properties for a non-Piecewise Linear Analysis problem, PREMAT is wrapped up and a RETURN to the calling routine is executed.

For a non-Piecewise Linear Analysis problem for which a temperature set for material properties was selected in the user's Case Control Deck, all MATT1, MATT2 and MATT3 cards are read into open core from the MPT data block. For a Piecewise Linear Analysis problem MATS1 cards are read into open core from the MPT. A sorted list, with duplicates discarded, of the table numbers referenced on these cards is constructed in open core. This table number list is constructed so that every referenced table has eleven locations allocated to it. These eleven locations are used as a dictionary for the tables. The contents are: the table number (word 1); the table type 1,2,3, or 4 (word 2); pointers to the first and last entries in the table (words 3 and 4); parameters from the TABLE card (words 5 through 11). The DIT data block is then read. For each table read, it is determined by scanning the table number list whether or not the table is required for problem solution. If it is required, the table is read into open core and the dictionary entry for the table is completed. For a required table which is a type 4 (polynomial) table, the functional values of the polynomial at the end points of the interval of the real line over which the polynomial is defined are calculated by an "internal subroutine" and stored in the table dictionary. If the table is not required, it is read until an end-of-table indicator is sensed. This process continues until all tables of the set TABLEM1, TABLEM2, TABLEM3 and TABLEM4 or of the set TABLES1, are exhausted. When all referenced tables have been read into core, PREMAT is wrapped up and a return is generated.

2. MAT: The basic logic of the MAT routine is straightforward. Eight types of table look-ups, described above for INFLAG = 1, 2, 3, 4, 5, 6, 7 and 8 are supported. A computed-go-to on INFLAG is executed and each option is carried out as described above. "Internal subroutines" which are entered via FØRTRAN ASSIGN and GØ TØ statements and return to their correct "calling" locations via ASSIGNED GØ TØ's are used liberally by MAT. It should be noted that each time MAT

is called, MATID, INFLAG and other applicable input items, are saved. On the next call if the input is identical with the input of the previous call, nothing is stored in /MATØUT/. Hence, the calling routine should use /MATØUT/ as a "read-only data set".

3.4.36.5 Design Requirements

Subroutine GMMATS is the only non-root segment subroutine used by this routine. There are no other special requirements.

3.4.36.6 Diagnostic Messages

The following messages can be output via PREMAT and/or MAT: 3008, 2017, 2018, 2019, 2041, 2042, 2103, 2112, 2113, 2114, 2115, 2116, and 2117.

3.4.37 PRETRD (Utility for Modules Which Use the CSTM Data Block - Double Precision Version).

3.4.37.1 Entry Points: PRETRD, TRANSD

3.4.37.2 Purpose

A utility routine for modules which use the CSTM (Coordinate System Transformation Matrices) data block, TRANSD generates a real double precision 3x3 direction cosine matrix which maps a vector from a local coordinate system to basic coordinates. PRETRD sets up eventual calls to TRANSD. For a module to use TRANSD a call to PRETRD is made once and only once.

3.4.37.3 Calling Sequence

CALL PRETRD(CSTM,NCSTM)

CSTM = array of coordinate system transformation matrices (see data block description for CSTM, section 2.3) - mixed - input.

NCSTM = length of the CSTM array. NCSTM = 14*the number of coordinate systems in the CSTM data block - integer - input.

CALL TRANSD(ECPT,TA)

ECPT = array of length 4. The first word is an integer coordinate system identification number and the next 3 words are the components of a vector in basic coordinates - input only.

TA = real double precision 3x3 direction cosine matrix which maps a vector from the local coordinate system designated by ECPT(1) to basic coordinates - output.

3.4.37.4 Method

The CSTM array is searched to find a coordinate system transformation identification number that matches ECPT(1). If the coordinate system is rectangular, the 3x3 matrix, call it T, which is in words 6 through 14 of the CSTM blocks, is stored in TA and a RETURN is generated. If the coordinate system is basic, the identity matrix is returned. If the coordinate system is spherical or cylindrical, the [T] matrix defines the rectangular system from which the angles are defined. In these cases calculate:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = [T]^T \begin{Bmatrix} E - V \end{Bmatrix}$$

where E is the input vector stored at ECPT(2) and V is the translation offset vector in basic

coordinates found in the CSTM block in words 3, 4 and 5; and

$$r = \sqrt{x^2 + y^2}$$

If the coordinate system is cylindrical define:

$$\left[T_\ell\right] = \begin{bmatrix} x/r & -y/r & 0 \\ y/r & x/r & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

If the coordinate system is spherical define:

$$\ell = \sqrt{x^2 + y^2 + z^2},$$

$$\left[T_\ell\right] = \begin{bmatrix} x/\ell & \frac{xz}{r\ell} & -y/r \\ y/\ell & \frac{yz}{r\ell} & x/r \\ z/\ell & -r\ell & 0.0 \end{bmatrix}$$

Then $[T_A] = [T][T_\ell]$ is computed and the subroutine returns to the calling program.

3.4.37.5 Design Requirements

The routine is designed so that a module which uses the CSTM data block can have a utility routine to fetch a coordinate system transformation matrix. Typically, a module driver will attempt to open the file which contains the CSTM data block. If the data block is not purged, the module will read the entire data block into open core, close the file and call PRETRD to transmit the address of the array and the length of the array. Once this initialization call has been made, TRANSD may be called in the module as many times as necessary. The routine does not perform any I/Ø operations. The routine assumes the format of the CSTM data block, as outlined in the Data Block Description for the CSTM (section 2.3 of the Programmer's Manual) is correct, and no numerical checks are made.

3.4.37.6 Diagnostic Messages

If the coordinate system identification number transmitted via ECPT(1) can not be found in the CSTM array user fatal message 2025 occurs. The user should check coordinate system numbers on GRID bulk data cards against those defined on CØRD1C, CØRD1R, etc., bulk data cards to insure that there are no undefined coordinate systems.

3.4.38 PRETRS (Utility for Modules Which Use the CSTM Data Block - Single Precision Version).

3.4.38.1 Entry Points: PRETRS, TRANSS.

3.4.38.2 Purpose

A utility routine for modules which use the CSTM (Coordinate System Transformation Matrices) data block, TRANSS generates a real single precision 3x3 direction cosine matrix which maps a vector from a local coordinate system to basic coordinates. PRETRS sets up eventual calls to TRANSS. For a module to use TRANSS a call to PRETRS is made once and only once.

3.4.38.3 Calling Sequence

```
CALL PRETRS(CSTM,NCSTM)

CALL TRANSS(ECPT,TA)
```

This routine is exactly the same as subroutine PRETRD (see section 3.4.37) and TRANSD except that TRANSD, an entry point, returns a real double precision matrix TA and uses double precision arithmetic, while TRANSS returns a real single precision matrix TA and uses single precision arithmetic. See subroutine description for PRETRD for details on subroutine arguments, method, design requirements and diagnostic messages.

3.4.39 PRETAB (Table Look-Up).

3.4.39.1 Entry Points: PRETAB, TAB.

3.4.39.2 Purpose

To read tables (functions) from the data block DIT, Direct Input Tables, into core and to set up table dictionaries which are subsequently used when the calling routine requests a functional value from a table via a call to the entry point TAB. The routine is designed so that PRETAB is called once and only once by a module and so that TAB may be called many times as a table look-up routine.

3.4.39.3 Calling Sequence

CALL PRETAB(DITF,Z,IZ,BUF,LCRGVN,LCUSED,TABNØL,LIST)

DITF - GINØ file number of the Direct Input Tables data block - integer - input.

Z - Array of core given to the subroutine as working storage - real - input and output.

IZ - Same address as Z. Used as integer in this routine.

BUF - A GINØ buffer (plus one cell) used by subroutine PRELØC - input.

LCRGVN - The length of Z array, given to PRETAB and TAB - integer - input.

LCUSED - The number of cells of core used by PRETAB - integer - output.

TABNØL - List of table numbers that the calling routine will be referencing via TAB calls. TABNØL(1) = N is the number of tables to be referenced. TABNØL(2), ... , TABNØL(N +1) contain the table numbers. Note that 0 is an admissible table number. Table 0 defines a function which is identically zero for all values of the independent variable - integer - input.

LIST - Array of control words for subroutine LØCATE and table types. LIST(1) = M is the number of triples which follow in the list. The first two words of each triple are the subroutine LØCATE control words for the particular table being referenced and the third word is the table type: 1, 2, 3 or 4 - integer - input.

CALL TAB(TABID,X,Y)

TABID - Table number - integer - input.

X - Abscissa for table number TABID at which the functional value is desired - real - input.

Y - Functional value (ordinate) of abscissa X for table number TABID - real - output.

3.4.39.4 Method

PRETAB: For each table in the TABNØL list an 11 word table dictionary entry is defined in open core. The first word in each entry is the table number obtained from the TABNØL list. Then the DIT data block is read. For each entry of the DIT, it is determined whether or not this table number is in the TABNØL list. If it is not, then the table is read serially until an end-of-table indicator is sensed. If it is a table called for in the TABNØL list, the program sets words 2 and 3 of the table dictionary, the table type (1,2,3 or 4) and the pointer to the 1st entry in the table respectively. The table is then read into core, and the 4th word of the table dictionary, the pointer to the last entry in the table, is set. Words 5 through 11 of the dictionary, the table parameters, are set. If the table type is 4, indicating a polynomial, the functional values of the polynomial at the end points of the interval of the real line over which the polynomial is defined are calculated. After the tables for an entry in the LIST array have been exhausted, a check is made to determine if all tables in the TABNØL list have been found (after each table is found the table number is set negative). If all tables have been found, the table numbers in TABNØL are set to their original positive status and the routine is wrapped up. If all tables have not been found, the next class of table cards, defined by the next triple in the LIST array, are located in the DIT data block and the process is repeated.

TAB: The table dictionary is searched until a match is found with the input argument TABID. The table type (1, 2, 3 or 4) is determined, the (functional) argument is computed after a 4-way branch on table type, and a transfer is made to either the "internal subroutine" which performs linear interpolation--if the table type is 1, 2 or 3--or the "internal subroutine" which performs polynomial evaluation--if the table type is 4.

3.4.39.5 Design Requirements

DIT must not be purged. Enough open core must be made available to construct the table dictionaries and to contain all referenced tables in core. All table numbers must be unique. All table numbers input via the TABNØL array must be found in the DIT data block. A table number referenced by the TABID argument of TAB must have been referenced previously in the TABNØL array.

3.4.39.6 Diagnostic Messages

The following diagnostic messages may appear:

3008

2088

2089

2090

3.4.40 AXIS (Draw an Axis on a Plot).

3.4.40.1 Entry Point: AXIS.

3.4.40.2 Purpose

To draw an x or y axis on a plotter.

3.4.40.3 Calling Sequence

CALL AXIS(X1,Y1,X2,Y2,PEN,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X1,YL = starting point of the axis line - real - input.

X2,Y2 = terminal point of the axis line - real - input.

PEN = pen number or line density to be used (its meaning depends on the plotter) - integer - input.

ØPT = { -1 to initiate the line mode. / +1 to terminate a series of plot commands. / 0 to draw an axis. } - integer - input

/PLTDAT/

MØDEL = plotter model number - integer - input.

PLØTER = plotter number (i) - integer - input.

NPENS = largest number of pens or maximum density for plotter i - integer - input.

3.4.40.4 Method

This subroutine calls LINE or AXISi, depending on whether the plotter has available a single command used for drawing an axis. At this writing, only plotter 3 has a special axis command.

If ØPT $\neq$ 0, all other arguments are ignored, and LINE or AXISi is called. Otherwise, alternate pen number (PENX) is calculated modulo NPENS and is used as the pen number passed to

LINE or AXISi, as follows:

```
PENX = PEN - NPENS * ((PEN-1)/NPENS)
```

3.4.40.5 Design Requirements

Generally, AXIS or LINE should be called with ØPT = -1 before axes are generated, even though it is not necessary to specifically put all plotters in the line mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the typing mode).

Subroutines used: LINE, AXISi.

3.4.41 AXISi (Axis Routine for Plotter i).

3.4.41.1 Entry Point: AXISi.

3.4.41.2 Purpose

To set up a plot command to draw an x or y axis on plotter i.

3.4.41.3 Calling Sequence

CALL AXISi(X1,Y1,X2,Y2,PEN,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X1,Y1 = starting point of the axis line - real - input.

X2,Y2 = terminal point of the axis line - real - input.

PEN = pen number or line density to be used (meaning depends on plotter) - integer - input.

ØPT = { -1 to initiate the line mode
+1 to terminate a series of plot commands
0 to draw an axis } - integer - input.

/PLTDAT/

XYMIN = minimum x and y values of the region permitted on plotter i - real - input.

XYMAX = maximum x and y values of the region permitted on plotter i - real - input.

ØRIGIN = location of the lower left corner of the plotter relative to its true physical origin - real - input.

3.4.41.4 Method

Taking into account the true origin of the plotter, the plot command is generated.

3.4.41.5 Design Requirements

Subroutine used: WPLTi.

3.4.42 SKPFRM (Skip a Variable Number of Frames).

3.4.42.1 Entry Point: SKPFRM.

3.4.42.2 Purpose

Tc skip a variable number of frames, if appropriate to the plotter.

3.4.42.3 Calling Sequence

CALL SKPFRM (BFRAMS)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

BFRAMS = number of frames to be skipped - integer - input.

/PLTDAT/

MØDEL = plotter model number - integer - input.

PLØTER = plotter number - integer - input.

REG = plot region parameters - real - input.

AXYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - input.

EDGE = size of the borders (x,y) in plotter units - real - input.

CAMERA = currently active camera - integer - input.

ØRIGIN = location (x,y) of the lower left corner of the plotter relative to its true physical origin - real - input.

3.4.42.4 Method

For plotters 3 and 9, the specified number of frames (BFRAMS) are skipped. For plotters 4 to 7, the remainder of the current plot is skipped, and another half plot is also skipped. For plotters 1, 2 and 4, nothing is done due to the absence of any automatic method of skipping blank paper.

3.4.42.5 Design Requirements

Subroutines used: LINE, WPLTi.

3.4.43 SELCAM (To Initiate a New Plot).

3.4.43.1 Entry Point: SELCAM.

3.4.43.2 Purpose

To select a camera and/or to generate a setup record for a new plot.

3.4.43.3 Calling Sequence

CALL SELCAM (CAMERA,PLTNUM,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

CAMERA = camera number to be selected (if appropriate) - integer - input.

PLTNUM = plot number - integer - input.

ØPT ≠ 0 = if the camera is to be selected when appropriate, and nothing is to be done when not appropriate - integer - input.

/PLTDAT/

MØDEL = plotter model number - integer - input.

PLØTER = plotter number - integer - input.

XYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - input.

EDGE = size of the borders (x,y) in plotter units - real - input.

CAMNUM = last selected camera - integer - output.

ØRIGIN = location (x,y) of the lower left corner of the plotter relative to its true physical origin - real - input and output.

3.4.43.4 Method

If ØPT ≠ 0 and a camera is not appropriate to the plotter, nothing is done by this subroutine.

Otherwise, what is done is dependent upon the plotter hardware requirements.

For plotters 1, 2 and 8, the plotter is stopped with the plot number displayed in the console lights. For plotters 2 and 9 the specified camera is selected. And for plotters 4 to 7, a block address record with the plot number is generated.

3.4.43.5 Design Requirements

Subroutines used: WPLTi, LINE.

3.4.44 IDPLØT (Generate an "ID" Plot).

3.4.44.1 Entry Point: IDPLØT.

3.4.44.2 Purpose

To identify the owner of all the plots by printing the information contained on the PLØTID card in the user's Case Control Deck prior to generating the first plot.

3.4.44.3 Calling Sequence

CALL IDPLØT (IDX)

CØMMØN/ØUTPUT/SKIP(32,6),ID(32)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

IDX = { 0 if a plot id was not generated / 1 if a plot id was generated } - integer - output.

/ØUTPUT/

ID = user supplied PLØTID, in the Case Control Deck - BCD - input.

/PLTDAT/

XYMIN, XYMAX = { plot region parameters - real - input.

AXYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - input.

EDGE = size of the borders (x,y) in plotter units - real - input.

CNTX,CNTY= number of counts per printed character in the x and y directions respectively - real - input.

PLTYPE = plotter type - integer - input.

3.4.44.4 Method

If there is no PLØTID (ID = blanks), IDX is set to zero and no identification is generated. Otherwise, IDX is set to one and an identification is generated. The current region parameters are saved (they will be restored at the end of the subroutine) and are set to include the entire paper area. The identification generated varies, depending upon the plotter type.

If the plotter is a microfilm plotter (|PLTYPE| = 1), an entire frame is generated as identification. The top and bottom of the frame are a series of closely spaced horizontal lines. The PLØTID is then printed three times in the center of the frame.

If the plotter is a drum or table plotter (|PLTYPE| ≠ 1), the identification is printed once at the very bottom of the paper within the bottom border.

After the identification is generated, the PLØTID is set to blanks. This insures that the identification will be generated prior to the first plot only.

3.4.44.5 Design Requirements

Subroutines used: AXIS, PRINT.

3.4.45 INTGPX (Search a List of Integers).

3.4.45.1 Entry Points: INTGPX, INTGPT.

3.4.45.2 Purpose

Given a list of N integers, to find the index of the list item equal to ITEM (primarily used to search a list of external grid point id's).

3.4.45.3 Calling Sequence

```
CALL INTGPX(LIST,N)
K = INTGPT (ITEM)
```

where:

LIST = list of N integers, in arbitrary order - input.

N = number of entries in LIST - integer - input.

ITEM = integer for which a match is to be found in LIST - input.

3.4.45.4 Method

Search LIST using a linear search until a match for ITEM is found. Then the result (INTGPT) is set equal to the index of LIST where the match occurs. If no match is found, the result is set = 0.

3.4.45.5 Design Requirements

INTGPX must be called before INTGPT is used. As long as LIST does not change location and the value of N does not change, INTGPX need not be called again.

3.4.46 INTLST (Interpret a List of Integers).

3.4.46.1 Entry Point: INTLST.

3.4.46.2 Purpose

To interpret a list of integers and/or pairs of integers separated by the word TØ or THRU.

3.4.46.3 Calling Sequence

```
CALL INTLST(LIST,N,SIGN,N1,N2)
```

where:

LIST - the list to be interpreted - integer - input.

N - index location of the next list item(s) to be interpreted - integer - input.

SIGN - sign (±1) of the interpreted integer or the first of a pair of integers - output.

N1 - absolute value of the interpreted integer or the first of a pair of integers - output.

N2 - absolute value of the second integer of pair of integers (= N1 if not a pair) - output.

3.4.46.4 Method

SIGN = ±1 if LIST(N) is positive or negative.

N1 = absolute value of LIST(N).

If LIST(N+1) ≠ TØ or THRU, then N2 = N1 and N is incremented by 1.

If LIST(N+1) = TØ or THRU, then N2 = absolute value of LIST(N+2) and N is incremented by 3.

3.4.46.5 Design Requirements

Initially, N must be set to the index of the first integer or integer pair to be interpreted in LIST. If the list is consecutive, N need not subsequently be altered until a new list is to be interpreted. It is advisable that the value following the last item in LIST be set = 0 to avoid the chance that it may equal TØ or THRU.

3.4.47 LINE (Draw a Line on a Plotter).

3.4.47.1 Entry Point: LINE.

3.4.47.2 Purpose

To draw a line on a plotter.

3.4.47.3 Calling Sequence

CALL LINE(X1,Y1,X2,Y2,PEN,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X1,Y1 = starting point of the line - real - input.

X2,Y2 = terminal point of the line - real - input.

PEN = pen number or line density to be used - integer - input.

ØPT = { -1 to initiate the line mode. / +1 to terminate a series of plot commands. / 0 to draw a line. } integer - input.

/PLTDAT/

MØDEL = plotter model number - integer - input.

PLØTER = plotter number (i) - integer - input.

REG = x and y values defining the region in which the line is to be drawn - real - input.

NPENS = maximum number of pens or line density possible for plotter i - integer - input.

3.4.47.4 Method

If the line to be drawn is entirely outside the specified region, the subroutine immediately returns without drawing anything. If only part of the line is outside the region, only that portion of the line within the region is drawn. The actual pen number or line density used will be modulo the maximum number of pens or line density as follows:

PENX = PEN - NPENS* ((PEN-1)/NPENS)

Then LINEi is called.

3.4.47.5 Design Requirements

Generally, LINE should be called with ØPT = -1 before any lines are drawn, even though it is not necessary to specifically put all plotters in the line mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the typing mode). If ØPT ≠ 0, all other arguments are ignored. Subroutine used: LINEi.

3.4.48 LINEi (Draw a Line on Plotter i).

3.4.48.1 Entry Point: LINEi.

3.4.48.2 Purpose

To draw a line on plotter i.

3.4.48.3 Calling Sequence

CALL LINEi(X1,Y1,X2,Y2,PEN,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description section 2.5.

where:

X1,Y1 = starting point of the line - real - input.

X2,Y2 = terminal point of the line - real - input.

PEN = pen number or line density to be used - integer - input.

ØPT = { -1 to initiate the line mode. / +1 to terminate a series of plot commands. / 0 to draw a line. } - integer - input.

/PLTDAT/

MØDEL = plotter model number - integer - input.

PLØTER = plotter number - integer - input.

MAXLEN = maximum length of a line segment - real - input.

ØRIGIN = x and y values of the current position of the pen (applicable only to incremental plotters) - real - input and output.

3.4.48.4 Method

If ØPT ≠ 0, all other arguments are ignored. If ØPT = -1 and if applicable for plotter i, a flag is set so that when LINEi is subsequently called with ØPT = 0, the plotter will be put into the line mode before drawing the requested line. If ØPT = +1 and if applicable for plotter i, the pen is raised. Then, no matter which plotter is being used the current sequence of plotter commands is terminated. If ØPT = 0, the line is drawn as a series of line segments, each of maximum length MAXLEN.

3.4.48.6 Design Requirements

Subroutines used: WPLTi.

3.4.49 PRINT (Print a Title on a Plotter).

3.4.49.1 Entry Point: PRINT.

3.4.49.2 Purpose

To type a title on a plotter horizontally or vertically.

3.4.49.3 Calling Sequence

CALL PRINT(X,Y,XYD,CHR,N,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X,Y - starting or ending point of the title to be typed (always left-to-right or top-to-bottom) - real - input.

XYD - $\begin{cases} \pm 1 \text{ if X = starting or ending point of the title - integer - input.} \\ \pm 2 \text{ if Y = starting or ending point of the title - integer - input.} \end{cases}$

CHR - title to be typed (four characters/word - left adjusted followed by blanks) - BCD - input.

N - number of words in the title - integer - input.

ØPT - $\left\{ \begin{cases} -1 \text{ to initiate the typing mode.} \\ +1 \text{ to terminate a series of plot commands.} \\ 0 \text{ to type a title.} \end{cases} \right\}$ - integer - input.

/PLTDAT/

CNTCHR = number of plotter counts per character in the x and y directions - real - input.

3.4.49.4 Method

If ØPT ≠ 0, all other arguments are ignored and TIPE is called. Otherwise, each character in the title (CHR) is separated and put into another array (C). This is done for each 20 words of the title (80 characters), and TIPE is then called to type these characters.

3.4.49.5 Design Requirements

Generally, one of the typing subroutines (PRINT, TIPE, TYPFLT, TYPINT, SYMBØL) should be

called with ØPT = -1 before any typing is attempted, even though it is not necessary to specifically put all plotters in the typing mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the line mode).

Subroutines used: TIPE.

3.4.50 RDMØDX (Read a File Containing XRCARD Translations).

3.4.50.1 Entry Points: RDMØDX, RDMØDY, RDMØDE, RDWØRD.

3.4.50.2 Purpose

To read from a file or storage a record containing the subroutine XRCARD interpretation of free field data cards (e.g., the PCDB data block).

3.4.50.3 Calling Sequence

CALL RDMØDX(FILE,MØDE,WØRD)

CALL RDMØDY(A,MØDE,WØRD)

CALL RDMØDE(n_1,n_2,n_3)

CALL RDWØRD

where:

FILE = GINØ file name which is to be read - integer - input.

MØDE = storage location into which the XRCARD mode value is to be read - integer - output.

WØRD = 2 locations into which XRCARD card items are to be read - integer - output.

A = array which is to be "read" (instead of FILE) - integer - input.

n_1 = the FØRTRAN statement number defining the return at which numeric data are interpreted (MØDE < 0).

n_2 = the FØRTRAN statement number defining the return at which alphabetic data are interpreted (0 < MØDE < 1,000,000).

n_3 = the FØRTRAN statement number defining the return when the end of a logical card is encountered (MØDE $\geq$ 1,000,000).

3.4.50.4 Method

RDMØDX and RDMØDY are initialization calls for the file and core oriented options respectively.

For RDMØDE:

1. An XRCARD mode value is read into MØDE. If MØDE = 0, the end of a physical card has been encountered, but not the end of a logical card. In this case, the record is terminated (if FILE is being read). Then the first word of the next record or location is read into MØDE.

2. If MØDE < 0, the next word is read into WØRD(1). If MØDE = -4, another word is read into WØRD(2).

3. If 0 < MØDE < 1,000,000, BCD information follows as pairs of 4-character words. The first two of these words are read into NEXT(1) and NEXT(2). If NEXT(1) is a blank or NEXT(2) is a delimiter, the value of MØDE is decremented by one, and if MØDE is still greater than zero, the next two words are read into NEXT(1) and NEXT(2). This continues until either MØDE = 0, or NEXT(1) is not a blank and NEXT(2) is not a delimiter. If MØDE does become zero, step 1 is then re-executed.

4. If MØDE $\geq$ 1,000,000, the end of a logical card has been encountered. If FILE is being read, the current record is terminated.

For RDWØRD:

1. The two words now in NEXT(1) and NEXT(2) are stored in WØRD(1) and WØRD(2).

2. MØDE is decremented by one. If MØDE is still gerater than zero, the next two words are read into NEXT(1) and NEXT(2). If NEXT(1) is a blank or NEXT(2) is a delimiter, this step is repeated until either MØDE = 0, or NEXT(1) is not a blank and NEXT(2) is not a delimiter.

3.4.50.5 Design Requirements

RDMØDX or RDMØDY must be called before RDMØDE and RDWØRD. As long as FILE does not change in value, and MØDE, WØRD, and A do not change locations, RDMØDX and RDMØDY need not be called again. If RDMØDX is called, FILE must be opened and properly positioned by the calling program. In addition, RDMØDE and RDWØRD cannot be called when FILE is closed. If an end-of-file or-record condition is encountered, a fatal error occurs (see subroutine FREAD).

3.4.51 SGINØ (GINØ for Unformatted Tapes).

3.4.51.1 Entry Points: SØPEN, SWRITE, SEØF, SCLØSE.

3.4.51.2 Purpose

To write unformatted BCD and binary tapes to drive NASTRAN plotters.

3.4.51.3 Calling Sequences

CALL SØPEN($n,PLTTP,BUFFER,LBUFF)

n -- FØRTRAN statement number defining the return if PLTTP is not available for writing.

PLTTP - GINØ file name of the plot tape. This may have two values: PLT1 - BCD plot tape; PLT2 - binary plot tape - BCD - input.

BUFFER - Array in which the plot data transmitted during SWRITE calls are stored.

LBUFF - Length of the buffer array - integer - input.

CALL SWRITE(PLTTP,DATA,LDATA,IØPT)

PLTTP - GINØ file name of the plot tape - BCD - input.

DATA - Array of plot data (1 character/word, right justified, leading zeros).

LDATA - Length of the DATA array in words - integer - input.

IØPT - { 0, potentially more data to be transmitted in this record. / 1, end of record with this data transmission. } integer - input.

CALL SEØF(PLTTP)

PLTTP - GINØ file name of the plot tape on which a physical EØF will be written.

CALL SCLØSE(PLTTP)

PLTTP - GINØ file name of the plot tape.

3.4.51.4 Method

SGINØ stores data in BUFFER until IØPT = 1 or BUFFER is filled. It then transmits the data to a physical tape without any control words. The data are transmitted to SGINØ 1 character (right

justified, leading zeros) per word. SGINØ packs these characters into full words. SGINØ is in FØRTRAN on all machines. On the IBM 7094 it interfaces with GINØ; the Univac 1108 version uses NTRAN; the IBM S/360 uses FØRTRAN I/Ø; and the CDC 6600 use XIØRTNS. See section 5 for details.

3.4.51.5 Design Requirements

Only one of PLT1 or PLT2 may be open at one time.

SØPEN must be called before SWRITE, SEØF, or SCLØSE.

PLT1 or PLT2 must be physical tapes if they are written on.

3.4.52 STPLØT (To Initiate a New Plot or Terminate the Current Plot).

3.4.52.1 Entry Point: STPLØT.

3.4.52.2 Purpose

To initiate a new plot or terminate the current plot.

3.4.52.3 Calling Sequence

CALL STPLØT(PLTNUM)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/XXPARM/ - see XXPARM Miscellaneous Table description, section 2.5.

where:

PLTNUM = { if nonnegative, the plot number / if negative, terminate the current plot } - integer - input.

/PLTDAT/

MØDEL = plotter model index - integer - input.

PLØTER = plotter number - integer - input.

REG = plot region parameters - real - input.

XYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - input.

PLTYPE = plotter type - integer - input.

PLTAPE = plot tape - BCD - input.

EØF = { 0 if an end-of-file mark is to be written on the plot tape after each plot / 1 if no end-of-file mark is to be written on the plot tape after each plot } - integer - input.

/XXPARM/

CAMERA = camera number (if applicable) to be used - integer - input.

BFRAMS = number of blank frames between plots - integer - input.

3.4.52.4 Method

A. If PLTNUM is nonnegative:

1. Select the specified camera or create a setup record appropriate to the plotter (CALL SELCAM).

2. Skip to a new frame (if applicable) and create the owner identification. If the owner identification is generated by subroutine IDPLØT, re-execute step 1 and skip to a new frame.

3. If appropriate to this plotter, insert the desired number of blank frames on film only. If the camera specified is camera 2 (paper only), no blank frames are inserted.

4. If the plot number is nonzero, type this number in the upper left and right corners of the picture.

B. If PLTNUM is negative:

1. Terminate the current plot tape record.

2. Close the current plot tape file (CALL SCLØSE).

3. If each plot is to be separated by an end-of-file mark (EØF = 0), write an end-of-file on the plot tape (CALL SEØF).

3.4.52.5 Design Requirements

Subroutines used include: IDPLØT, SELCAM, SKPFRM, TYPINT, SCLØSE, SEØF.

3.4.53 SYMBØL (Type a Symbol on a Plotter).

3.4.53.1 Entry Point: SYMBØL.

3.4.53.2 Purpose

To type a symbol on a plotter.

3.4.53.3 Calling Sequence

CALL SYMBØL(X,Y,SYM,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/SYMBLS/ - see SYMBLS Miscellaneous Table description, section 2.5.

where:

X,Y - point at which the symbol is to be typed - real - input.

SYM - two consecutive storage locations each containing an index into the SYMBLS table - integer - input.

ØPT - { -1 to initiate the typing mode. / +1 to terminate a series of plot commands. / 0 to type the symbol. } - integer - input.

/PLTDAT/

MØDEL - plotter model number - integer - input.

PLØTER - plotter number (i) - integer - input.

/SYMBLS/

NSYM - number of symbols defined in the SYMBLS table - integer - input.

SYMBL(20,i) - character indices defining the symbols of plotter i - integer - input.

3.4.53.4 Method

If ØPT $\neq$ 0, all other arguments are ignored and TYPEi or DRWCHR is called. Otherwise, an alternate symbol index (SYMX) is calculated modulo NSYM for each index in SYM and is used as the actual symbol index, as follows:

$$SYMX = SYM_j - NSYM*((SYM_{j-1})/NSYM) \quad , \quad j = 1, 2.$$

Then TYPEi or DRWCHR is called for each symbol.

The reason for SYM being two indices is to enable the user to create any additional symbol by combining any two of the valid symbols in the SYMBLS table. Note: any of the indices in SYM may = 0. This would imply that a new symbol is not being created.

3.4.53.5 Design Requirements

Generally, one of the typing subroutines (PRINT, TIPE, TYPFLT, TYPINT, SYMBØL) should be called with ØPT ≠ -1 before any typing is attempted, even though it is not necessary to put all plotters in the typing mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the line mode).

Subroutines used: TYPEi, DRWCHR.

3.4.54 TIPE (Type a Line of Characters on a Plotter).

3.4.54.1 Entry Point: TIPE.

3.4.54.2 Purpose

To type a line of characters on a plotter horizontally or vertically.

3.4.54.3 Calling Sequences

CALL TIPE (X,Y,XYD,CHR,N,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/CHAR94/ - see CHAR94 Miscellaneous Table description, section 2.5.

where:

X,Y - starting or ending point of the line to be typed (always left-to-right or top-to-bottom) - real - input.

XYD - { ±1 if X = starting or ending point of the line. / ±2 if Y = starting or ending point of the line. } - integer - input.

CHR - line of characters to be typed (one character/word - left adjusted followed by blanks) - BCD - input.

N - number of characters to be typed - integer - input.

ØPT - { -1 to initiate typing mode. / +1 to terminate a series of plot commands. / 0 to type a line of characters. } - integer - input.

/PLTDAT/

MØDEL - plotter model number - integer - input.

PLØTER - plotter number (i) - integer - input.

CNTCHR - number of plotter counts per character in the x and y directions - real - input.

/CHAR94/

CHAR - Section I of the CHAR94 table - BCD - input.

3.4.54.4 Method

If ØPT ≠ 0, all other arguments are ignored and TYPEi or DRWCHR is called. Otherwise, for each character to be typed, an index into the CHAR character set is found. This is done 80 characters at a time. If a character cannot be located, it is treated as a blank. For each set of 80 character indices set up, TYPEi or DRWCHR is called.

3.4.54.5 Design Requirements

Generally, one of the typing subroutines (PRINT, TIPE, TYPFLT, TYPINT, SYMBØL) should be called with ØPT ≠ -1 before any typing is attempted, even though it is not necessary to put all plotters in the typing mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the line mode).

Subroutines used: TYPEi, DRWCHR.

3.4.55 TYPEi (Type a Line of Characters on Plotter i).

3.4.55.1 Entry Point: TYPEi.

3.4.55.2 Purpose

To type a line of characters on plotter i horiziontally or vertically.

3.4.55.3 Calling Sequence

CALL TYPEi(X,Y,XYD,CHR,N,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/CHAR94/ - see CHAR94 Miscellaneous Table description, section 2.5.

where:

X,Y = starting or ending point of the line to be typed (always right-to-left or top-to bottom) - real - input.

XYD = $\left\{\begin{array}{l}\pm 1 \text{ if x = starting or ending point of the line.} \\ \pm 2 \text{ if y = starting or ending point of the line.}\end{array}\right\}$ - integer - input.

CHR = indices of the line of characters to be typed (see description for TIPE, section 3.4.54) - integer - input.

N = number of characters to be typed - integer - input.

ØPT = $\left\{\begin{array}{l}-1 \text{ to initiate the typing mode.} \\ +1 \text{ to terminate a series of plot commands} \\ 0 \text{ to type a line of characters.}\end{array}\right\}$ - integer - input.

/PLTDAT/

XYMIN = minimum x and y values of the region in which the line is to be typed - real - input.

XYMAX = maximum x and y values of the region in which the line is to be typed - real - input.

CNTCHR = number of plotter counts per character in the x and y directions - real - input.

/CHAR94/

CHRCØD = Section II, III, or IV of the CHAR94 table - integer - input.

3.4.55.4 Method

If ØPT ≠ 0, all other arguments are ignored. If ØPT = -1 and if applicable for plotter i, a flag is set so that when TYPEi is subsequently called with ØPT = 0, the plotter will be put into the typing mode before typing the first character. If ØPT = +1, the current sequence of plotter commands is terminated.

Define:

LSTCHR = last legitmate character index for plotter i.

NCHR = number of character indices which must be changed for plotter i.

CHAR = NCHR pairs of character indices. The first index of each pair is the index which must be changed, and the second index is the replacement index.

If N $\leq$ 0, it is assumed that one character is to be typed.

Each character index in CHR is checked against LSTCHR. If the index is greater than LSTCHR, a blank is inserted at the corresponding point on the plot. Otherwise, indices are altered if need be from CHAR and the character is typed.

No characters will be typed outside the region as defined by XYMIN and XYMAX.

3.4.55.5 Design Requirements

Subroutines used: WPLTi.

3.4.56 TYPFLT (Type a Floating Point Number on a Plotter).

3.4.56.1 Entry Point: TYPFLT.

3.4.56.2 Purpose

To type a floating point number on a plotter, horizontally or vertically.

3.4.56.3 Calling Sequence

CALL TYPFLT (X,Y,XYD,V,FIELD,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X,Y - point at which the number is to be typed (always left-to-right or top-to-bottom) - real - input.

XYD - $\left\{\begin{array}{l}\pm 1 \text{ if X = starting or ending point of the typed number.}\\ \pm 2 \text{ if Y = starting or ending point of the typed number.}\end{array}\right\}$ - integer - input.

V - number to be typed - real - input.

FIELD - field width of the typed number. If FIELD > 0, the number will be centered at (X,Y). If FIELD < 0, the number will be typed starting or ending at (X,Y). If |XYD| = 1 or 2, the number will be typed horizontally or vertically respectively - integer - input.

ØPT - $\left\{\begin{array}{l}-1 \text{ to initiate the typing mode.}\\ +1 \text{ to terminate a series of plot commands.}\\ 0 \text{ to type the number.}\end{array}\right\}$ - integer - input.

/PLTDAT/

MØDEL - plotter model number - integer - input.

PLØTER - plotter number (i) - integer - input.

CNTCHR - number of plotter counts per character in the x and y directions - real - input.

3.4.56.4 Method

If ØPT ≠ 0, all other arguments are ignored and TYPEi or DRWCHR is called. Otherwise, the

number of significant digits (NSIG) to be typed is determined.

If V $\geq$ 0, the typed number will be unsigned. If FIELD > 4, the number of significant digits typed will be at least = FIELD - 4. If FIELD $\leq$ 4, NSIG = FIELD - 1.

If V < 0, the typed number will be signed. If FIELD > 5, the number of significant digits typed will be at least FIELD - 5. If FIELD $\leq$ 5, NSIG = FIELD - 2.

The number (V) is multiplied by some power of ten such that the product is between 10^7 and 10^8. It can then be expressed as an 8-significant digit integer. If the number is such that NSIG digits cannot be typed without an exponent, a standard form is used: -X.XXXX ... $\pm$ XX. Otherwise the decimal point is adjusted and the exponent will not be printed.

3.4.56.5 Design Requirements

Generally, one of the typing subroutines (PRINT, TIPE, TYPFLT, TYPINT, SYMBØL) should be called with ØPT = -1 before any typing is attempted, even though it is not necessary to put all the plotters in the typing mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the line mode).

Subroutines used: TYPEi, DRWCHR.

3.4.56.6 Diagnostic Messages

If NSIG significant digits cannot possibly be typed in the field width (FIELD) specified, the entire field will be filled with asterisks (**...*).

3.4.57 TYPINT (Type an Integer Number on a Plotter).

3.4.57.1 Entry Point: TYPINT.

3.4.57.2 Purpose

To type an integer number on a plotter, horizontally or vertically.

3.4.57.3 Calling Sequence

CALL TYPINT (X,Y,XYD,NUM,FIELD,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

X,Y - point at which the number is to be typed (always left-to-right or top-to-bottom) - real - input.

XYD - { ±1 if X = starting or ending point of the typed number. / ±2 if Y = starting or ending point of the typed number. } - integer - input.

NUM - number to be typed - integer - input.

FIELD - { +1 if the typed number is to be centered at (X,Y). If |XYD| = 1 or 2, the number will be typed horizontally or vertically, respectively. / -1 or 0, the number will be typed starting or ending at (X,Y). If FIELD = -1, FIELD will be set to the number of digits typed by the subroutine; in this case, FIELD must be a symbol in the call statement. - integer - input and output. }

ØPT - { -1 to initiate the typing mode. / +1 to terminate a series of plot commands. / 0 to type the number. } - integer - input.

/PLTDAT/

MØDEL - plotter model number - integer - input.

PLØTER - plotter number (i) - integer - input.

CNTCHR - number of plotter counts per character in the x and y directions - real - input.

3.4.57.4 Method

If ØPT ≠ 0, all other arguments are ignored and TYPEi or DRWCHR is called. Otherwise, each digit of the number is separated and used as character indices for the TYPEi or DRWCHR subroutines. In addition, if FIELD < 0, FIELD is set = the number of digits printed.

3.4.57.5 Design Requirements

Generally, one of the typing subroutines (PRINT, TIPE, TYPFLT, TYPINT, SYMBØL) should be called with ØPT = -1 before any typing is attempted, even though it is not necessary to specifically put all plotters in the typing mode (e.g., plotter 3). Once this is done, it need not be repeated unless the plotter has been put into some other mode (e.g., the line mode).

Subroutines used: TYPEi, DRWCHR.

3.4.58 WPLT1 (Write a Plotter Command for Plotter 1).

3.4.58.1 Entry Point: WPLT1.

3.4.58.2 Purpose

To write a plotter command for plotter 1.

3.4.58.3 Calling Sequence

CALL WPLT1 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/CHAR94/ - see CHAR94 Miscellaneous Table description, section 2.5.

where:

A(1) - x-coordinate (integer).

A(2) - y-coordinate (integer).

A(3) - annotation character index (a).

A(4) - control character index (c_1).

A(5) - control character index (c_2).

A(6) - control character index (c_3).

ØPT - {0, if A is a plot command; 1, if a series of plot commands is to be terminated} integer - input.

/PLTDAT/

EDGE - size of the x and y borders of the paper - real - input.

PLØT - GINØ file name of the plot tape to be written - BCD - input.

/CHAR94/

CHAR(60,3) - sections II, III, and IV of the CHAR94 character table - integer - input.

3.4.58.4 Method

If computer 1 (IBM 7094) is the computer being used, section II of the CHAR94 table is used as the characters written on the plot tape; if computer 4 (CDC 6600) section IV is used; if any

other computer, section III is used.

The lower left corner of the paper is assumed to be at (0,0). Taking into account the x and y borders, the true x and y coordinates are calculated. These coordinates are then separated into four integer digits. The plot command is then set up and written as follows:

$$rbx_4x_3x_2x_1bby_4y_3y_2y_1bc_1c_2bbc_3babbbbb$$

preceeded by 35 blanks. The resulting plot command is 60 characters long.

r = record mark (character 49 in the CHAR94 table)

b = blank (character 48 in the CHAR94 table)

x_i = x-coordinate digit

y_i = y-coordinate digit

c_i = control character

a = annotation character.

3.4.58.5 Design Requirements

Subroutine used: SWRITE.

3.4.59 WPLT2 (Write a Plotter Command for Plotters 2 and 8)

3.4.59.1 Entry Point: WPLT2.

3.4.59.2 Purpose

To write a plot command for plotters 2 and 8.

3.4.59.3 Calling Sequence

CALL WPLT2 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/CHAR94/ - see CHAR94 Miscellaneous Table description, section 2.5.

where:

A(1) = x-coordinate (integer).

A(2) = y-coordinate (integer).

A(3) = annotation character index (a).

A(4) = control character index (c_1).

A(5) = control character index (c_2).

A(6) = control character index (c_3).

ØPT = {0, if A = plot command; 1, if a series of plot commands is to be terminated} - integer - input.

/PLTDAT/

AXYMAX - size of the paper (in plotter units) being used, less the border - real - input.

PLØT - GINØ file name of the plot tape to be written - BCD - input.

/CHAR94/

CHAR(60,3) - sections II, III and IV of the CHAR94 table - integer - input.

3.4.59.4 Method

If computer 1 (IBM 7094) is the computer being used, section II of the CHAR94 table is used for the characters written on the plot tape; if computer 4 (CDC 6600), section IV is used; if any

other computer, section III is used.

Assuming the true physical origin of the plotter to be at the center of the paper, the true x and y coordinates are calculated. These coordinates are then separated into four integer digits. A plot command is then set up and written as follows:

$$Xs_x x_4 x_3 x_2 x_1 Ys_y y_4 y_3 y_2 y_1 bbbbbbbbc_1 c_2 ac_3$$

preceeded by 96 blanks. The resulting plot command is 120 characters long.

X = character X (character 34 in the CHAR94 table)

Y = character Y (character 35 in the CHAR94 table)

s_x = + or - character depending upon the sign of the x-coordinate.

s_y = + or - character depending upon the sign of the y-coordinate.

x_i = x-coordinate digit.

y_i = y-coordinate digit.

b = blank (character 48 in the CHAR94 table).

c_i = control character.

a = annotation character.

3.4.59.5 Design Requirements

Subroutine used: SWRITE.

3.4.60 WPLT3 (Write a Plotter Command for Plotter 3).

3.4.60.1 Entry Point: WPLT3.

3.4.60.2 Purpose

To write a plot command for plotter 3.

3.4.60.3 Calling Sequence

CALL WPLT3 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

A(1) and A(2) = 36 bit plot command set up by AXIS3, LINE3, or TYPE3, as 2 18-bit words (right justified, leading zeros) - input.

$$\text{ØPT} = \left\{\begin{array}{l} 0, \text{ if A = plot command} \\ 1, \text{ if a series of plot commands is to be terminated} \end{array}\right\} \text{ - integer - input.}$$

/PLTDAT/

PLØT - GINØ file name of the plot tape to be written - BCD - input.

MAXCHR - plot tape buffer size (number of characters) - integer - input.

3.4.60.4 Method

Each plotter command is 36 bits long (6 six-bit characters). Six of the 36 bits in A(1) and A(2) are written on the plot tape until all 36 bits have been written. In addition, the number of six-bit characters written in a record is calculated. When WPLT3 is called with ØPT = 1, a check is made to determine if the number of 6 bit characters written in the current record is an integer multiple of the number of characters per word on the computer. If such is not the case, an additional 36 bit command is written as many times as necessary until this condition does exist before terminating the plot tape record. The command used will do nothing to affect the generated plot.

3.4.60.5 Design Requirements

Subroutine used: SWRITE.

3.4.61 GINØIØ (GINØ Input/Output Routine).

3.4.61.1 Entry Point: GINØIØ.

3.4.61.2 Purpose

GINØIØ executes the physical input/output operations for subroutine GINØ.

3.4.61.3 Calling Sequence

CALL GINØIØ($n,ØPCØDE,BUFF)

CØMMØN/GINØX/LGINØX,FILEX,EØR,ØP,ENTRY,LSTNAM,N,NAME,NTAPE,XYZ(2),UNITAB(75),BUFADD(75),
NBUFF3,ERRØR,NØSECT.

n - FØRTRAN statement number defining return in the event of an I/Ø error.

ØPCØDE - { 1, Rewind
2, Write one block
3, Read one block
4, Backspace one block
5, Forward space one block } input - integer.

BUFF - Address of the block to be read or written.

FILEX - Unit number of file - integer - input.

NBUFF3 - Length of block to be read or written - integer - input.

ERRØR - { 7, Abnormal completion of I/Ø operation
8, Physical end-of-file encountered
9, Data transmission error } integer - output.

NØSECT - Number of sectors per block on FASTRAND drum (Univac 1108 only) - integer - input.

3.4.61.4 Method

The machine cell in /SYSTEM/ is tested. For the IBM 7094 or IBM S/360 computers, FØRTRAN REWIND, WRITE, READ and BACKSPACE operations are used. For the Univac 1108, the NTRAN routine is used.

3.4.61.5 Design Requirements

GINØIØ is designed as an integral part of the GINØ collection of routines and is to be called only by GINØ.

Since all input/output operations by GINØ are made by GINØIØ, a change to interface with a new or different operating system can easily be made by modifying GINØIØ.

3.4.62 EJECT (Automatic Page Eject)

3.4.62.1 Entry Point: EJECT

3.4.62.2 Purpose

Automatic line counting for printed output and new page initiation when pages are filled.

3.4.62.3 Calling Sequence

K = EJECT (LINES)

COMMON /SYSTEM/ - see SYSTEM table description, section 2.4.1.8.

where:

LINES - Number of lines to be printed.

/SYSTEM/

MAXLIN - Maximum number of lines permitted per page.

LINCNT - Number of lines thus far printed on this page.

3.4.62.4 Method

If the number of lines already printed on this page (LINCNT) added to the number of lines about to be printed (LINES) would be greater than the number of lines permitted per page (MAXLIN), a new page is started (CALL PAGE1), the current line counter is set to the number of lines to be printed (LINCNT = LINES), and the result of this function is set to 1 (EJECT = 1).

If the number of lines about to be printed (LINES) will fit on this page (LINCNT + LINES $\leq$ MAXLIN), the result of this function is set to 0 (EJECT = 0).

3.4.62.5 Design Requirements

If it is desired to force a new page to be started, simply set LINCNT = MAXLIN before calling this function.

3.4.63 PLAMAT (Material Property Utility for Two-Dimensional Elements in Piecewise Linear Analysis).

3.4.63.1 Entry Point: PLAMAT.

3.4.63.2 Purpose

To perform the following matrix operation:

$$[C] = [A]^T [B] [A] ,$$

where [A] is equal to [U] (see the subroutine description for PREMAT and MAT, section 3.4.36.3, for a definition of [U] with INFLAG = 2), and [B] is equal to a previously calculated material properties matrix which is in common block /PLAGP/. The result [C], which is symmetric, is stored in common block /MATØUT/.

3.4.63.3 Calling Sequence

```
CALL PLAMAT
CØMMØN/PLAGP/GP(9),MIDGP,ELID
CØMMØN/MATIN/MATID,INFLAG,ELTEMP,PLAARG,SINTH,CØSTH
CØMMØN/MATØUT/G11,G12,G13,G22,G23,G33,DUMMY(14)
```

where:

/PLAGP/

GP(9) = 3x3 material properties matrix calculated in a PLA element driver - real - input.

MIDGP = the material identification number associated with GP - integer - input.

ELID = the element identification number associated with GP - integer - input.

/MATIN/

MATID = the incoming material identification number - integer - input.

INFLAG, ELTEMP, PLAARG = not used by PLAMAT.

SINTH = Sine of the material property orientation angle - real - input.

CØSTH = Cosine of the material property orientation angle - real - input.

/MATØUT/

Same as /MATØUT/ with INFLAG = 2 as described in section 3.4.36.3 except only the first six cells are used.

3.4.63.4 Method

This routine checks to see if the incoming material identification number (MATID) is equal to the material identification number (MIDGP) which was used to calculate the material properties matrix stored in /PLAGP/. If they are not equal, this routine calls MAT with INFLAG = 2 and returns to the calling program. This will only happen in combination elements (TRIA1, TRIA2, QUAD1, QUAD2) where there is a different material identification number used for the membrane and plate properties. If they are equal, then the matrix operation described above is performed.

3.4.64 WPLT4 (Write a Plotter Command for Plotters 4 Through 7).

3.4.64.1 Entry Point: WPLT4.

3.4.64.2 Purpose

To write plot commands for plotters 4 through 7.

3.4.64.3 Calling Sequence

CALL WPLT4 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

A(1) = command type (0 = control, 2 = line, 4 = position)

A(2-N) = additional data used to generate the plot commands (contents and length, N, vary with command type) - integer, input.

ØPT = 0, if a plot command is to be generated; 1, if the current command buffer is to be terminated - integer, input.

/PLTDAT/

PLTMDL = plotter model number - integer - input.

PLØTER = plotter number - integer - input.

PLØT = GINØ file name of the plot tape to be written - BCD - input.

3.4.64.4 Method

The resulting plot command varies in length, depending both on the command type and the amount of necessary drum movement. If A(1) = 0 (control command), A(2) = number of control characters in the resulting command (one character expressed as a right adjusted integer in each word of the A array, starting in A(3)).

If A(1) = 2 or 4 (line or positioning command), the resulting plot command will begin with the characters necessary to lower or raise the pen, respectively, unless the pen is already down or up, respectively. A(2) and A(3) contain the number of X and Y half steps necessary to draw the line

(with the pen down or up), while A(4) and A(5) contain pointers to two character strings needed to draw the entire line except for the final half step. A(6) and A(7) contain the pointers needed to draw the last half step of the line only. The pointers in A(4 - 7) will cause drum movements as follows:

1 = +Y	9 = +Y/2	17 = +X/2, +Y
2 = +X, +Y	10 = +X/2, +Y/2	18 = -X, +Y/2
3 = +X	11 = +X/2	19 = +X, -Y/2
4 = +X, -Y	12 = +X/2, -Y/2	20 = +X/2, -Y
5 = -Y	13 = -Y/2	21 = -X/2, -Y
6 = -X, -Y	14 = -X/2, -Y/2	22 = -X, -Y/2
7 = -X	15 = -X/2	23 = -X, +Y/2
8 = -X, +Y	16 = -X/2, +Y/2	24 = -X/2, +Y

The number of characters in a string is a function of the internal plotter model number, PLTMDL. If PLTMDL = 1, each string is three characters; if PLTMDL = 2 or 4, each string is two characters; and if PLTMDL = 3 or 5, each string is only one character.

As required, this subroutine will automatically initiate each plot tape record with the necessary "conditioning, synchronizing, and start plot" characters, and terminate each plot tape record with the necessary "stop plot" characters.

3.4.64.5 Design Requirements

The only incremental drum movements available for the CALCOMP drum plotter indicated as PLTMDL = 1 are the first eight (8) as listed above. Therefore, when A(1) = 2 or 4, the values in A(4 - 7) must be less than nine (9).

Subroutine used: SWRITE.

3.4.65 WPLT9 (Write a Plotter Command for Plotter 9).

3.4.65.1 Entry Point: WPLT9.

3.4.65.2 Purpose

To write a plot command for plotter 9.

3.4.65.3 Calling Sequence

CALL WPLT9 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

A = 10-character plot command (1 character per word, right justified, leading zeros) - integer - input.

ØPT = { 0 if A = plot command ; 1 if a series of plot commands is to be terminated } integer - input.

/PLTDAT/

PLØT = GINØ file name of the plot tape to be written - BCD - input.

3.4.65.4 Method

If ØPT = 0, the 10 characters are written on the plot tape without any changes. If ØPT = 1, two characters are appended to the current record:

62_8 (EXIT code) and 61_8 (NØP code).

3.4.65.5 Design Requirements

Subroutine used: SWRITE.

3.4.66 WPLT10 (Write a Plotter Command for the NASTRAN General Purpose Plotter).

3.4.66.1 Entry Point: WPLT10.

3.4.66.2 Purpose

To write the plotter commands for the NASTRAN general purpose plotter.

3.4.66.3 Calling Sequence

CALL WPLT10 (A,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

A(1) = plot mode index
A(2) = control index
A(3) = x_1 = x-coordinate
A(4) = y_1 = y-coordinate
A(5) = x_2 = x-coordinate
A(6) = y_2 = y-coordinate

} - integer - input.

ØPT = { 0 if A = plot command
1 if a series of plot commands is to be terminated } - integer - input.

/PLTDAT/

EDGE = size of the borders (x,y) in plotter units - real - input.

PLØT = GINØ file name of the plot tape to be written - BCD - input.

MAXCHR = plot tape buffer size (number of characters) - integer - input.

3.4.66.4 Method

Each plot command written is composed of 30 six-bit unsigned integers. The plot mode index, A(1), and the control index, A(2), are the first two integers. The next 20 integers represent the values in A(3-6). Each value is represented by five 6-bit integers, each integer being a decimal digit of the decimal representation of the value as follows:

$$d_4 d_3 d_2 d_1 d_0$$

where the original integer value is given by

$$d_0.10^0 + d_1.10^1 + d_2.10^2 + d_3.10^3 + d_4.10^4 \ .$$

This representation is used so as to make it easy to recover the original integer values on any binary computer. The last 8 characters are always zeros.

The end result is a plot command of the following format:

$$MCP_4P_3P_2P_1P_0Q_4Q_3Q_2Q_1Q_0R_4R_3R_2R_1R_0S_4S_3S_2S_1S_0OOOOOOOO$$

where:

M = plot mode index

C = control index

P_i = decimal digit of the 1^{st} integer value

Q_i = decimal digit of the 2^{nd} integer value

R_i = decimal digit of the 3^{rd} integer value

S_i = decimal digit of the 4^{th} integer value

O = zero

When WPLT10 is called with ØPT = 1, the current plot tape record is filled with as many dummy plot commands as is necessary to generate a fixed length record. The dummy plot command is made of 30 zeros. This is done so that the plot tape can be read in FØRTRAN without having to worry about variable length records as long as the plot tape buffer size (MAXCHR) is an integer multiple of the number of characters per word on the computer on which the plot tape is being read (see section 6.10.6 for further details).

3.4.66.5 Design Requirements

Subroutine used: SWRITE.

3.4.67 PLTSET (Plotting Parameter Initialization).

3.4.67.1 Entry Point: PLTSET.

3.4.67.2 Purpose

Given the internal plotter and model numbers, to initialize the /XXPARM/ and /PLTDAT/ tables as needed by the NASTRAN plotter software package.

3.4.67.3 Calling Sequence

```
CALL PLTSET
```

CØMMØN/XXPARM/ - see XXPARM Miscellaneous Table description, section 2.5.

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

where:

/XXPARM/

PBUFSZ = plot tape buffer size (number of words) - integer - output.

PAPSIZ = size of the paper to be used (inches) - real - input.

/PLTDAT/

MØDEL = internal plotter model number - integer - input.

PLØTER = internal plotter number - integer - input.

REG = plotting region parameters - real - output.

AXYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - output.

XYEDGE = size of the borders (x,y) in plotter units - real - output.

XYMAX = maximum useable x and y coordinate values on the plotter - real - output.

CNTSIN = number of plotter counts per inch of paper - real - output.

CNTCHR = number of plotter counts per character in the x and y directions - real - output.

PLTYPE = plotter type - integer - output.

PBFSIZ = plot tape buffer size (number of characters) - integer - output.

3.4.67.4 Method

Using the internal plotter (PLØTER) and model (MØDEL) numbers, the initialization needed to properly use the NASTRAN plotting software is performed as follows:

1. Section 2 of /PLTDAT/, of which XYMAX, CNTSIN, CNTCHR, PLTYPE and PBFSIZ are a part, is set to a duplicate of section PLØTER+2.

2. PBUFSZ of /XXPARM/ is then set to PBFSIZ/CHRWRD where CHRWRD = number of characters per word on the subject computer.

3. AXYMAX and XYEDGE are calculated based upon the plotter type and/or paper size. If the plotter is a table plotter (PLTYPE = +2 or -2), the borders are set up as 1/2 inch borders. If the plotter is not a table plotter and has no typing capability (PLTYPE = -1 or -3), the borders are set up as half the horizontal and vertical character sizes (CNTCHR/2). Otherwise, the borders are set to zero.

4. The plotting region is then set to (0,0,AXYMAX(1),AXYMAX(2)). This region can be subsequently altered by the module writer.

3.4.68 DRWCHR (To Draw a Line of Characters).

3.4.68.1 Entry Point: DRWCHR.

3.4.68.2 Purpose

To draw a line of characters on a plotter, horizontally or vertically.

3.4.68.3 Calling Sequence

CALL DRWCHR (X,Y,XYD,CHR,NN,ØPT)

CØMMØN/PLTDAT/ - see PLTDAT Miscellaneous Table description, section 2.5.

CØMMØN/CHRDRW/ - see CHRDRW Miscellaneous Table description, section 2.5.

where:

X,Y = starting or ending coordinate of the line of characters to be drawn (always left-to-right or top-to-bottom) - real - input.

XYD = { ±1 if X = starting or ending point of the line
      { ±2 if Y = starting or ending point of the line } - integer - input.

CHR = indices of the line of characters to be drawn (see subroutine TIPE) - integer - input.

NN = number of the characters to be drawn - integer - input.

ØPT = { -1 to initiate the line mode.
      { +1 to terminate a series of plot commands.
      { 0 to draw a line of characters. } - integer - input.

/PLTDAT/

REG = plot region parameters - real - input.

XYMAX = size of the paper (x,y) used, less the borders, in plotter units - real - input.

EDGE = size of the border (x,y) in plotter units - real - input.

CNTCHR = number of plotter counts per character in the x and y directions - real - input.

/CHRDRW/

LSTIND = index of the last character which can be drawn - integer - input.

CHRIND = indices into XYCHR used to locate the data needed to draw characters - integer - input.

XYCHR = lines which must be drawn to produce alphanumeric characters - integer - input.

3.4.68.4 Method

If ØPT = 0, all other arguments are ignored and LINE is called. Otherwise, the characters are drawn. The width and height of each character position are assumed to be integer multiples of 8 and 16, respectively. The size of the drawn character will be this integer multiple of 6. The remaining space in each character position is used as the horizontal and vertical spacing. No character will be drawn outside the region specified in REG.

3.4.68.5 Design Requirements

Subroutine used: LINE.

3.4.69 FNDPLT (Determine the Internal Plotter and Model Indices).

3.4.69.1 Entry Point: FNDPLT.

3.4.69.2 Purpose

Given the external name and model of a plotter, to determine the corresponding internal plotter and model numbers used by the NASTRAN plotting software package.

3.4.69.3 Calling Sequence

```
CALL FNDPLT (PLØTER,MØDEL,PLTNAM,PMØDEL)
```

where:

PLØTER = internal plotter number - integer - output.

MØDEL = internal model number - integer - output.

PLTNAM(2) = external plotter name - BCD - input.

PMØDEL(2) = external model name - integer or BCD - input and output.

3.4.69.4 Method

PLTNAM and PMØDEL are compared with an internal table of plotter names and models. When a match is found, PLØTER and MØDEL are set to the corresponding internal plotter and model numbers. If a match is found only for the plotter name (PLTNAM), the model name for the first model appropriate to the matched model name will be used to determine PLØTER and MØDEL, and the model name used will be stored in PMØDEL. If no match is found, PLØTER and MØDEL will be set to zero. See section 3.1 for further details.

3.4.70 PHDMIA (DMI punch routine)

3.4.70.1 Entry Points: PHDMIA, PHDMIB, PHDMIC, PHDMID

3.4.70.2 Purpose

Writes DMI bulk data card images on a FØRTRAN unit for small real matrices.

3.4.70.3 Calling Sequence

CALL PHDMIA - Initializes matrix
CALL PHDMIB - Initializes each non-null column
CALL PHDMIC - Collect each non-zero term of column
CALL PHDMID - Wrap up column
CØMMØN /PHDMIX / N(2),C,IFØ,TIN,TØUT,IR,IC,NØ,KPP,NLP,ERNØ,ICØL,IRØ,XX

Communication area as follows:

N - Alphanumeric name of matrix, 2A4.

C - Alphanumeric string for continuation chaining, A3.

IFØ - 1 for a square, non-symmetric matrix;
2 for a rectangular matrix;
6 for a symmetric matrix.

TIN - 1 (input to IFP will be single precision).

TØUT - 1 if IFP is to generate single-precision terms.
2 if IFP is to generate double-precision terms.

IR - Number of rows in matrix, Integer > 0.

IC - Number of columns in matrix, Integer > 0.

NØ - FØRTRAN printer output unit number (if NØ $\leq$ 0, no printing will be done; if NØ > 0, the card images will be listed on FØRTRAN unit NØ as well as "punched").

KPP - 1, single-field DMI card images will be generated;
2, double-field DMI card images will be generated.

NLP - Number of data lines per page.

ERNØ (output) - 0, no errors were detected;
1, more than 9999 card images for a single matrix were requested.

ICØL - Current column number.

IRØ - Current row number.

XX - Current value of matrix term as a single-precision floating point number.

3.4.70.4 Method

To use this routine, carry out the steps below after loading the common block.

1. For each matrix, CALL PHDMIA. All data items in /PHDMIX/ must be loaded except ERNØ (output), ICØL, IRØ and XX.

2. For each non-null column, do the following:

   a. Load ICØL, IRØ and XX with data corresponding to the first non-zero term in the column.

   b. CALL PHDMIB

   c. For any other non-zero terms in the column, load IRØ and XX and

   d. CALL PHDMIC

   e. After all non-zero terms have been processed, CALL PHDMID to wrap up the column.

Matrices will be punched on single-field DMI cards using a F8.1 format for the element values if KPP = 1; double-field cards will be punched using a 1PE16.8 field if KPP = 2.

3.4.70.5 Design Requirements

A PUNCH file is assumed to exist on FØRTRAN unit 7.

3.4.70.6 Diagnostic Messages

None.

3.4.71 HEAD (Plot Heading)

3.4.71.1 Entry Point: HEAD

3.4.71.2 Purpose

Creates heading blocks for plot frames.

3.4.71.3 Calling Sequence

CALL HEAD (T,N,L,V)

T - Type - 1 = STATIC
2 = MØDAL
3 = TRANSIENT

N - Deformation Number (0 = undeformed shape)

L - Load Case Identification Number

V - Value of eigenvalue or time.

3.4.71.4 Method

The TITLE, SUBTITLE and LABEL are picked up from /ØUTPUT/ and plotted in the lower left hand corner of the plot frame, followed by the plot identification line.

3.4.71.5 Design Requirements

The plotter software package must be available to this routine.

3.4.71.6 Diagnostic Messages

None.

3.4.72 DELSET (Dummy Element Setup)

3.4.72.1 Entry Point: DELSET

3.4.72.2 Purpose

Modifies /GPTA1/ to accommodate any dummy elements present.

3.4.72.3 Calling Sequence

CALL DELSET

3.4.72.4 Method

The ADUMi bulk data card information is picked up from the 46^{th} thru 54^{th} words of /SYSTEM/ where it was placed by IFS5P. The desired entries in /GPTA1/ are generated and inserted into the 53^{rd} thru 61^{st} positions as required.

3.4.72.5 Design Requirements

All modules using /GPTA1/ should call this routine to insure that the dummy elements are properly recognized.

3.4.72.6 Diagnostic Messages

None.

3.4.73 HMAT (Heat Transfer Material Property Utility)

3.4.73.1 Entry Point: HMAT

3.4.73.2 Purpose

To obtain material property data for Heat Transfer element routines.

3.4.73.3 Calling Sequence

CALL HMAT (ID,Z)

ID - = 0, set up call made by SMA1A;
> 0, element identification number on calls made by element routines.

Z - Working core.

3.4.73.4 Method

1. Initialization call (ID = 0)

   Read into core all MAT4 and MAT5 cards and check for any duplicate identification numbers.

2. Element Routine calls (ID > 0)

   If previous call had the same request data, return to the calling routine. Otherwise, look up the desired material data in core, extract the desired information, and return to the calling routine.

3.4.73.5 Design Requirements

Working core must be sufficient to hold all of the MAT4 and MAT5 data. Utility routines PRELØC and BISRCH are used.

3.4.73.6 Diagnostic Messages

Messages 3002, 3008, 2157, 3062 and 2156 may be issued.

3.4.74 BISRCH (Binary Search)

3.4.74.1 Entry Point: BISRCH

3.4.74.2 Purpose

To perform a binary search on a list of sorted data.

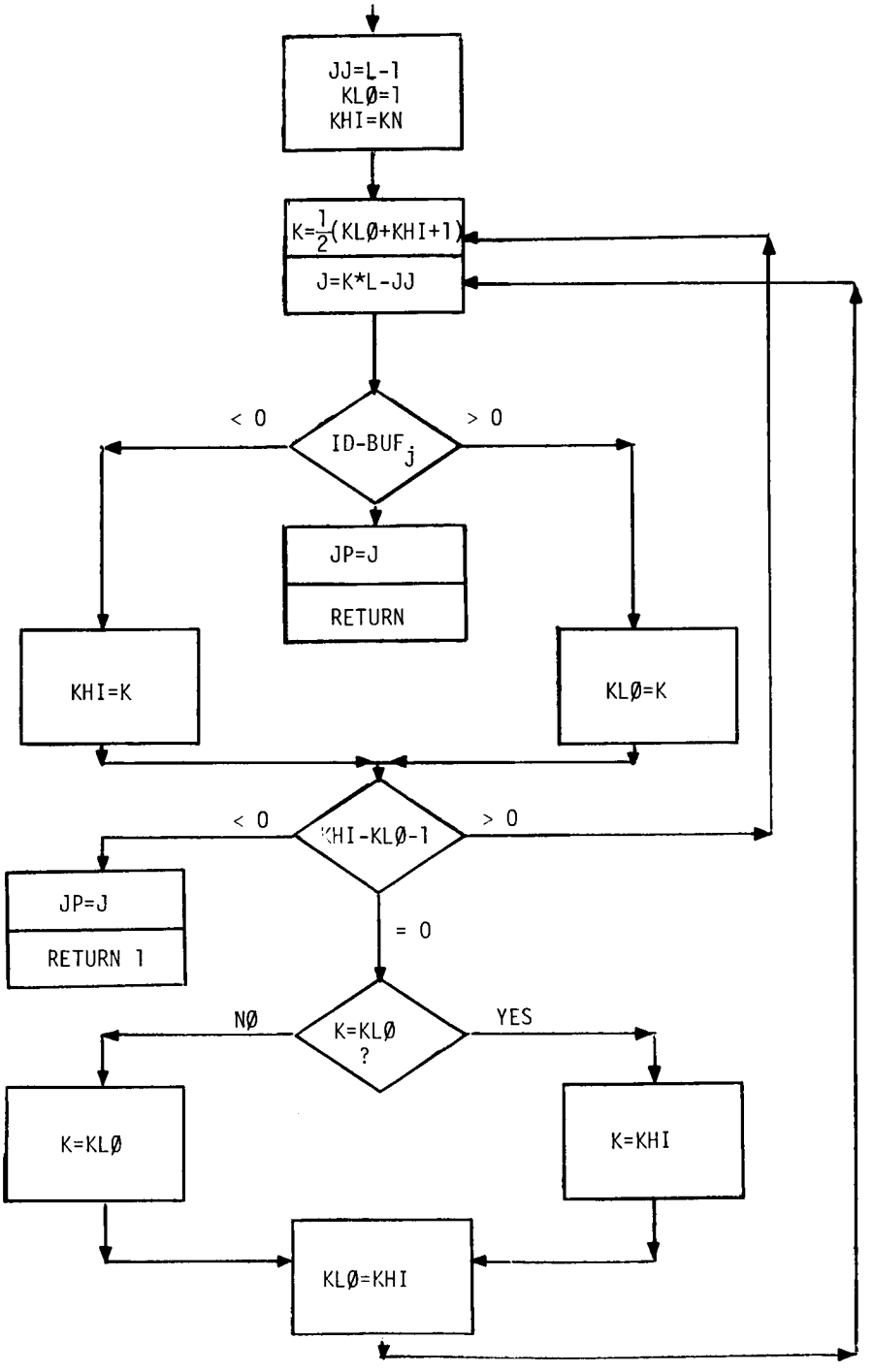
3.4.74.3 Calling Sequence

CALL BISRCH ($n ID,BUF,L,KN,JP)

- n - FØRTRAN statement number defining the return to be taken in the event a match is not found.
- ID - Word to match with first word of entry.
- BUF - Array to be searched.
- L - Length of each entry of array.
- KN - Number of entries in BUF.
- JP - Pointer returned to calling program. This pointer gives the first word of the matching entry in the array.

3.4.74.4 Method

A standard binary search algorithm is used as shown below:



3.4.74.5 Design Requirements

None.

3.4.74.6 Diagnostic Messages

None.

3.4.75 FØRFIL (File Unit)

3.4.75.1 Entry Point: FØRFIL

3.4.75.2 Purpose

To extract the logical unit to which a given GINØ file name belongs.

3.4.75.3 Calling Sequence

```
INTEGER FØRFIL
NUNIT = FØRFIL(NAME)
```

NAME - GINØ file name

3.4.75.4 Method

FØRFIL searches the FIST for the GINØ file name. When a match is found, the internal unit number is either /XXFIAT/ or /XFIAT/ and is extracted and returned through the function name as in integer.

3.4.75.5 Design Requirements

None.

3.4.75.6 Diagnostic Messages

Message 2179 may be issued in the event that the requested GINØ file name cannot be found.

3.4.76 DADØTB (Double Precision Vector Dot Product)

3.4.76.1 Entry Point: DADØTB

3.4.76.2 Purpose

To compute the scalar inner product of two vectors in double precision.

3.4.76.3 Calling Sequence

```
DØUBLE PRECISIØN DADØTB, A(3),B(3),C
C = DADØTB(A,B)
```

3.4.76.4 Method

$$C = \sum_{2=1}^{3} A_i B_i$$

3.4.76.5 Design Requirements

None.

3.4.76.6 Diagnostic Messages

None.

3.4.77 DAXB (Double Precision Vector Cross Product)

3.4.77.1 Entry Point: DAXB

3.4.77.2 Purpose

To compute the vector product of two vectors in double precision.

3.4.77.3 Calling Sequence

```
DØUBLE PRECISIØN A(3),B(3),C(3)
CALL DAXB (A,B,C)
```

3.4.77.4 Method

$\vec{D} = \vec{A} \times \vec{B}$

$\vec{C} \Leftarrow \vec{D}$

3.4.77.5 Design Requirements

$\vec{C}$ may overlay $\vec{A}$ or $\vec{B}$ in core.

3.4.77.6 Diagnostic Messages

None.

3.4.78 SADØTB (Single Precision Vector Dot Product)

3.4.78.1 Entry Point: SADØTB

3.4.78.2 Purpose

To compute the scalar inner product of two vectors in single precision.

3.4.78.3 Calling Sequence

```
DIMENSIØN A(3),B(3)
C  =  SADØTB (A,B)
```

3.4.78.4 Method

$$C = \sum_{i=1}^{3} A_i B_i$$

3.4.78.5 Design Requirements

None.

3.4.78.6 Diagnostic Messages

None.

3.4.79 SAXB (Single Precision Vector Cross Product)

3.4.79.1 Entry Point: SAXB

3.4.79.2 Purpose

To compute the vector product of two vectors in single precision.

3.4.79.3 Calling Sequence

```
DIMENSIØN  A(3),B(3),C(3)
CALL SAXB (A,B,C)
```

3.4.79.4 Method

$\vec{D} = \vec{A} \times \vec{B}$

$\vec{C} \Leftarrow \vec{D}$

3.4.79.5 Design Requirements

$\vec{C}$ may overlap $\vec{A}$ or $\vec{B}$ in core.

3.4.79.6 Diagnostic Messages

None.

3.5 MATRIX SUBROUTINE DESCRIPTIONS.

3.5.1 BLDPK (Build a Packed Column of a Matrix).

3.5.1.1 Entry Points: BLDPK, BLDPKI, ZBLPKI, BLDPKN.

3.5.1.2 Purpose

To write a column of a matrix in NASTRAN packed format.

3.5.1.3 Calling Sequence

If several different matrices are to be packed concurrently, the multi-column version is used:

```
CALL BLDPK(TYPIN,TYPØUT,NAME,BLØCK,ØPT,1)
CALL BLDPKI(A,I,NAME,BLØCK,ØPT)
CALL BLDPKN(NAME,BLØCK,ØPT,MCB)
```

where:

BLDPK is an initialization call and is made once for each column to be packed.

BLDPKI is the call made to supply a single element of the column to be packed.

BLDPKN is a call to terminate processing of the column.

TYPIN - Arithmetic type of the elements to be packed (1 = real single precision, 2 = real double precision, 3 = complex single precision, 4 = complex double precision)- integer - input.

TYPØUT - Arithmetic type of the elements in the packed column - integer - input.

NAME - { ØPT = 'WRITE': GINØ file name of data block where packed column will be written.
ØPT = 'WRTCØR': An array in core where packed column will be written.

BLØCK - An array of dimension $\geq$ 20 for use by BLDPK and BLDPKI.

ØPT - { 'WRITE': The packed column will be written by GINØ. } Input
'WRTCØR': The packed column will be written in core. } Subroutine name

A - An array of dimension 1, 2 or 4 (depending on TYPIN) where the element to be packed is stored - real - input.

I - Row position of element to be packed - integer - input.

MCB - An array of dimension 7 where the trailer information about the matrix is accumulated.

If only one matrix is being packed, the single column version should be used as it is more efficient.

```
CØMMØN/ZBLPKX/A(4),I
```

```
CALL BLDPK(TYPIN,TYPØUT,NAME,0, ØPT,0)
CALL ZBLPKI
CALL BLDPKN(NAME,0,ØPT,MCB)
```

where:

BLDPK and its arguments are as defined above.

ZBLPKI is the call made to provide an element of the column to be packed. The element (A), and its row position (I), are stored in /ZBLPKX/ by the user prior to each CALL ZBLPKI.

BLDPKN and its parameters are defined as above.

Note:

BLDPKN accumulates the following two words of MCB:

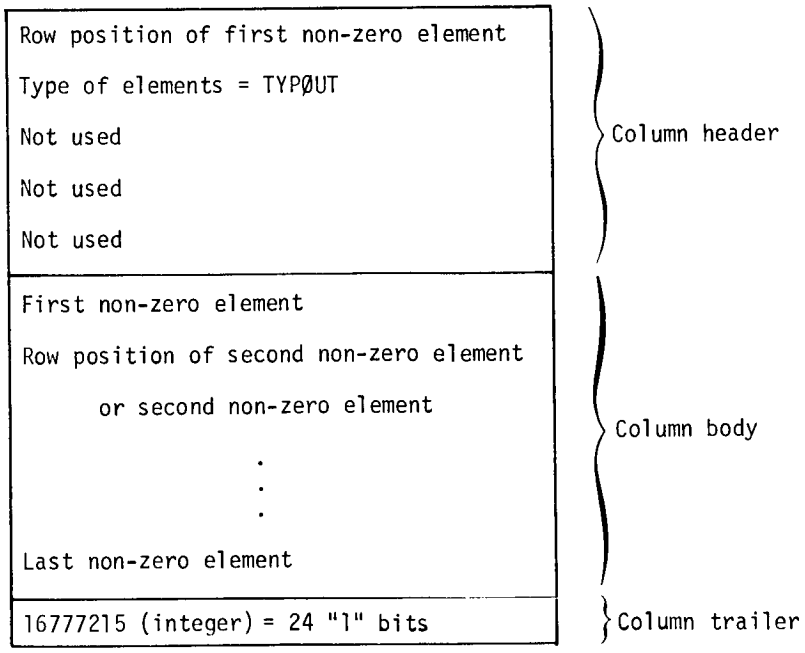
MCB(2) = column number

MCB(6) = number of words in the densest column

In the multi-column version, BLØCK must be different for each matrix being packed.

3.5.1.4 Method

Format of a packed column (one logical record):



Example:

Assume a column of a real single precision 19xN matrix is to be packed in real single precision form:

Row Position	Value	Packed Format
1	0.0	4
2	0.0	1
3	0.0	Not used
4	1.0	Not used
5	2.0	Not used
6	0.0	1.0
7	3.0	2.0
8	4.0	7
9	5.0	3.0
10	6.0	4.0
11	7.0	5.0
12	8.0	6.0
13	0.0	7.0
14	0.0	8.0
15	0.0	16777215
16	0.0	
17	0.0	
18	0.0	
19	0.0	

For each of the 16 possible combinations of TYPIN and TYPØUT, BLDPK sets switches for the type of conversion to be used in packing. For the multi-column version, these switches and other pointers are saved in BLØCK. BLDPKI restores the switches and pointers and moves the element and its row position to /ZBLPKX/ then enters code common with ZBLPKI. If the element is zero, an immediate return is given. If the element is the first non-zero element for the column, the 5-word header is written followed by the element. Otherwise, the row position of the current element is compared to the row position of the last element. If the difference is unequal to one, the current row position is written. In either case, the non-zero element is written and return is made.

3.5.1.5 Design Requirements

Let I_j and I_{j+1} be the rows positions of two elements supplied in successive calls to BLDPKI or ZBLPKI. Then $I_{j+1} > I_j$ for all j of a column.

If ØPT = 'WRTCØR', then the block NAME must be initialized prior to each call to BLDPK (see ØPNCØR).

If the single column version is used, subroutine PACK may not be called between calls to BLDPK and BLDPKN.

MCB(2), MCB(6) and MCB(7) must be set to zero by the user prior to the first call of BLDPKN for a matrix.

The exact format of a packed column is machine dependent. See Section 5 for details.

3.5.2 PACK (Pack a Column of a Matrix).

3.5.2.1 Entry Point: PACK.

3.5.2.2 Purpose

To pack and write a column of a matrix.

3.5.2.3 Calling Sequence

```
CØMMØN/PACKX/TYPIN,TYPØUT,I,N,INCR
CALL PACK(A,NAME,ØPT,MCB)
```

A - An array where the elements of the column are stored in unpacked form.

NAME - ØPT = 'WRITE', GINØ name of the data block where the packed column will be written.
ØPT = 'WRTCØR', an array in core where the packed column will be stored.

ØPT - WRITE: Packed column will be written by GINØ.
WRTCØR: Packed column will be stored in core at NAME.
} Input Subroutine name

MCB - An array of dimension = 7 where the matrix trailer information will be accumulated.

TYPIN - Arithmetic type of the elements of the column stored at A (1 = real single precision, 2 = real double precision, 3 = complex single precision, 4 = complex double precision).

TYPØUT - Arithmetic type in which the elements are to be in packed form. Same convention as TYPIN.

I - Row position of the element stored at A(1).

N - Row position of the last element in the column stored at A.

INCR - Spacing of the elements in column stored at A in units of elements, e.g., if real double precision elements are stored consecutively, INCR = 1.

3.5.2.4 Method

BLDPK is called to initiate activity for the column. For each element in the column, ZBLPKI is called to perform packing and writing. BLDPKN is called to terminate activity for the column and update the matrix trailer.

3.5.2.5 Design Requirements

See subroutine description for BLDPK, section 3.5.1.

3.5.3 INTPK (Interpret a Packed Column of a Matrix).

3.5.3.1 Entry Points: INTPK, INTPKI, ZNTPKI.

3.5.3.2 Purpose

To read and interpret a column of a matrix in NASTRAN packed format.

3.5.3.3 Calling Sequence

If several different matrices are to be read and interpreted concurrently, the multi-column version is used.

```
CALL INTPK($n,NAME,BLØCK,ØPT,TYPØUT,1)

CALL INTPKI(A,I,NAME,BLØCK,ØPT,EØL)
```

where INTPK is the initialization call and is made once for each column to be read and interpreted.

INTPKI is the call made to read successive non-zero elements of the column. Each call to INTPKI returns one non-zero element.

n - FØRTRAN statement number defining return to be taken in the event the column is null.

NAME { ØPT = 'READ', GINØ file name of data block where the matrix is stored.
{ OPT = 'RDCØR', as array of core storage where the matrix is stored.

BLØCK - An array of dimension $\geq$ 20 for use by INTPK and INTPKI.

ØPT { 'READ' - The column will be read by GINØ. } Input,
{ 'RDCØR' - The column will be read from core storage. } Subroutine name

TYPØUT - Arithmetic type into which the elements are to be unpacked ($\pm$1 = real single precision, $\pm$2 = real double precision, $\pm$3 = complex single precision, $\pm$4 = complex double precision). If TYPØUT < 0, the sign of each non-zero element is to be changed - integer - input.

A - An array of dimension 1, 2 or 4, depending on TYPØUT, where the non-zero element is to be stored - real - output.

I - Row position of the non-zero element - integer - output.

EØL = 1 indicates last non-zero element in the column was read on the current call to INTPKI, =0 otherwise - integer - output.

If only one matrix is to be read and interpreted, the single-column version should be used as it is more efficient.

```
COMMON/ZNTPKX/A(4),I,EOL,EOR

CALL INTPK($n,NAME,0,OPT,TYPOUT,0)

CALL ZNTPKI
```

where INTPK and its arguments are defined as above.

ZNTPKI is the call made to read successive non-zero elements of the column. One element (A), its row position (I), end-of-column indicator (EOL), and end-of-record indicator (EOR) are stored in /ZNTPKX/ for each call to ZNTPKI.

EOL is defined as above.

EOR = 1 indicates the end-of-record has been read by ZNTPKI, = 0 otherwise (ZNTPKI buffers ahead so that EOR will usually be one before EOL is one. EOR is always one when EOL = 1).

3.5.3.4 Method

INTPK reads the line header for the column. If OPT exits via RETURN 2, a null column exists and RETURN 1 is made to the user. Otherwise, for each of the 32 combinations of TYPOUT and the type of the elements in the column, a switch for pickup and conversion of the elements is set. For the multi-column version, this switch and other pointers are stored in BLOCK. For the single column version, one buffer is read. INTPKI restores the switch and pointers and then enters code common with ZNTPKI. A test is made to determine if a read is necessary (this is almost always required in the multi-column version since only one element at a time is read). The non-zero element is picked up, converted if necessary, and stored in /ZNTPKX/. Its row position is stored in /ZNTPKX/. The next word in the column is now tested (a read being given first if necessary). If the (integer) absolute value of this number is less than 16777215, the number is the row position of the next non-zero element. If = 16777215, it is the trailer word and the last non-zero element has been read. In this case EOL is set to 1. If > 16777215, the number is a real number and the row position of the next non-zero element equals the current row position plus one. For the multi-column version, A, I and EOL are moved from /ZNTPKX/ to the user, and the parameters are saved in BLOCK.

3.5.3.5 Design Requirements

1. If ØPT = RDCØR, the calling module must initialize NAME prior to each call to INTPK see ØPNCØR (section 3.4.13).

2. If the single column version is used, subroutine UNPACK must not be called during interpretation of a column, i.e., subsequent to a call to INTPK and prior to a return from ZNTPKI with EØL = 1.

3. The format of floating point words on computers which execute this program must be such that any non-zero floating point word is larger in absolute value than the integer 16777215.

4. When using the single column version, if the user does not complete interpretation of the column, he must insure that the remainder of the column is skipped. This may be accomplished by

```
IF (EØR.EQ.0) CALL FWDREC($n,NAME).
```

3.5.3.6 Diagnostic Messages

The following messages may be issued by INTPK:

3002

3003

3.5.4 UNPACK (Unpack a Packed Column of a Matrix).

3.5.4.1 Entry Point: UNPACK.

3.5.4.2 Purpose

To read and unpack a column of a matrix stored in NASTRAN packed format.

3.5.4.3 Calling Sequence

CALL UNPACK($n,NAME,A,ØPT)

CØMMØN/UNPAKX/TYPØUT,I,N,INCR

n - FØRTRAN statement number defining return to be taken if the column is null.

NAME - {ØPT = 'READ', GINØ name of data block containing the column to be unpacked.
{ØPT = 'RDCØR', an array where the packed column is stored.

ØPT = {'READ' - column will be read by GINØ.
{'RDCØR' - column will be read from core at NAME.} Subroutine name

A - An array where the unpacked column will be stored.

TYPØUT - Arithmetic type in which the elements are to be stored at A (1 = real single precision, 2 = real double precision, 3 = complex single precision, 4 = complex double precision). TYPØUT ≤ 0 means that each of the elements will be stored with a change of sign.

I - Row position of the element to be stored at A(1).

N - Row position of the last element to be stored at A.

INCR - Spacing of the elements to be stored at A in units of elements, i.e., if complex single precision elements are to be stored at A(1), A(5), A(7), etc., INCR = 2.

Notes:

1. Zeros are stored for zero elements.

2. If I ≤ 0 or N ≤ 0, the column is unpacked from the first non-zero element through the last non-zero element and I and N are set to these row positions.

3. If return to statement n is given, zeros are <u>not</u> stored at A.

3.5.4.4 Method

Activity for the column is initiated by a call to INTPK. A non-standard return from INTPK results in an immediate RETURN 1 to the user. ZNTPKI is called to obtain the first non-zero element. If its row position is less than I, ZNTPKI is repeatedly called until a row position ≥ I or end-of-column is found. If the row position of the first non-zero element is greater than I, zeros are stored for the missing elements. Each non-zero element whose row position is less than or equal to N is stored and zeros are stored for missing elements. Non-zero elements whose row positions are greater than N are skipped until the end-of-column is reached.

3.5.4.5 Design Requirements

See subroutine INTPK (see section 3.5.3).

3.5.4.6 Diagnostic Messages

In a coding sense messages 3002 and 3003 are possible. However, they violate the design of GINØ or ØPNCØR and therefore, if obtained, should indicate an obscure program design error or machine error.

3.5.5 CALCV (Compute a Partitioning Vector).

3.5.5.1 Entry Point: CALCV.

3.5.5.2 Purpose

To build a partitioning vector of zeros, ones and twos to be used by subroutines MERGE and PARTN.

3.5.5.3 Calling Sequence

CALL CALCV(FILEP,SET1,SUB0,SUB1,CØRE)

FILEP - GINØ file number of partitioning vector - integer - input.

SET1 - Bit position of major set - integer - input.

SUB0 - Bit position of zero subset - integer - input.

SUB1 - Bit position of one subset - integer - input.

CØRE - Open core.

CØMMØN/PATX/LCØRE,NSUB0,NSUB1,NSUB2,FUSET

LCØRE - Length of open core - integer - input.

NSUB0 - Number of rows in zero subset - integer - output.

NSUB1 - Number of rows in one subset - integer - output.

NSUB2 - Number of rows in two subset (not in one or zero subset) - integer - output.

FUSET - File name of USET - integer - input.

3.5.5.4 Method

Each element of USET is examined and classified. If it belongs to SET1 it is further classified into SUB0, SUB1, and SUB2.

A vector is constructed which has zeros, ones and twos in order as elements of USET are so classified.

3.5.5.5 Design Requirements

LCØRE must be ≥ twice length of GINØ buffer.

3.5.5.6 Diagnostic Messages

System messages if USET or FILEP are not correct GINØ files.

3.5.6 PARTN - MERGE (Partition a Matrix - Merge Matricies Together).

3.5.6.1 Entry Point: PARTN, MERGE. PARTN and MERGE are two distinct routines but are so closely related that they are described together here.

3.5.6.2 Purpose

PARTN will break up a matrix into four submatrices.

$$[A] = \left[\begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array}\right]$$

MERGE is the inverse of PARTN in that given the four building blocks $A_{11},\ldots,A_{22}$ MERGE will reconstruct [A].

3.5.6.3 Calling Sequence

CALL PARTN (RP,CP,Z)

CALL MERGE (RP,CP,Z)

RP - Matrix control block of the row partitioning vector - integer - input.

CP - Matrix control block of the column partitioning vector - integer - input.

Z - Array of open core.

If RP(1) ≤ 0, or CP(1) ≤ 0, the core locations from RP(8) or CP(8) will contain this vector in packed form.

If RP(1) = CP(1) < 0 the arrays RP and CP coincide in core.

COMMON/PARMEG/MCBA(7),MCBA11(7),MCBA21(7),MCBA12(7),MCBA22(7),LCORE,RULE

MCBA - Matrix control block for [A] - input.

MCBA11 - Matrix control block for [A11] - input.

MCBA21 - Matrix control block for [A21] - input.

MCBA12 - Matrix control block for [A12] - input.

MCBA22 - Matrix control block for [A22] - input.

If any submatrix is not desired or does not exist set MCBAij(1) = 0.

LCORE - Length of Z array - integer - input.

RULE - Rule to be applied to the row and column partitioning vectors - integer - input.

3.5.6.4 Method

Each element of [A] is assigned to the appropriate submatrix by the following schemes.

RULE $\geq$ 0 N = |RULE|

$a_{ij} \in$ [A11] if RP(I) = CP(J) = N

$a_{ij} \in$ [A21] if RP(I) = N, CP(J) $\neq$ N

$a_{ij} \in$ [A12] if RP(I) $\neq$ N, CP(J) = N

$a_{ij} \in$ [A22] if RP(I) $\neq$ N, CP(J) $\neq$ N

RULE $<$ 0 N = |RULE|

$a_{ij} \in$ [A11] if RP(I) $\geq$ N, CP(J) $\geq$ N

$a_{ij} \in$ [A21] if RP(I) $\geq$ N, CP(J) $<$ N

$a_{ij} \in$ [A12] if RP(I) $<$ N, CP(J) $\geq$ N

$a_{ij} \in$ [A22] if RP(I) $<$ N, CP(J) $<$ N

Subroutine RULER (RULE,IP,ZCØNT,ØNCNT,LIST,NRØWP,BUFF,IØPT) is called twice to accomplish this assignment where

RULE - Rule to be applied

IP - Either RP or CP

ZCØNT - Number of elements (row or column) assigned to the one class.

ØNCNT - Number of elements (row or column) assigned to the two class.

For example, if RULER is analyzing RP and RP(I) = N this element of RP is said to belong to the 1 class in that it will go either to [A11] or [A21].

LIST - A list of zeros and ones. Zero, if the element belongs to the one class. One, if the element belongs to the two class.

NRØWP - Number of rows in IP

BUFF - One GINØ buffer space

IØPT - If IØPT = 1, LIST will be stored 1 number per word. If IØPT = 0, LIST will be packed 32 bits/word.

Non-zero elements are read, classified and output.

3.5.6.5 Design Requirements

Open core must contain n GINØ buffers + 1 column (single precision) of [A] and 1 row/32 of [A], where n = the number of submatrices present plus one.

3.5.6.6 Diagnostic Messages

If insufficient core is available as described above, fatal message 3008 is given.

3.5.7 SSG2A (Driver for PARTN).

3.5.7.1 Entry Point: SSG2A.

3.5.7.2 Purpose

To partition a vector into two subsets (i.e., to be a driver for PARTN).

3.5.7.3 Calling Sequence

CALL SSG2A(VECTØR,PART1,PART2,PVECT)

VECTØR - GINØ file number of vector to be partitioned - integer - input.

PART1 - GINØ file number of major partition - integer - input.

PART2 - GINØ file number of minor partition - integer - input.

PVECT - GINØ file number of partitioning vector - integer - input.

CØMMØN/PATX/XXX,NRØW1,NRØW2

NRØW1 - Number of rows in PART1 - integer - input.

NRØW2 - Number of rows in PART2 - integer - input.

3.5.7.4 Method

The PARTN common block is filled.

Based on the trailer of VECTØR and NRØW1, NRØW2:

$$\left\{\text{VECTOR}\right\} \Rightarrow \left\{\begin{matrix}\text{PART1}\\ \overline{\text{PART2}}\end{matrix}\right\}$$

3.5.7.5 Design Requirements

Open core is needed at /SSGA2/.

3.5.8 SDR1B (Driver for MERGE).

3.5.8.1 Entry Point: SDR1B

3.5.8.2 Purpose

To drive MERGE forming VECTØR

$$\left\{\text{VECTØR}\right\} = \left\{\begin{matrix}\text{PART1}\\ \text{PART2}\end{matrix}\right\}$$

3.5.8.3 Calling Sequence

CALL SDR1B(PVECT,PART1,PART2,VECTØR,MAJØR,SUBO,SUB1,USET,IØPT,IYS)

PVECT - GINØ name of partition vector - integer - input.

PART1 - GINØ name of vector which corresponds to SUBO set - integer - input.

PART2 - GINØ name of vector which corresponds to SUB1 set - integer - input

VECTØR - GINØ name of merged vector - integer - input.

MAJØR - Bit position of set of VECTØR - integer - input.

SUBO - Bit position of set of PART1 - integer - input.

SUB1 - Bit position of set of PART2 - integer - input.

USET - GINØ name of USET - integer - input.

IØPT - '0' }
IYS - '0' } These are used in a module specific call to handle the YS data block in a special manner.

3.5.8.4 Method

CALCV is called to obtain partitioning vector.

PARMEG common block is filled.

MERGE is called.

3.5.8.5 Design Requirements

Open core at /SDRB1/.

3.5.9 UPART (Symmetric Partition Driver).

3.5.9.1 Entry Points: UPART, MPART

3.5.9.2 Purpose

To compute a partitioning vector and then perform a series of symmetric partitions. A symmetric partition is such that the row partitioning vector equals the column partitioning vector.

For example:

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right]$$

3.5.9.3 Calling Sequence

CALL UPART(USET,SCR1,MAJØR,SUB0,SUB1)

USET - GINØ file number of USET - integer - input.

SCR1 - Scratch file on which the partitioning vector will be written - integer - input.

MAJØR - Bit position within a USET word of the super set (e.g., n set in the above example) - integer - input.

SUB0 - Bit position of the first subset (e.g., f set in the above example) - integer - input.

SUB1 - Bit position of the second subset (e.g., s set in the above example) - integer - input.

CALL MPART(KNN,KFF,KSF,KFS,KSS)

KNN - GINØ name of the matrix to partitioned - integer - input.

KFF,KSF,KFS,KSS - GINØ names of the partition outputs. A zero will cause the respective matrix not to be written.

3.5.9.4 Method

A call to UPART causes CALCV to compute a partitioning vector.

MPART drives PARTN and is called repeatedly to partition several matrices (i.e. KNN, MNN, BNN, K4NN) in a similar symmetric manner using the same partitioning vector.

3.5.9.5 Design Requirements

Open core at /UPARTX/.

3.5.10 ADD (Driver for SADD)

3.5.10.1 Entry Point: ADD.

3.5.10.2 Purpose

To drive SADD to compute [X] = α[A] + β[B] or on option [X] = α[A].

3.5.10.3 Calling Sequence

CALL ADD (Z)

Z -- Array of core

CØMMØN/ADDX/MCBA(7),MCBB(7),MCBC(7),TYPA,ALPHA(4),LCØRE,TYPB,BETA(4)

MCBA - Matrix Control Block for [A] - input.

MCBB - Matrix Control Block for [B] - input.

MCBC - Matrix Control Block for [X] - input.

TYPA - Type of Alpha - integer - input.

1 - real single precision

2 - real double precision

3 - complex single precision

4 - complex double precision

ALPHA - α - input - type depends on TYPA.

LCØRE - Length of Z array.

TYPB - Type of BETA - integer - input.

BETA - β - input - type depends on TYPB.

3.5.10.4 Method

ADD rearranges and moves /ADDX/ to /SADDX/, and calls SADD

to compute [X] in above equation.

3.5.10.5 Design Requirements

Matrix add routine ADD is replaced by SADD. The revised ADD routine is kept

in the system to accommodate the existing calls to the ADD routine.

However, all future calls to matrix addition should be made directly to SADD.

3.5.11 SSG2C (Driver for ADD).

3.5.11.1 Entry Point: SSG2C.

3.5.11.2 Purpose

To drive ADD to compute [C] = α[A] + β[B].

3.5.11.3 Calling Sequence

CALL SSG2C (FILEA,FILEB,FILEC,IØP,BLØCK)

FILEA - GINØ file number of [A] - integer - input.

FILEB - GINØ file number of [B] - integer - input.

FILEC - GINØ file number of [C] - integer - input.

IØP - Option flag - integer - input.
IF IØP < 0 the first column of [A] will be added to each column of [B] to give [C].

BLØCK - 11-word array containing coefficients - input.

Word	Type	Meaning
1	Integer	Type of α
2	Real	α
3		α
4		α
5		α
6		Not used
7	Integer	Type of β
8	Real	β
9		β
10		β
11		β

3.5.11.4 Method

The trailers of FILEA and FILEB and BLØCK are used to fill the ADDX common block.

The type of FILEC is the minimum type compatible with α[A] and β[B].

3.5.11.5 Design Requirements

Open core at /SSGC2/.

3.5.12 MPYAD (Matrix Multiplication Routine).

3.5.12.1 Entry Point: MPYAD.

3.5.12.2 Purpose

To evaluate the matrix equation

$$D = \pm [A] [B] \pm [C] \quad \text{or} \quad D = \pm [A]^T [B] \pm [C].$$

3.5.12.3 Calling Sequence

```
CALL MPYAD(Z,Z,Z)

CØMMØN/MPYADX/A(7),B(7),C(7),D(7),NZ,T,SIGNAB,SIGNC,PREC,SCR
```

Z - An area of working storage.

NZ - The number of computer words at Z.

A,B,C - Matrix control blocks for the matrices A, B, C.

If C(1) = 0, C is not used, i.e. $[D] = \pm [A] [B]$ or $\pm [A^T] [B]$.

D - Matrix control block for the product matrix.

D(1) must contain the GINØ file name prior to entry.

D(5) must contain the arithmetic type of the elements of D. MPYAD will accumulate D(2), D(6) and set D(7) = 0.

T $\begin{cases} = 0, \pm [A] [B] \pm [C] \text{ is computed.} \\ \neq 0, \pm [A]^T [B] \pm [C] \text{ is computed.} \end{cases}$

SIGNAB $= \begin{cases} +1, \text{ compute } +[A] [B] \text{ or } +[A]^T [B] \\ -1, \text{ compute } -[A] [B] \text{ or } -[A]^T [B] \end{cases}$

SIGNC $= \begin{cases} +1, \text{ use } + C \\ -1, \text{ use } - C \end{cases}$

Note: If C(1) = 0, SIGNC is ignored.

PREC $= \begin{cases} 1, \text{ perform arithmetic in single precision} \\ 2, \text{ perform arithmetic in double precision} \end{cases}$

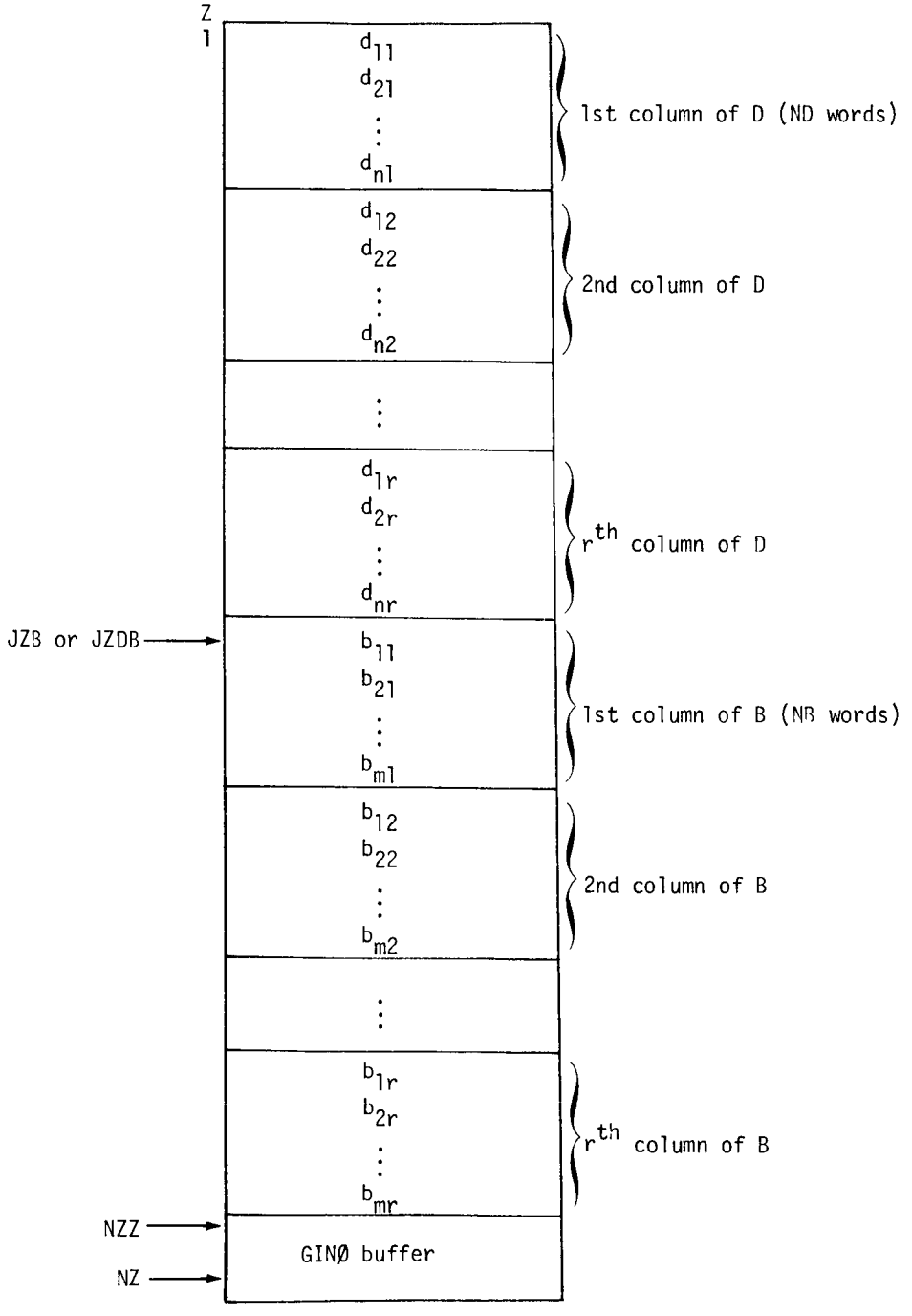
SCR = GINØ file name of a scratch file for use by MPYAD.

3.5.12.4 Method

1. General Comments. Two alternative methods of performing the matrix multiplication are available in MPYAD. Method One holds as many unpacked columns of the B and D matrices as core storage will allow. The A matrix is read interpretively by INTPK. For each non-zero element in A, all combinatorial terms for columns of B currently in core are computed and accumulated in the storage for D. At the completion of one pass of the A matrix, the matrix product is complete to the extent of the number of columns of B currently in core. (If the C matrix is present, columns are initially unpacked into the storage for D.) The process is repeated until the B matrix is exhausted. One GINØ buffer only is required for Method One. The number of passes of the A matrix for Method One equals the number of columns of B divided by the number of columns of B and D which can be held in core at one time. In Method Two either one element of B (T = 0) or one column of B in unpacked form (T = 1) is held in core at one time, and either one column of D in unpacked form (T = 0) or one element of D (T = 1). The remaining storage is allocated to storage of columns of A in packed form (i.e., nonzero terms and row positions only). For all the columns of A in storage at one time the B and E matrices are passed, column by column, forming partial answers on each pass. The E matrix is initially the C matrix (if present) and thereafter is the partial product matrix from the previous pass. Three GINØ buffers are required for Method Two. It may be seen that the A matrix is passed once and the number of passes of the B and E matrices equals the number of columns of A divided by number of columns of A that may be held in core at one time.

2. Initialization Phase. The arithmetic type of the elements of D is determined as a function of the types of A, B and C and the precision requested by the user. Various pointers for both Methods One and Two are computed. A determination of sufficient core storage is made (one unpacked column of B plus one unpacked column of D plus one GINØ buffer). The execution times for Methods One and Two are estimated. The method giving the minimum execution time is selected for use.

3. Method One. The allocation of core storage for Method One is shown below:



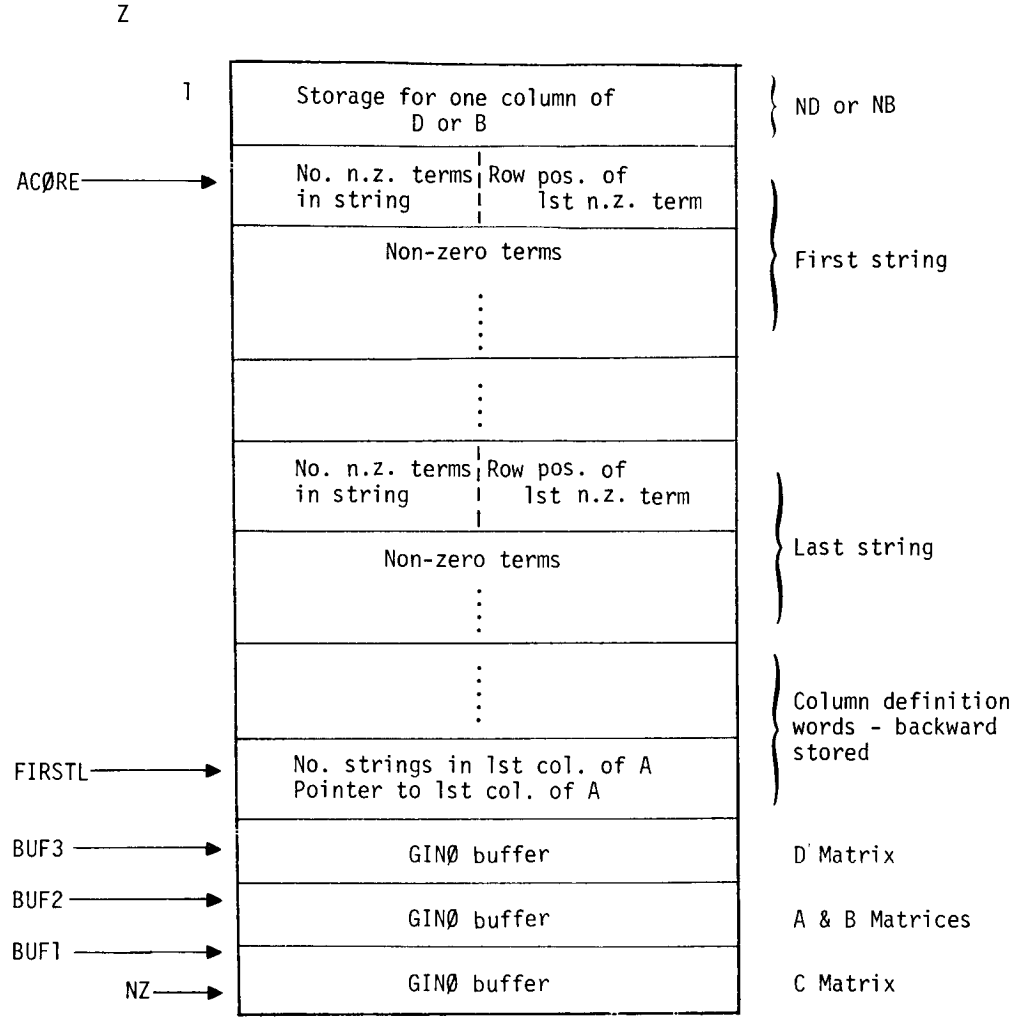
Columns of B and C are read and unpacked by UNPACK. INTPK is called to initiate reading and interpreting the ℓth column of A (ℓ = 1 initially). For each non-zero term in A, $a_{i\ell}$ or $a_{\ell i}$ depending on T, the following arithmetic computations are made:

$$T = 0: \quad d_{ij} = a_{i\ell}\, b_{\ell j} + d_{ij}$$

$$T \neq 0: \quad d_{\ell j} = a_{\ell i}\, b_{ij} + d_{\ell j}$$

where j runs across the columns of B and D currently in core. At the conclusion of a pass of the A matrix, the columns of D in core are packed and written by PACK. The process is repeated until the multiplication is complete.

4. Method Two. The allocation of core storage for Method Two is shown on the next page.


Z
1
Storage for one column of D or B
ND or NB
ACØRE
No. n.z. terms in string
Row pos. of 1st n.z. term
Non-zero terms
First string
No. n.z. terms in string
Row pos. of 1st n.z. term
Non-zero terms
Last string
Column definition words - backward stored
FIRSTL
No. strings in 1st col. of A
Pointer to 1st col. of A
BUF3
GINØ buffer
D' Matrix
BUF2
GINØ buffer
A & B Matrices
BUF1
GINØ buffer
NZ
C Matrix

To begin each pass of Method Two, as many columns of A that can be held in core are read using INTPK and stored in core in strings. Each string consists of a string definition word followed by consecutive terms of a column such that no two consecutive terms are zero. For each column there exists a pair of column definition words -- one points to the first string in the column and the other defines the number of strings in the column. The number of passes is determined by the size and density of the A matrix.

The following operations are performed for the nontranspose case:

1. UNPACK is called to unpack the next column of C into the D matrix area.
2. INTPK is called to read the non-zero terms of the corresponding column of B.
3. MPY2NT is called to perform the operation $d_{ik} = a_{ij} b_{jk} + c_{ik}$. Each non-zero element of B (b_{jk}) will combine with all non-zero elements in the j^{th} column of A and add to the corresponding elements in the k^{th} column of D in core.
4. When all columns of A in core are complete, the column of D is packed and written by PACK.
5. When all columns of B and C are complete, a test for completion of the multiplication is made.
6. If incomplete, the C and D files are switched and the process described above is repeated.

The following operations are performed for the transpose case:

1. UNPACK is called to unpack the next column of B into core.
2. INTPK is called to read the non-zero terms for the corresponding column of C.
3. BLDPK is called to initiate the packing of a column of D.
4. MPY2T is called to perform the operation $d_{ik} = \Sigma a_{ij} b_{jk} + c_{ik}$ for each row of A in core.
5. The elements of D are packed using ZBLPKI.
6. When all columns of B and C are complete, a test for completion of the multiplication is made.
7. If incomplete, the C and D files are switched and the process described above is repeated.

If, after completion of Method Two, there has been an even number of passes of the B matrix, FILSWI is called to switch the D matrix from a scratch file to its assigned unit.

3.5.12.5 Auxiliary Subroutine MPYQ

1. Entry Points: MPY1, MPY2NT, MPY2T.

2. Purpose: MPYQ is called once per execution of MPYAD. It performs general initialization for each of the other entry points.

   MPY1, MPY2NT, and MPY2T perform the inner loops for Method One, Method Two (non-transpose), and Method Two (transpose) respectively. For efficiency these routines are written in assembly language for each of the machines.

3.5.12.6 Auxiliary Subroutine FILSWI

1. Entry Point: FILSWI

2. Purpose: Auxiliary subroutine to switch unit reference numbers in /XFIAT/ in the event that the product matrix in Method Two ends up on a scratch file (even number of passes of B matrix).

3.5.12.7 Design Requirements

Core storage must be sufficient to hold one unpacked column of B plus one unpacked column of D plus one GINØ buffer.

The matrices to be multiplied (and added) must have compatible dimensions. MPYAD does not check this.

3.5.12.8 Information Messages

CØNMSG is called at entry and at exit from MPYAD. Consequently, the line xxxxx MPYAD will appear twice for each call to MPYAD (where xxxxx = time in seconds). The difference is the execution time for MPYAD.

MPYAD method selection data is printed under control of DIAG 19.

2102 LEFT-HAND MATRIX RØW PØSITIØN _____ ØUT ØF RANGE - IGNØRED.

A term in the A matrix whose row position is larger than the stated dimension was detected and ignored.

3.5.12.9 Diagnostic Messages

The following messages may be issued by MPYAD:

3001

3002

3008

3.5.13 SSG2B (Driver for MPYAD).

3.5.13.1 Entry Point: SSG2B.

3.5.13.2 Purpose

To drive MPYAD to compute

$$[D] = \pm [A] [B] \pm [C]$$

or

$$[D] = \pm [A]^T [B] \pm [C]$$

3.5.13.3 Calling Sequence

CALL SSG2B(FILEA,FILEB,FILEC,FILED,T,PREC,ISIGN,SCR1)

FILEA - GINØ name of [A] - integer - input.

FILEB - GINØ name of [B] - integer - input.

FILEC - GINØ name of [C] - integer - input.

FILED - GINØ name of [D] - integer - input.

T - Transpose flag - integer - input.

T = 0 implies use [A]

T = 1 implies use $[A]^T$

PREC - Precision of computation - integer - input. 1 = real single precision, 2 = real double precision, 3 = complex single precision, 4 = complex double precision.

ISIGN - Sign of products - integer - input.

$$\text{ISIGN} = \pm 1 \Rightarrow \begin{cases} \text{sign [AB]} = \text{sign (ISIGN)} \\ \text{sign [C]} = \text{sign (ISIGN)} \end{cases}$$

$|\text{ISIGN}| > 1 \Rightarrow + [AB] - [C]$

$|\text{ISIGN}| < 1 \Rightarrow - [AB] + [C]$

SCR1 - GINØ scratch file - integer - input.

3.5.13.4 Method

SSG2B fills /MPYADX/ and calls MPYAD to compute [D] in above equation.

3.5.13.5 Design Requirements

Open core at /SSGB2/.

3.5.14 SDCØMP (Symmetric Decomposition).

3.5.14.1 Entry Point: SDCØMP.

3.5.14.2 Purpose

To decompose a real symmetric matrix [A] into the form [A] = [L] [D] $[L]^T$ where [L] is a unit lower triangular matrix and [D] a diagonal matrix stored in place of the unit elements on the diagonal of [L]. On option, the Cholesky decomposition [A] = [C] $[C]^T$ is done for a real, positive definite matrix, with only the lower triangle [C] being output. SDCØMP will also compute the determinant of [A].

3.5.14.3 Calling Sequence

CALL SDCØMP($$n_1$$,Z,Z,Z)

CØMMØN/SFACT/A(7),L(7),C(7),SCR1,SCR2,NZ,DET,PØWER,CHLSKY

A(7) - Matrix control block for [A].

L(7) - Matrix control block for [L].

C(7) - Matrix control block for $[L]^T$ or [C].

SCR1, SCR2 - Two scratch files.

NZ - The number of computer words at Z.

DET - Double precision cell where the scaled value of the determinant of [A] will be stored.

PØWER - Scale factor to be applied to DET (Determinant = DET*10**PØWER).

CHLSKY - When CHLSKY = 1, form [C]

Z - An area of working storage.

n_1 - Statement number to which control is transferred if the decomposition fails.

3.5.14.4 Method

1. Mathematical Considerations. Any non-singular real symmetric matrix [A] can be uniquely decomposed into the factors [A] = [L] [D] $[L]^T$. The elements of [D] and [L] are given by:

$$d_i = a_{ii} - \sum_{k=1}^{i-1} \ell_{ik} d_k$$

$$\ell_{ij} = [a_{ij} - \sum_{k=1}^{j-1} \ell_{ik}\, d_k\, \ell_{jk}]/d_j$$

2. General Comments. Interpretation of the above equations identifies that element ℓ_{ij} is composed of products of the elements in the i^{th} row of [L] times the elements in the j^{th} row of [L] times the diagonal elements of [D] (Figure 1). Also, element ℓ_{ij} affects only the elements in the i^{th} row or the i^{th} column of [L], (Figure 2).

The above considerations indicate the means of optimizing the decomposition process to perform only the necessary operations and to keep elements in core only as long as needed. As an example, if [A] was strictly banded, with a bandwidth of B, then the inner product calculation of ℓ_{ij} extends only to the band as all other terms are zero (Figure 3). Also in this example, all terms of [L] in column 5 affect only the elements inside the triangle. As soon as these terms are computed, column 5 need not be held in core. The optimum algorithm for banded matrices would be to hold the triangular portion of the band in core, compute terms corresponding to the first column, output the first column, and move the triangular area down the band (Figure 4).

In practice, however, structural matrices are not strictly banded, but semi-banded with a few scattered terms existing outside the band. The basic algorithm remains the same except that the terms outside the band (active elements) must be handled in an analogous manner to those inside the band (band elements). This creates a rectangular storage area for the active rows (rows of [L] which contain at least one active element) plus a second traingular area for terms arising out of interactions between active rows. The storage requirements are shown in Figure 5.

Given a matrix [A], SDCØMP will determine the optimum combination of B (bandwidth), and C (number of active rows) by estimating the time required to decompose [A] for all combinations of B and C and choosing the pair corresponding to the minimum time.

Figures 6, 7, and 8 show how storage is allocated to various operations.

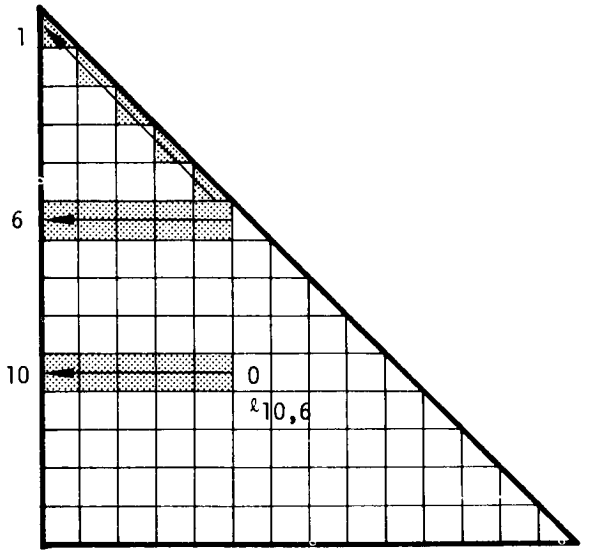


Figure 1. Computation of element ℓ_{ij}:

$$\ell_{10,6} = \left[a_{10,6} - \ell_{10,5}\, d_5\, \ell_{6,5} - \ell_{10,4} d_4 \ell_{6,4} \cdots - \ell_{10,1} d_1 \ell_{6,1}\right] / d_6$$

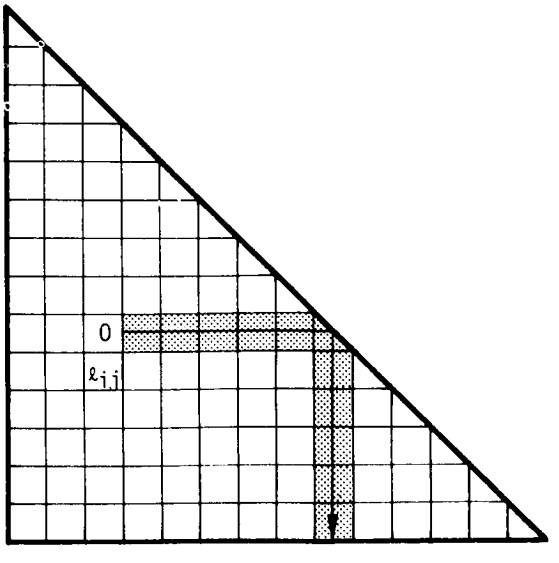


Figure 2. Affect of element ℓ_{ij}.

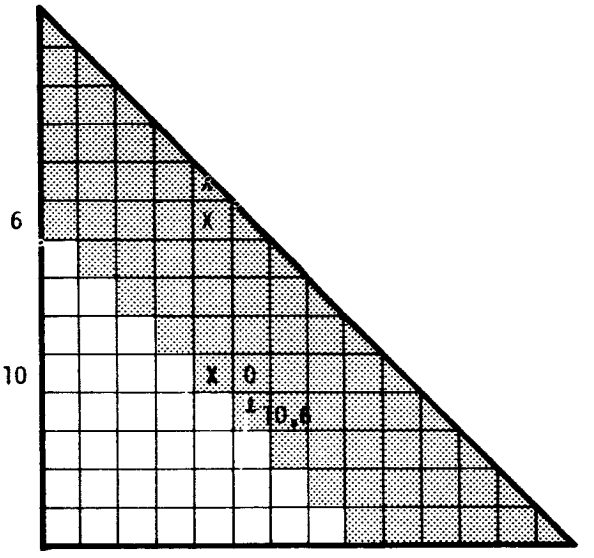


Figure 3. Computation of element ℓ_{ij} (banded matrix):

$$\ell_{10,6} = \left[a_{10,6} - \ell_{10,5}\, d_5 \ell_{6,5}\right] / d_6$$

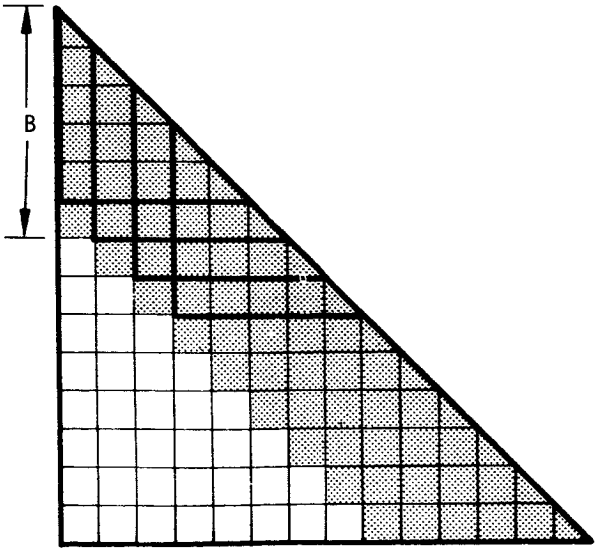


Figure 4. Core storage requirements for a banded matrix.

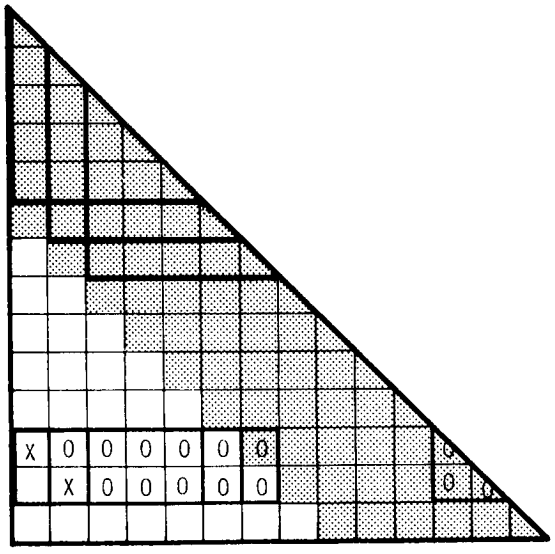


Figure 5. Core storage requirements for a matrix with active rows.

I Storage for the partially computed elements of [L] that are within the band.

II Storage for a completed column of [L].

III Storage for the next column of [A] to be read in.

IV Storage for the partially computed elements of [L] that are outside the band.

V Storage for intermediate results computed from interactions between active rows.

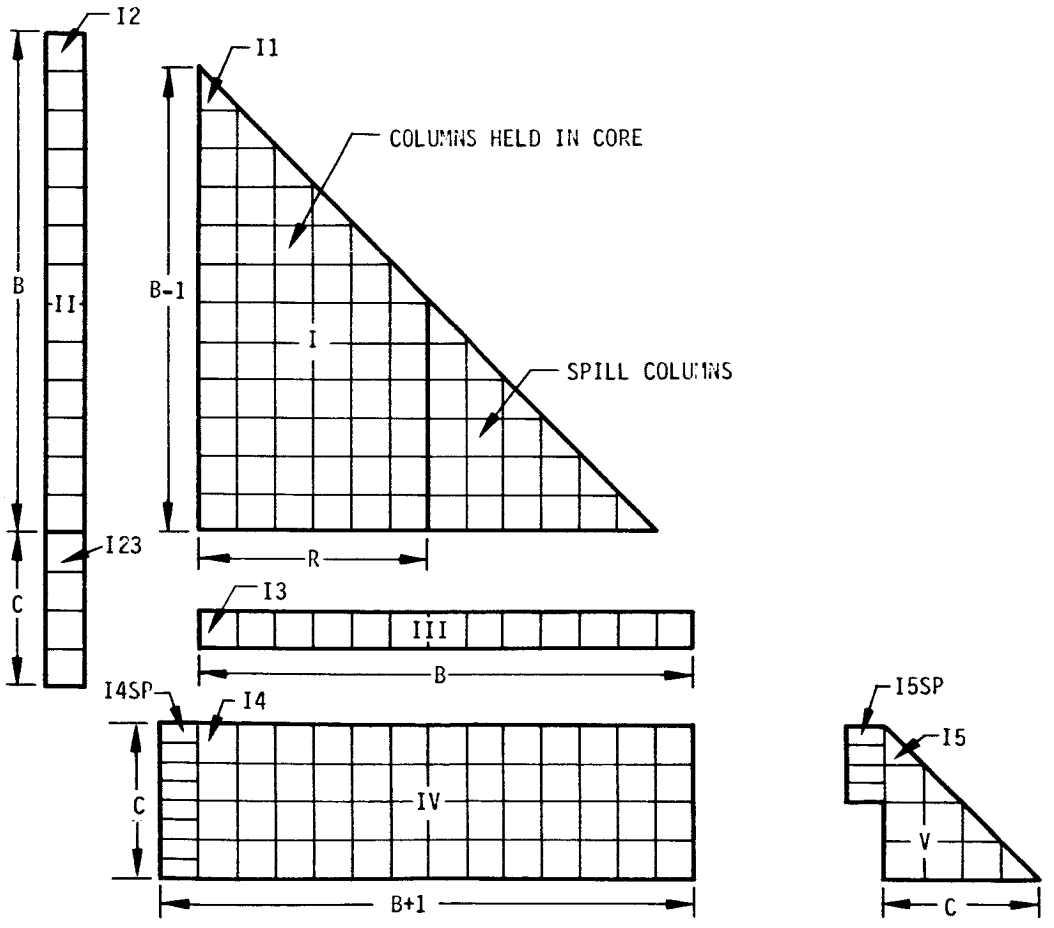


Figure 6. Definition of storage areas.

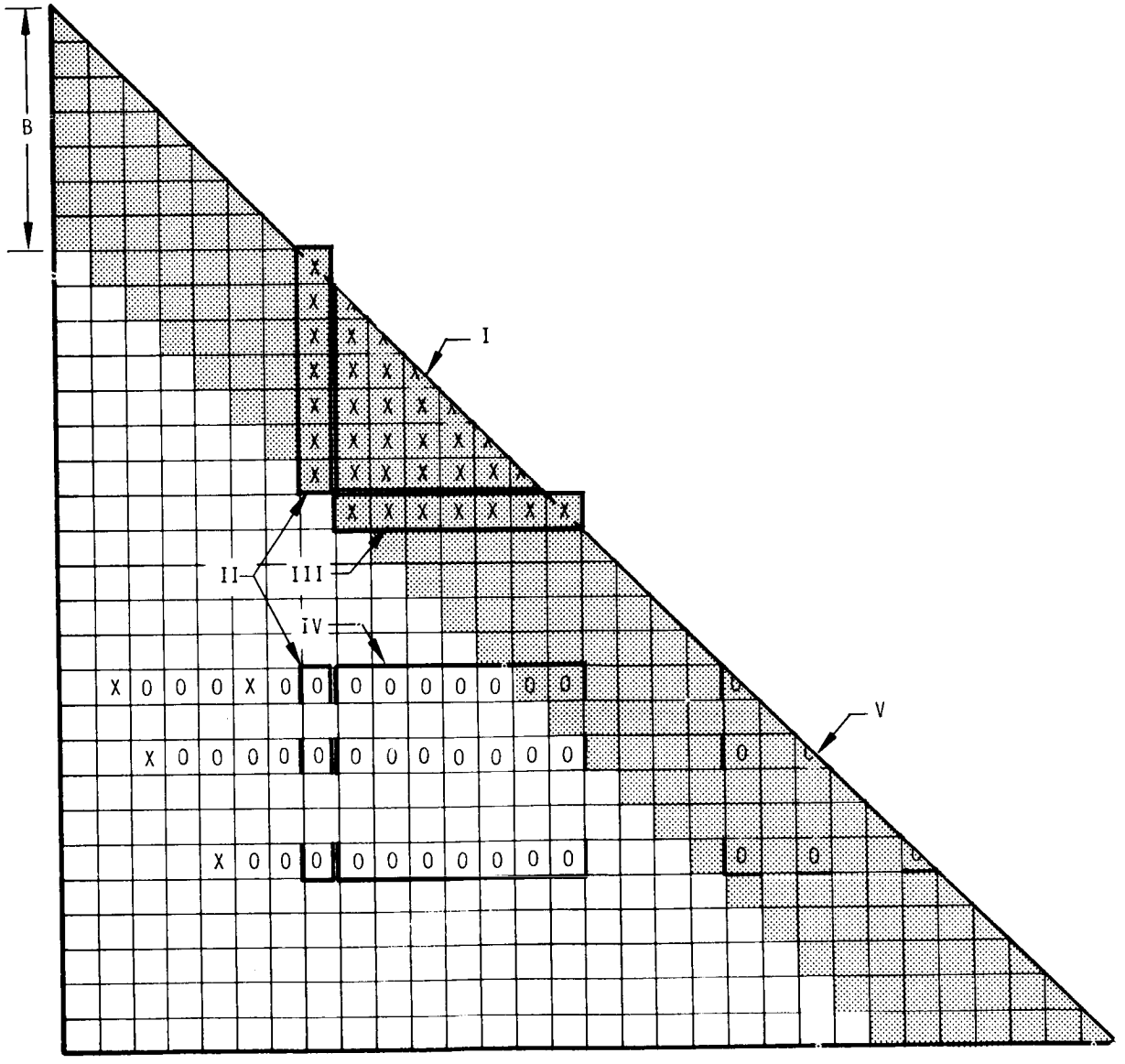


Figure 7. Location of storage areas within the matrix.

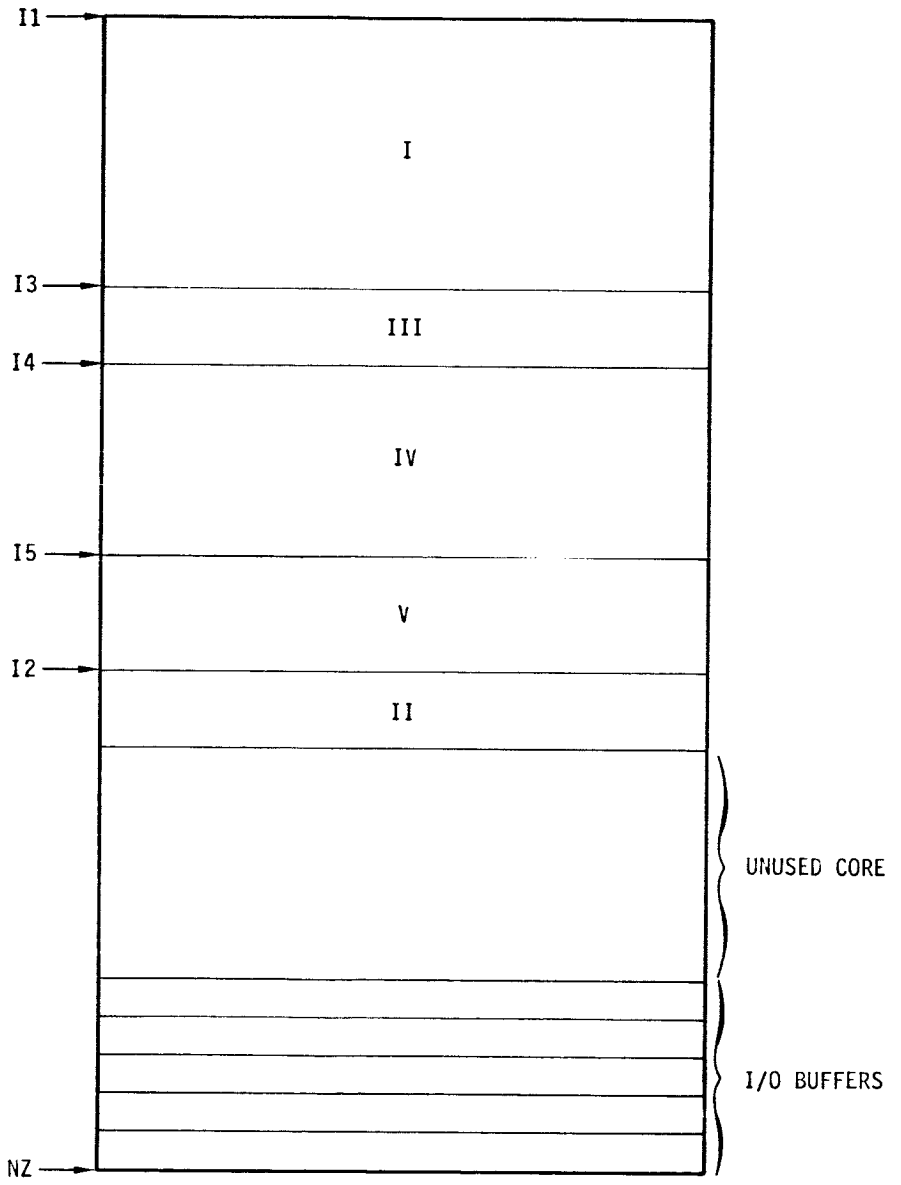


Figure 8. Location of storage areas within core.

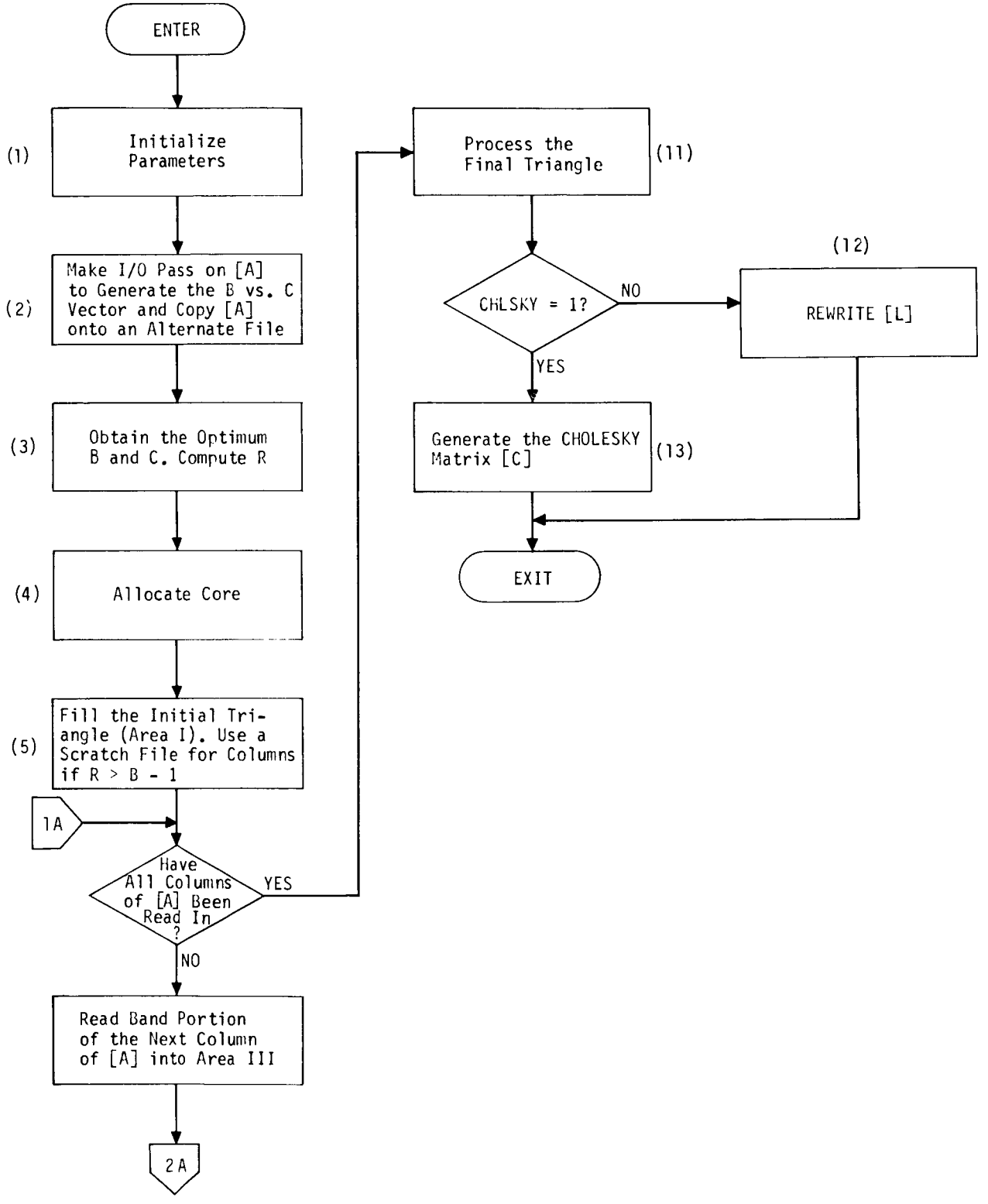


Figure 9.(a) SDCØiP program flow

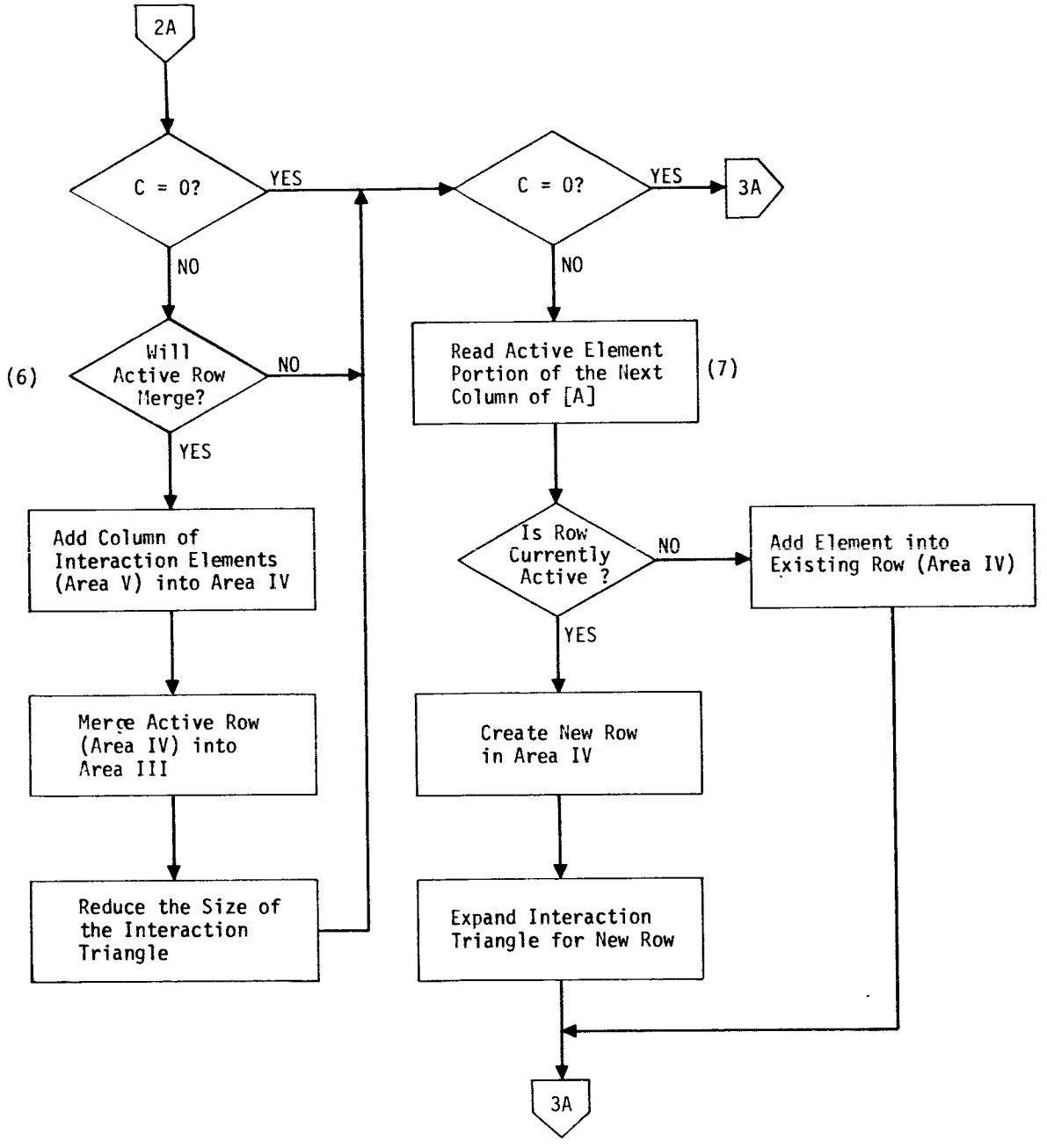


Figure 9.(b) SDCØiP program flow

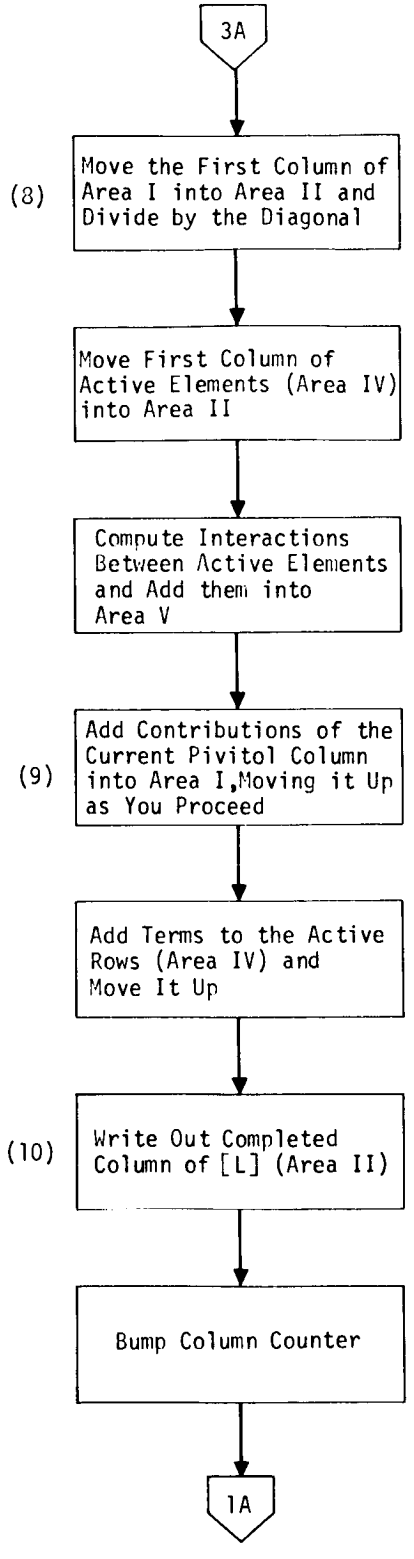


Figure 9.(c) SDCØi1P program flow

3. Program Flow. The flowchart in Figure 9 gives the logical flow of SDCØMP. The following are comments expanding on certain areas of the flowchart:

(1) Allocate buffers, initialize determinant, and write header records.

(2) A vector is generated containing the number of active rows for varying bandwidths. The matrix [A] is copied onto an alternate file for use during the decomposition.

(3) The estimated time for decomposition is computed for each combination of B and C. The B and C corresponding to the minimum time is picked. R, the number of columns which can be held in core, is also computed at this time.

(4) Pointers to the various areas of core shown in Figure 6 are computed as a function of B, C and R.

(5) The banded portion of the first B-1 columns of [A] are read into Area I. If $R \leq B-1$, columns are written on a scratch file.

(6) As the decomposition proceeds, active rows gradually merge into the band. This means a column from Area V will merge into Area IV and a row from Area IV will merge into Area III. When this occurs, the current number of active rows decreases by one and the size of the interaction triangle is reduced.

(7) As active elements corresponding to the next column of [A] are read in, they are either added to an already existing active row, or a new active row must be created. Whenever a new row is created, indices are stored identifying the row, the active element is stored in Area IV, and the interaction triangle is expanded to accomodate the added row.

(8) As a column emerges from the triangle in Area I, it is a completed column of [L].

(9) Before the column can be output, all terms involving this column must be computed and stored. These intermediate terms are stored in either Areas I, IV, or V, depending where the elements are located.

(10) A column of [L] can be output. All areas of temporary storage have been updated. Areas I, IV, and III have all moved over one column relative to their previous position in the matrix.

(11) When all columns of [A] have been read in, all active rows have merged and only Area I exists. This final triangle is processed to complete the computation of [L]. If spill exists, as more core is made available by columns of [L] being output, additional columns of the spill file are read in.

(12) The file containing [L] is now complete. An additional file is created with the columns of [L] written in the reverse order. This generates a pseudo upper triangular matrix that is used by FBS for the solution of a set of equations.

(13) If CHLSKY was set, [L] is read, the diagonal term picked up, each column is multiplied by the square root of the diagonal, and the resulting [C] matrix is output.

3.5.14.5 Auxiliary Subroutines

Subroutine Name: LØØP

Purpose: To compute the inner arithmetic loop of SDCØMP.

3.5.14.6 Design Requirements

The input matrix [A] should be well conditioned or positive definite as the decomposition is done without pivoting.

Core storage requirements depend on the parameters B and C. For a given B and C, Areas II, III, IV, and V must reside in core along with a minimum of two columns of Area I and 5 GINØ buffers.

Files containing [L] and $[L]^T$ should be used as input only to FBS as they are not in standard NASTRAN format.

3.5.14.7 Information Messages

1. CØNMSG is called at entry and exit from SDCØMP. The line

xxxx SDCØMP

will appear twice per decomposition. The execution time of SDCØMP will be the difference in the times (where xxxxx = time in seconds).

2. Message 3023 gives the values of the parameters, B, C, and R chosen for the decomposition.

3. Message 3027 gives the estimated time in seconds to do the decomposition.

4. Message 3024 indicates that a matrix has scattered terms way off the diagonal (i.e., a large bandwidth). Instead of searching all combinations of B and C, the search is started at the maximum bandwidth.

3.5.14.8 Diagnostic Messages

1. If SDCØMP was unable to find a combination of B and C which would meet core restrictions, fatal message 3008 occurs.

2. In a coding sense, message 3025 is possible. However, it violates the design of SDCØMP and therefore, if obtained, should indicate an obscure program design error, or machine error.

3. Message 3026 indicates that sufficient space was not reserved for the generation of the B vs. C vector. SDCØMP should be recompiled to increase BMAX and CMAX.

3.5.15 DECØMP (Unsymmetric Matrix Decomposition)

3.5.15.1 Entry Point: DECØMP

3.5.15.2 Purpose

To decompose a real square matrix [A] into the form

$$[A] = [L][U] \qquad (1)$$

(where [L] is a unit lower triangular matrix, and [U] is an upper triangular matrix), using partial pivoting within the lower band.

3.5.15.3 Calling Sequence

```
CALL DECØMP ($n,X,X,X)
CØMMØN /DCØMPX/ A(7),L(7),U(7),SCR(3),DET,PØWER,NX,MINDIA,B,BBAR,C,CBAR,R
```

- n - Statement number to which control is transferred if [A] is singular.
- X - An area of core available to DECØMP.
- A - Matrix control block for the input matrix [A] (if A(1) < 0, avoid re-writing [U] in reverse order).
- L,U - Matrix control blocks for the output matrices [L] and [U].
- SCR(3) - GINØ file names for three scratch files - integer.
- DET - Double precision cell where the scaled value of the determinant of [A] will be stored.
- PØWER - Scale factor to be applied to DET (det([A]) = DET * 10**PØWER).
- NX - Number of computer words available at X.
- MINDIA - Double precision word where the value of the minimum diagonal of [U] is stored.
- B,BAR, C,CBAR, R - Integer values describing the upper and lower semi-bandwidths, number of active rows and columns and number of columns of [L] held in core, used to decompose [A]. (If B, BBAR = 0, GENVEC is called to compute the parameters before decomposing [A]. If B, BBAR ≠ 0, the given parameters are used for decomposition).

3.5.15.4 Method

1. Mathematical Considerations: By expanding Equation 1, introducing element notation, and forming the multiplication, we can solve for the elements of [L] and [U]. These equations are given by:

$$\ell_{ij} = [a_{ij} - \sum_{k=1}^{j-1} \ell_{ik} u_{kj}]/u_{jj}, \quad i > j \tag{2}$$

$$u_{ij} = a_{ij} - \sum_{k=1}^{i-1} \ell_{ik} u_{kj}, \quad i \leq j . \tag{3}$$

2. General Comments: The implementation of the above equations is accomplished with several constraints in mind. The decomposition procedure is optimized such that the minimum number of operations is performed, with the minimum amount of core used. To accomplish this, the elements of the input matrix [A] are separated into two groups: terms inside the band (band elements), and terms outside the band (active elements). Also, pivoting is used only within the lower band to avoid unnecessarily filling the matrix with non-zero terms.

Since, in practice, structural matrices tend to be semi-banded with scattered terms existing outside the band, this division of the matrix should optimize the decomposition process. Several parameters are generated to describe this division. B is defined as the upper bandwidth, $\overline{B}$ as the lower bandwidth, C is defined as the number of active columns, and $\overline{C}$ as the number of active rows, where an active column is defined as a column containing one or more active elements above the diagonal, and an active row contains one or more active elements below the diagonal. Corresponding to these parameters, several storage areas are defined to hold the various parts of the matrix. The description and location of these areas are given in Figures 1, 2 and 3. A flow chart for DECØMP is given in Figure 4.

The storage areas in Figures 1, 2, and 3 are defined as follows:

I Storage for the completed columns of [L] still required for computation.
II Storage for the current column being computed.
III Storage for active column elements.
IV Storage for active row elements.
V Storage for elements created by interactions between active row and column elements.
VI Storage for indexes identifying active columns.
VII Storage for indexes identifying active rows.

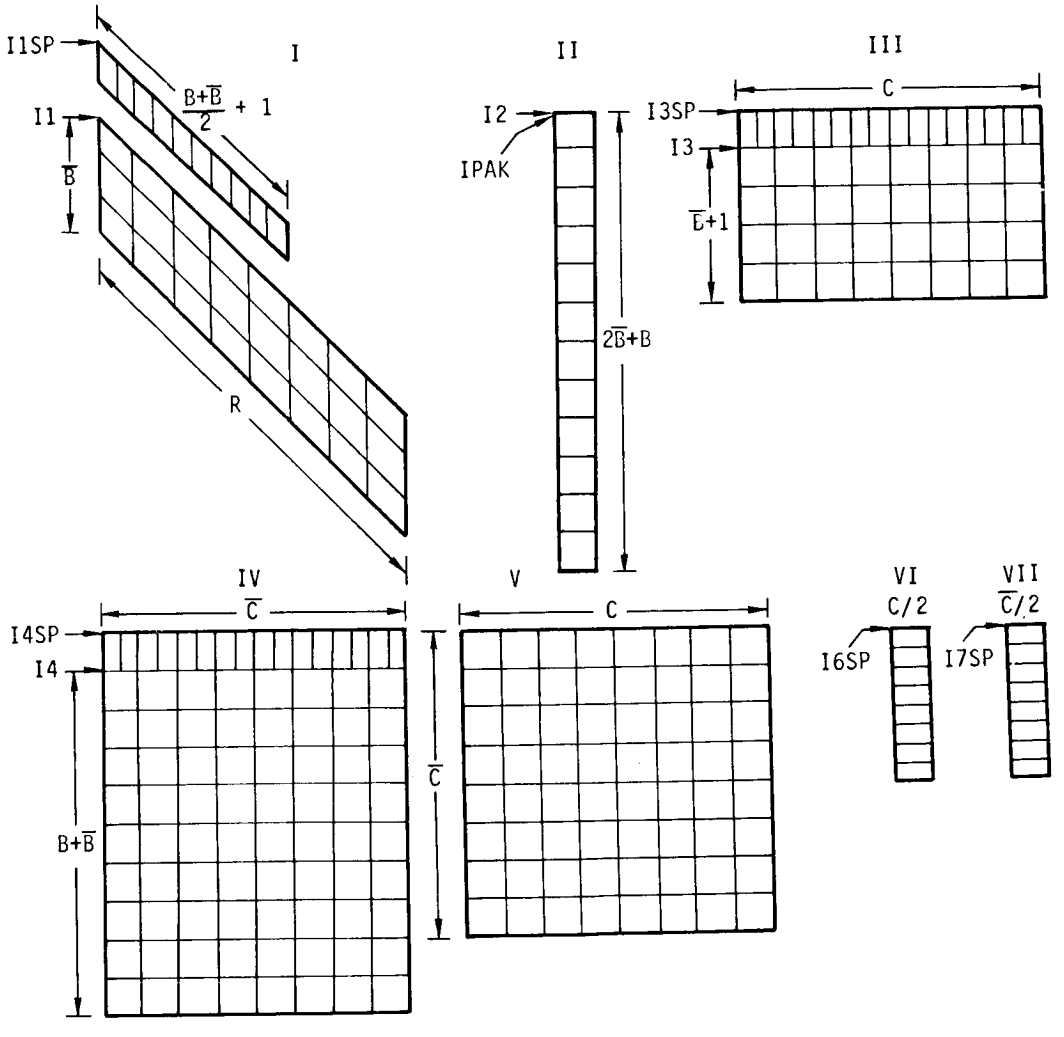


Figure 1. Definition of storage areas for DECØMP.

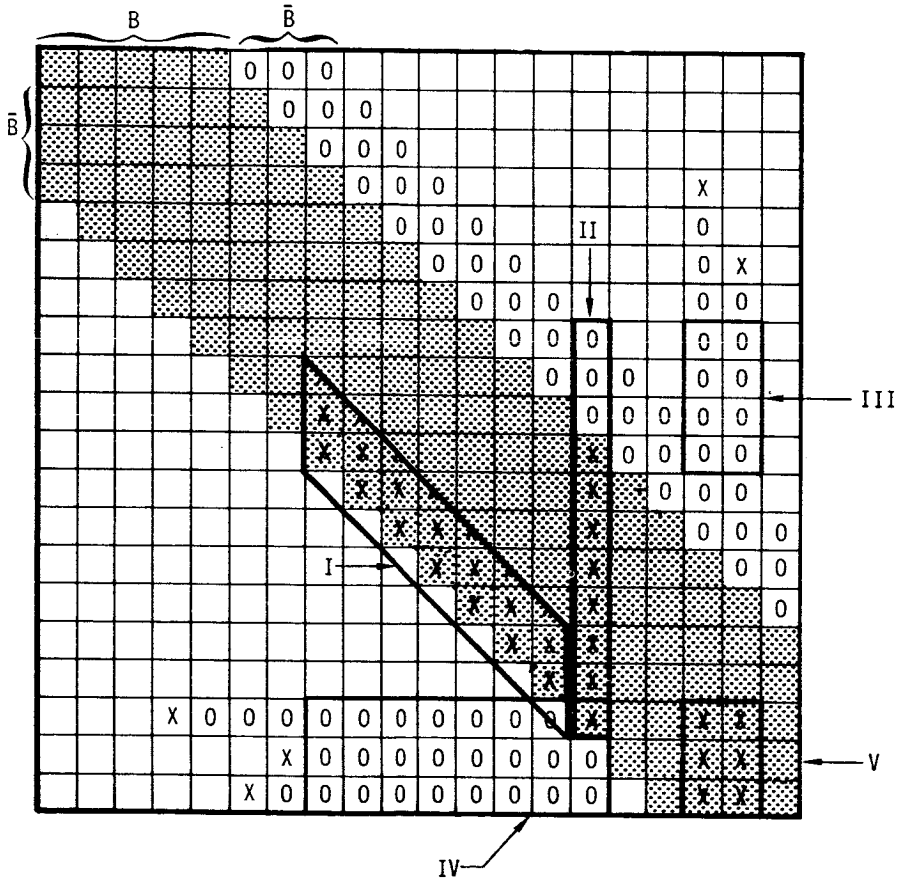


Figure 2. Location of storage areas within the matrix

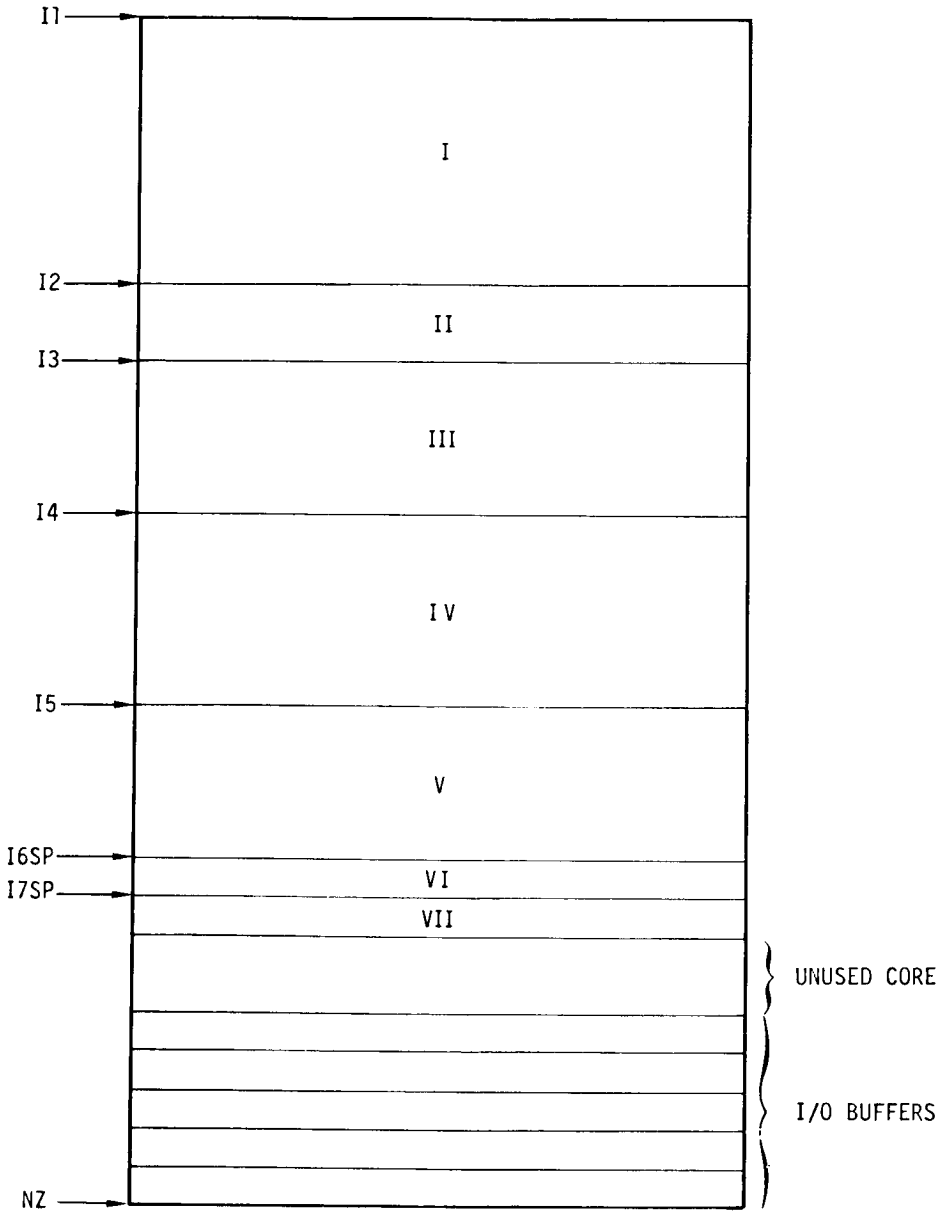


Figure 3. Allocation of core for DECØMP

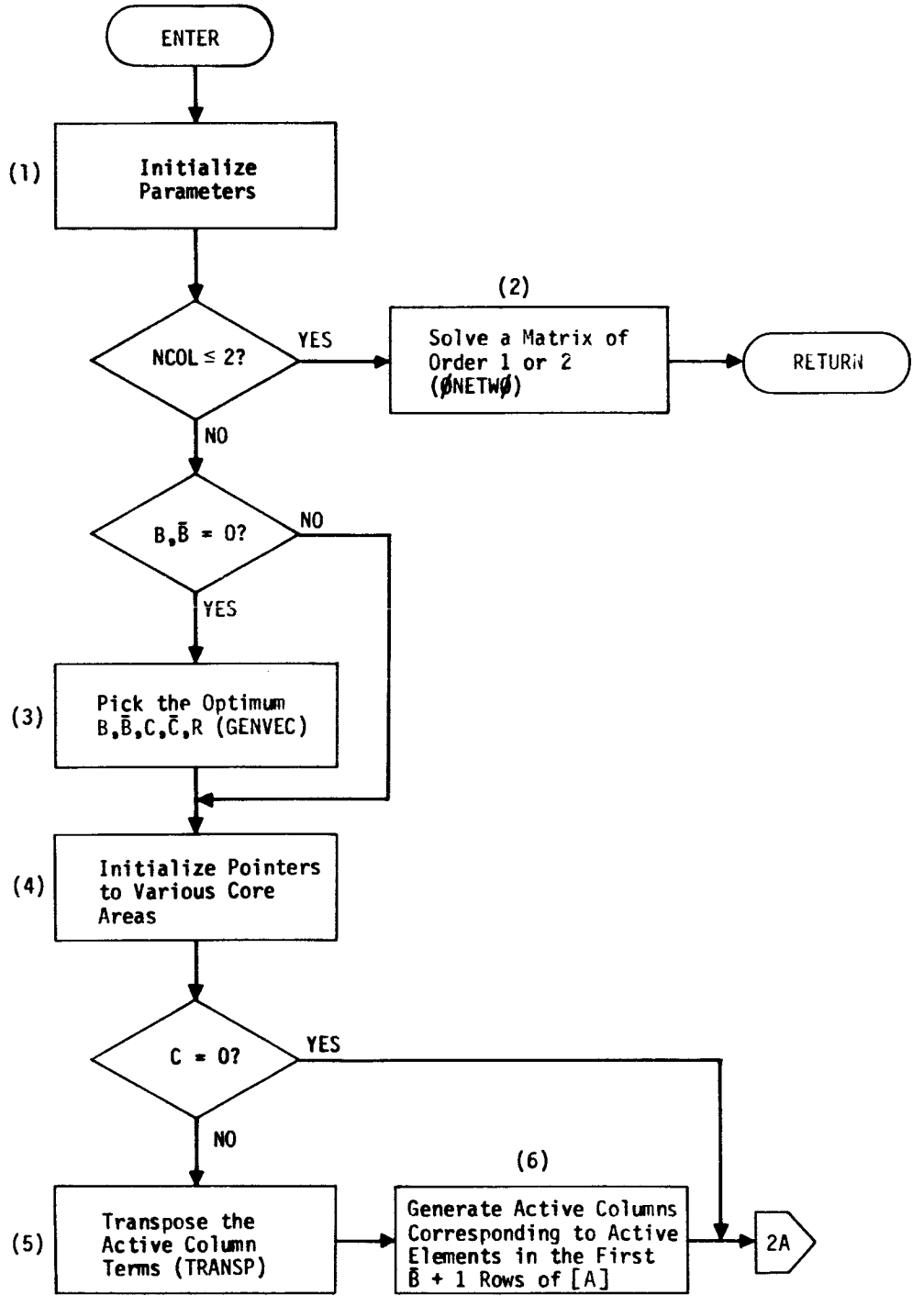


Figure 4.(a) DECØMP program flow

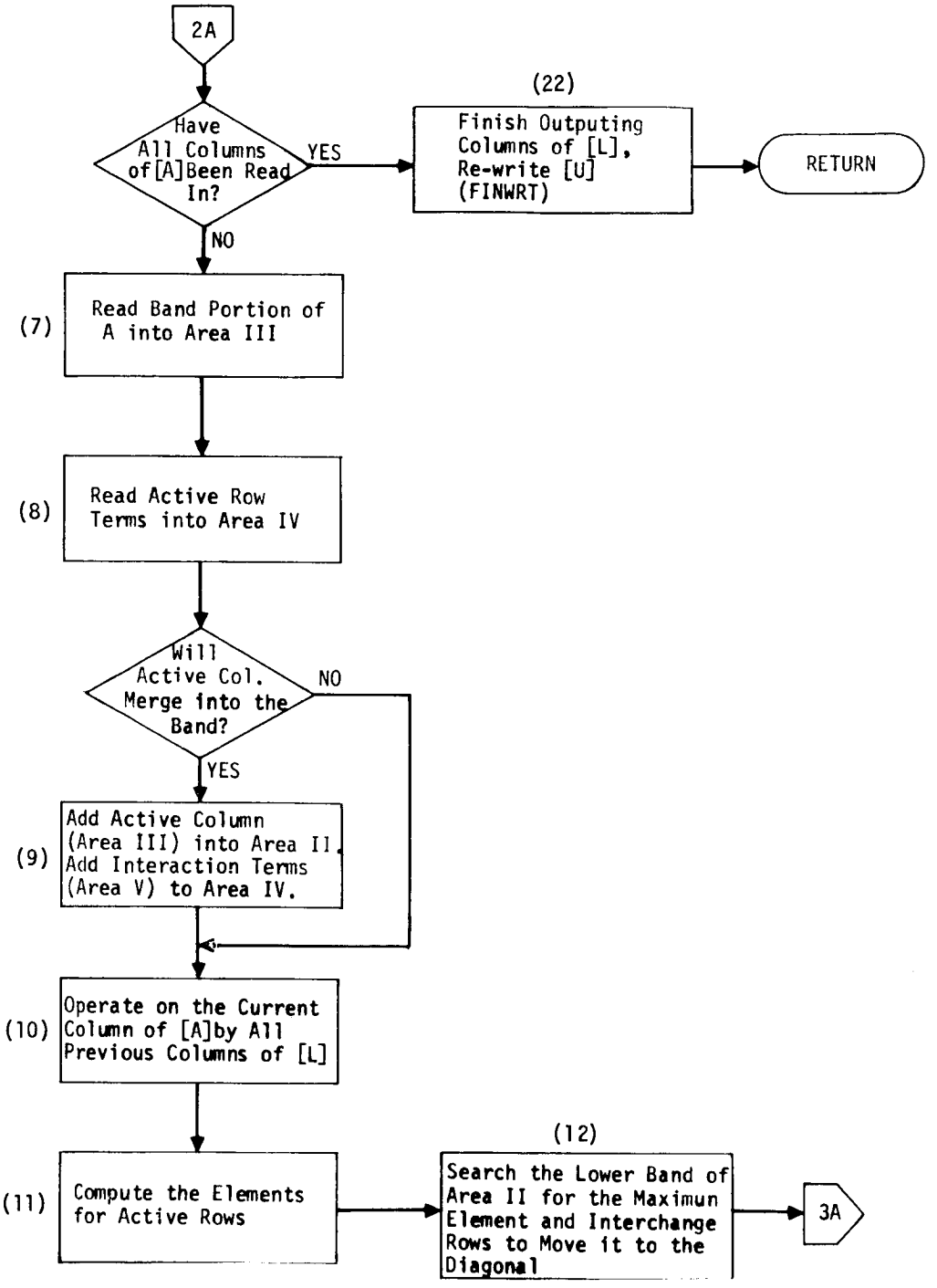


Figure4.(b) DECØMP program flow

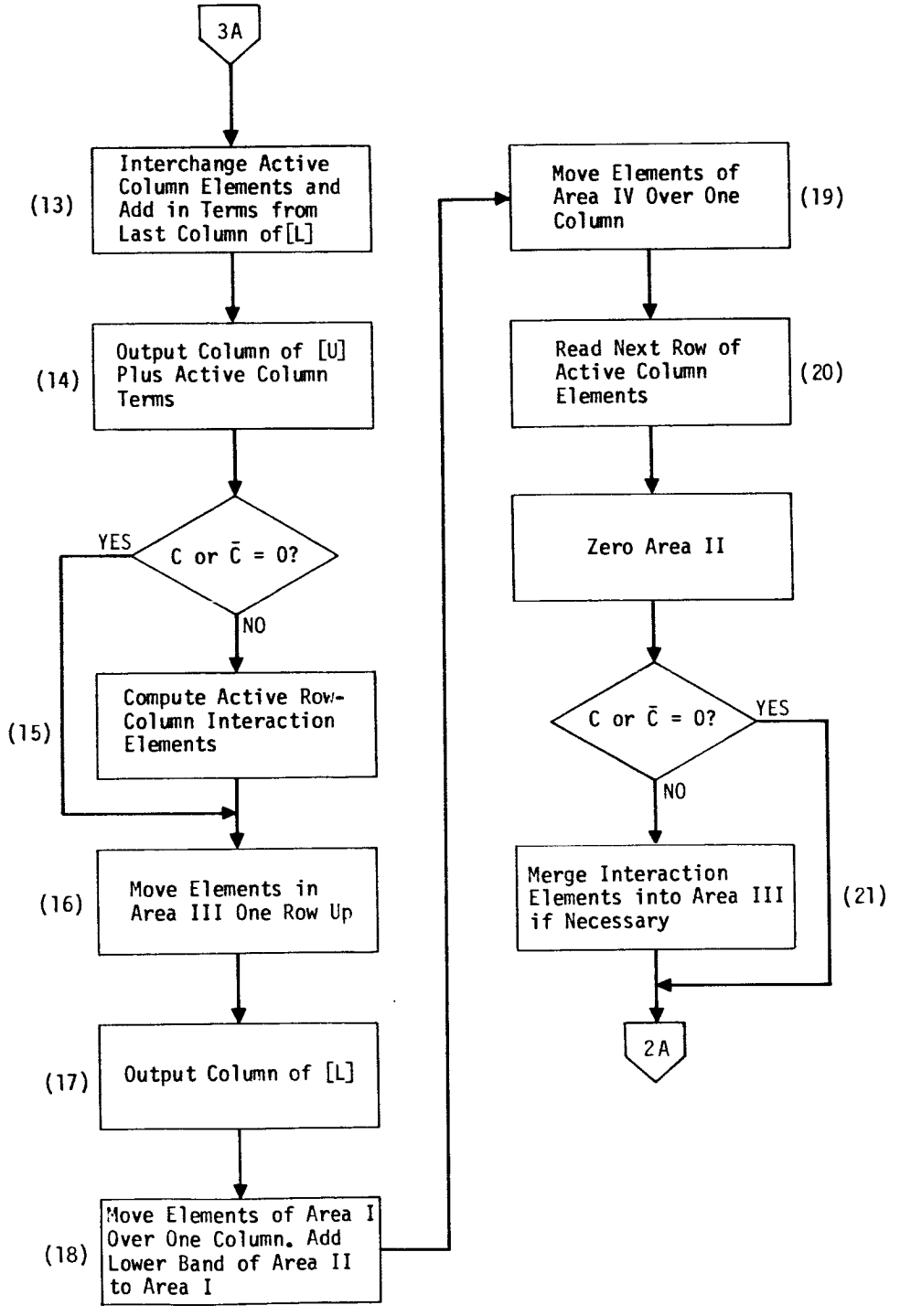


Figure 4.(c) DECØMP program flow

3. Program Flow: The flow chart in Figure 4 gives the logical program flow of DECØMP. The following comments expand on certain portions of the flow chart:

(1) Allocate buffers, initialize the determinant, and write header records.

(2) If the order of [A] is 1 or 2, subroutine ØNETWØ is called to handle the decomposition.

(3) If B and $\bar{B}$ are input as zero, GENVEC is called to pick the optimum parameters for decomposition.

(4) The pointers into the various areas of core shown in Figure 1 are computed.

(5) If there exist active elements in the upper triangle, TRANSP is called to transpose these elements.

(6) Active columns are initialized for all columns having an active element within the first $\bar{B}$ + 1 rows of [A].

(7) The band portion of the next column of [A] is read into Area II.

(8) Any active elements occurring below the diagonal in the current column are added into existing active rows, or new active rows are created.

(9) When an active column merges into the band, a column from Area III is added into corresponding positions in Area II, and a column of interaction elements in Area V is added to the active row terms in Area IV.

(10) The current column of [A] in Area II is operated on by the columns of [L] stored in Area I.

(11) Terms corresponding to active rows not yet merged into the band are added into Area II.

(12) The lower band portion of Area II is searched for the maximum element. Rows are interchanged to bring it to the diagonal position, and the interchange index is stored in Area I.

(13) Active columns elements are interchanged corresponding to the interchange within the band. If a column of [L] is about to be output (i.e., B + $\bar{B}$ columns of [L] are stored in Area I), terms arising from that column are added into the active columns.

(14) The column of [U] from Area II plus a row of active column terms in Area III are output.

(15) If active rows and columns exist, terms arising from their interaction are computed and added into Area V.

(16) Elements in the active columns are moved up one row position in Area III to replace the output elements, and make room for a new row.

(17) The first column of [L] in Area I is written out if Area I is full. The active row elements belonging to that column are also output.

(18) The columns of [L] in Area I are moved over one column and the lower band portion of Area II is stored in Area I.

(19) Active rows in Area IV are moved over one column.

(20) The next row of active elements in the upper triangle of [A] is read. Elements are added to existing active columns, or new columns are created.

(21) When possible, a row of interaction elements in Area V is merged into the bottom row of active column elements (Area III).

(22) After processing all columns of [A], FINWRT is called to complete the outputting of [L] and to re-write [U].

3.5.15.5 Auxiliary Subroutine TRANSP

1. Entry Point: TRANSP

2. Purpose: To do an in-core transpose of the active elements occurring outside the band and in the upper half of the matrix (i.e., transpose all elements a_{ij} such that $j - i \geq B$).

3. Calling Sequence: CALL TRANSP (X,X,NX,A,B,SCRFIL)

X - An area of core available to TRANSP.

NX - Number of words available at X.

A - GINØ file containing the input matrix [A] - integer.

B - Upper bandwidth of matrix [A].

SCRFIL - GINØ file where transposed elements are stored.

4. Method: The input matrix [A] is read, and all elements occurring outside the band in the upper triangle are stored in core, along with their row and column position. This list is then searched and elements output in transposed order.

3.5.15.6 Auxiliary Routine ØNETWØ

1. Entry Points: ØNETWØ,FINWRT

2. Purpose: ØNETWØ is a separate routine whose sole responsibility is to solve matrices of order one or two.

FINWRT is a section of code separated from DECØMP due to compiler overflow. Its function is to finish outputting the remaining columns of [L] and to re-write the columns of [U].

3.5.15.7 Auxiliary Subroutine GENVEC

1. Entry Point: GENVEC

2. Purpose: To pick the optimum B, $\bar{B}$, C, $\bar{C}$, and R for a given matrix [A].

3. Calling Sequence: CALL GENVEC ($\$n_1$,BUF,A,NX,X,N,B,BBAR,C,CBAR,R,IENTRY)

n_1 - Statement to which control is transferred if a null column is discovered in [A].

BUF - Location of a GINØ buffer.

A - GINØ file containing the input matrix [A].

X - An area of core available to GENVEC.

NX - Number of words of core available at X.

N - The order of the matrix [A].

B,BBAR, C,CBAR, R - Integer output parameters giving the optimum values for the upper and lower bandwidths, the number of active rows and columns, and the number of columns of [L] held in core.

IENTRY - = 1 implies DECØMP called GENVEC.
= 2 implies CDCØMP called GENVEC.

4. Method: The following logic flow gives the means by which the optimum bandwidths are chosen.

A. Locate extreme non-zero terms

1. Initialize active column list to zero. The length of the list is equal to the maximum value of the upper bandwidth (B) that is of interest. ($B_{max} = \frac{10^5}{NM_B}$, or the order of the problem, whichever is less, where N is the order of the matrix and M_B is the arithmetic time in μ seconds for performing one multiply and one add.

2. Initialize the column list to zero. The length of the list is the order of the problem.

3. Locate the non-zero elements in the next column of the matrix.

4. Insert the column number of all non-zero elements in the correct row position of the column number list with the following constraints:

   a. Consider only elements in the lower triangle.

   b. Do not insert column numbers in row positions already occupied.

5. Insert the row number of the non-zero element located in the lowest numbered row into the column position of the row number list for the current column under consideration.

6. Return to step 4 until all columns of the matrix have been processed.

B. Determine active columns

1. Zero counter E

   Set Counter F to N-1

   Set Counter G to N-1

   Set Counter H to 2

2. Beginning with the last entry in the row number list, subtract the current value of counter H, and test for a negative sign. If negative, increment counter E by one.

3. The current value of counter E is the number of active columns when the upper bandwidth is equal to the current value of counter F. Compare counter E with the existing entry in the active column list for the bandwidth indicated by counter F. Update the active column list if counter E is greater than the existing entry.

4. Decrement counter F by one. Return to step 2 unless counter F is zero.

5. Decrement counter G by one. Increment counter H by one. Set counter F to the value of counter G. Zero counter E. Return to step 2 unless counter G is zero.

6. The final active column list contains the maximum number of active columns for bandwidths of unity through the maximum upper bandwidth investigated.

7. Prepare reduced active column list by extracting pairs - minimum B and associated C for unique values of C.

C. Determine active rows for given B and $\bar{B}$

1. Extract pairs (row number, L, and column number, K) from the column number list for which

$$L - K > \bar{B}$$

2. Consider a new list of pairs consisting of K and L + B. For each pair (K, L + B) determine the number of remaining pairs $(K_i, (L + B)_i)$ for which

$$K_i < L + B \quad \text{and} \quad (L + B)_i \geq K$$

3. The maximum number of pairs satisfying the relation in step 2 for any single pair is $\bar{C}$ for the given B and $\bar{B}$.

D. Select B, B, C and $\bar{C}$ for Minimum Decomposition Time

1. Select the next value of B and associated C from the reduced active column list (begin with maximum B of interest).

2. Assume $B = \bar{B}$ and $C = \bar{C}$.

3. Calculate R and T with preliminary timing equations.

4. Save the minimum T and the associated B and C.

5. Return to step 1 unless all entries in reduced active column list have been used.

6. If the matrix is unsymmetric use B and C from step 4 and set $\overline{B} = B$.

7. Determine C for a given $\bar{B}$ and B.

8. Calculate R and T with the preliminary timing equations.

9. Compare with the previous minimum T.

10. If the new T exceeds the previous minimum by more than 20% or $\bar{B}$ = maximum B of interest go to 12.

11. Save the minimum T along with associated B, $\bar{B}$, C and $\bar{C}$. Increment $\bar{B}$ by 2% of the B associated with minimum T and go to 7.

12. Return to B = $\bar{B}$.

13. Decrement $\bar{B}$ by 2% of the B associated with minimum T and determine the associated C.

14. Calculate R and T with the preliminary timing equations.

15. Compare with the previous minimum T while decrementing $\bar{B}$.

16. If the new T exceeds the previous minimum by more than 20% or $\bar{B}$ = 2 go to 18.

17. Save the minimum T along with associated B, $\bar{B}$, C and $\bar{C}$ and go to 13.

18. Save values of B, $\bar{B}$, C and $\bar{C}$ associated with the minimum value of T from upsearch and downsearch on $\bar{B}$, for use in decomposition.

3.5.15.9 Auxiliary Function FINDC

1. Entry Point: FINDC

2. Purpose: To find the number of active rows ($\bar{C}$) for a given B and $\bar{B}$.

3. Calling Sequence: CALL FINDC (B,BBAR,N,X,Y,CBAR)

   B - Upper bandwidth - integer.

   BBAR - Lower bandwidth - integer.

   N - Order of the problem.

   X - Column number list.

   Y - Scratch vector.

   CBAR - The number of active rows, $\bar{C}$.

4. Method: See step C in the GENVEC method.

3.5.15.10 Auxiliary Routine TIMEEQ

1. Entry Points: T,TFIN,RCØRE

2. Purpose: To compute the preliminary and final timing equations for decomposition, and to compute the core allocation function.

3. Calling Sequences: CALL T (B,BBAR,C,CBAR,R,IENTRY,N,TIM)

CALL TFIN (B,BBAR,C,CBAR,R,IENTRY,N,TIMEX)

CALL RCØRE (B,BBAR,C,CBAR,N,IENTRY,NX,R)

B,BBAR
C,CBAR, - Upper and lower bandwidths, number of active rows and columns.

IENTRY - {=1 implies entry was from DECØMP.
{=2 implies entry was from CDCØMP.

N - The order of the problem.

TIM - Floating point value for the preliminary time.

TIMEX - Floating point value for the final timing equation.

NX - Number of core words available to DECØMP or CDCØMP.

R - The number of columns of [L] that can be held in core (output by RCØRE, input to T and TFIN).

4. Method: The following equations are evaluated to give the desired output.

A. Core Function

$$R = (NX - ((B + \bar{B} + 1) + 2*IENTRY*MINO(N,B + \bar{B} + \bar{B}) + 2*IENTRY*C*(\bar{B} + 2) + 2*\bar{C}*IENTRY*(MINO(B + \bar{B},N) + 1) + 2*IENTRY*C*\bar{C} + C + \bar{C}*IENTRY + \bar{C}) - 6*SYSBUF)/(2*IENTRY*\bar{B}) \quad (4)$$

B. Preliminary Timing Equation

$$TIM = \frac{N}{10^6}[M_B\bar{B}R + M_C(\bar{B}C + \bar{B}\bar{C} + B\bar{C} + 2C\bar{C}) + I\bar{B}(B + \bar{B} - R - 1)] \quad (5)$$

where

M_B = Arithmetic time in μ seconds for one term inside the band.

M_C = Arithmetic time in μ seconds for one term in the active row or active column.

I = I/Ø time in μ seconds for one term.

C. Final Timing Equations

TIMEX is a function of T_1, T_2, T_3 and T_4 as defined below (P = matrix packing time in μ seconds for one term).

T_1 is given by:

$$T_1 = K_1 [M_B \bar{B} R + I\bar{B}(B + \bar{B} - R) + P(B + 2\bar{B})] , \tag{6}$$

where

$$K_1 = \begin{cases} N - B - 2\bar{B} , & \text{if } N - B - 2\bar{B} > 0 \\ 0 , & \text{if } N - B - 2\bar{B} \leq 0 . \end{cases} \tag{7}$$

T_2 is given by:

$$T_2 = \frac{K_2}{2} [\bar{B} K_2 M_B + (K_3 - R)(I - M_B)\bar{B} + 2P\bar{B} + PK_2] , \tag{8}$$

where

$$K_2 = K_3 = B + \bar{B} \tag{9}$$

if $N \geq B + 2\bar{B}$; otherwise,

$$K_2 = N - B , \tag{10}$$

and

$$K_3 = \begin{cases} B + \bar{B} & \text{if } N \geq B + \bar{B} \\ N & \text{if } N < B + \bar{B} . \end{cases} \tag{11}$$

T_3 is given by:

$$T_3 = \frac{\bar{B}^3}{3} M_B + \frac{K_4^3}{2} I + P\bar{B}K_5 . \tag{12}$$

where

$$K_4 = \begin{cases} B + \bar{B} - R , & \text{if } B - R \leq 0 \\ \bar{B} , & \text{if } B - R > 0 . \end{cases} \tag{13}$$

and

$$K_5 = B + \frac{3}{2}\bar{B} , \tag{14}$$

if $N \geq B + 2\bar{B}$. Otherwise,

$$K_4 = \begin{cases} N - R , & \text{if } N - R \leq \bar{B} \\ \bar{B} , & \text{if } N - R > \bar{B} \end{cases} . \tag{15}$$

and

$$K_5 = N \tag{16}$$

T_4 is given by:

$$T_4 = (N - \bar{B})[M_C(\bar{B}C + B\bar{C} + \bar{B}\bar{C} + C\bar{C}) + P(C + \bar{C})] . \tag{17}$$

Finally,

$$TIMEX = (T_1 + T_2 + T_3 + T_4)10^{-6} , \tag{18}$$

where TIMEX is the total estimated time for decomposition.

3.5.15.11 Auxiliary Subroutine DLØØP

1. Entry Points: DLØØP,DDLØØP,XLØØP

2. Purpose: To improve efficiency of FØRTRAN generated code for several loops in DECØMP.

3.5.15.12 Design Requirements

Core storage requirements depend on the parameters B, $\bar{B}$, C and $\bar{C}$. Areas II, III, IV, and V must reside in core at all times, along with a minimum of two columns of Area I, and five GINØ buffers. GENVEC is designed to pick the combination of B, $\bar{B}$, C, and $\bar{C}$ such that the problem will allocate if at all possible.

The file containing [U] is not in standard format, as the active column terms are stored out of place. For this reason [L] and [U] should be used as input only to GFBS or an associated routine.

3.5.15.13 Information Messages

1. CØNMSG is called at entry and exit from DECØMP. The line

XXXX DECØMP

will appear twice per decomposition. The actual execution time of DECØMP will be the difference in the times (where XXXX = time in seconds).

2. 3023 B = XXX C = XXX R = XXX

3028 BBAR = XXX CBAR = XXX R = XXX

These messages give the parameters chosen for the decomposition.

3. 3027 DECØMPØSITIØN TIME ESTIMATE = XXX

Gives the estimated time for the decomposition in seconds.

3.5.15.14 Diagnostic Messages

Fatal error messages 3008 and 3025 may occur.

3.5.16 CDCØMP (Complex Matrix Decomposition)

3.5.16.1 Entry Point: CDCØMP

3.5.16.2 Purpose

To decompose a complex square matrix [A] into the form [A] = [L][U] where [L] is a unit lower triangular matrix and [U] is an upper triangular matrix.

3.5.16.3 Calling Sequence

```
CALL CDCØMP ($n1,X,X,X)
CØMMØN /CDCMPX/ A(7),L(7),U(7),SCR(3),DET(2),PØWER,NX,MINDIA,B,BBAR,C,CBAR,R
```

- n_1 - Location in calling program where control is transferred if [A] is singular.
- X - An area of working storage.
- A - Input matrix control block for [A].
- L,U - Output matrix control blocks for [L] and [U].
- SCR(3) - Three scratch files available for use.
- DET(2) - Two double precision words where the real and imaginary values of the determinant are stored.
- PØWER - Scale factor to be applied to the determinant (det ([A]) = DET*10**PØWER).
- NX - Number of computer words at X.
- MINDIA - Double precision word where the modulus of the minimum diagonal element of [U] is stored.
- B,BBAR, C,CBAR, R - If B = BBAR = 0, compute and store B,BBAR,C,CBAR,R before decomposing [A]. If B or BBAR ≠ 0, use previously stored values of B,BBAR,C,CBAR and R for decomposing.

3.5.16.4 Method

CDCØMP is simply a copy of DECØMP with the arithmetic statements replaced by complex arithmetic. Pointers to storage areas were modified to accommodate the extra words needed.

3.5.16.5 Auxiliary Subroutine CTRNSP

Purpose: Complex version of TRANSP (see Section 3.5.15.5).

3.5.16.6 Auxiliary Subroutine CØM12

Purpose: Complex version of ØNETWØ (see Section 3.5.15.6)

3.5.16.7 Auxiliary Routine CLØØP

Inner loop routine.

3.5.16.8 Auxiliary Routine CXLØØP

Inner loop routine.

3.5.16.9 Design Requirements

See subroutine descriptions for DECØMP, Section 3.5.15.

3.5.16.10 Diagnostic Messages

See subroutine descriptions for DECØMP, Section 3.5.15.

3.5.17 FBS (Forward - Backward Substitution).

3.5.17.1 Entry Point: FBS.

3.5.17.2 Purpose

Given the decomposition of a real symmetric matrix $[A] = [L] [D] [L]^T$ FBS will perform the forward-backward pass necessary to solve the system of linear equations $[A] [X] = [B]$.

3.5.17.3 Calling Sequence

```
CALL FBS(Z,Z)

COMMON/FBSX/L(7),U(7),B(7),X(7),NZ,PREC,SIGN
```

L,U - Matrix control blocks for the lower and upper triangular factors output from SDCOMP.

B,X - Matrix control blocks for the matrices [B] and [X].

NZ - Number of computer words at Z.

PREC - { 1, perform arithmetic in single precision.
       { 2, perform arithmetic in double precision.

SIGN - { +1, solve [A] [X] = [B].
       { -1, solve [A] [X] = -[B].

Z - An area of working storage.

3.5.17.4 Method

Mathematical Considerations. Given the unit upper and lower triangular matrices [L] and $[L]^T$, with the diagonal matrix [D] stored over their diagonals, FBS solves the two systems of equations given by

$$[L] [Y] = \pm[B]$$

and

$$[L]^T [X] = [D]^{-1}[Y]$$

Elements [Y] and [X] are given by

$$y_{ij} = b_{ij} - \sum_{k=1}^{i-1} \ell_{ik} y_{kj}$$

$$x_{ij} = y_{ij}/d_i - \sum_{k=i+1}^{n} \ell_{ki} x_{ij}$$

Program Flow. Overall program flow is identical to that of GFBS (see Section 3.5.19). The only difference in the two routines is that FBS uses the decomposed matrices output from SDCØMP, while GFBS uses those output by DECØMP. Likewise, the computed equations differ slightly.

3.5.17.5 Auxiliary Subroutine FBSDP

1. Entry Point: FBSDP

2. Purpose: Inner loop routine for double precision forward and backward substitution.

3. Calling Sequence: CALL FBSDP (X,Y,N,M)

   DØUBLE PRECISIØN X(1),Y(1),A

   CØMMØN /ZNTPKX/ A

   X - Input vector/output vector
   Y - Input vector
   N - Loop limit
   M - Skip Index

4. Method: $X_i = X_i - AY_i$, $i = 1(M)N$

3.5.17.6 Auxiliary Subroutine FBSSP

1. Entry Point: FBSSP

2. Purpose: Inner loop routine for single precision forward and backward substitution.

3. Calling Sequence: CALL FBSSP (X,Y,N,M)

   DIMENSIØN X(1),Y(1)

   CØMMØN /ZNTPKX/ A

   X - Input vector/output vector
   Y - Input vector
   N - Loop limit
   M - Skip Index

4. Method:

   xi = Xi - AY_i, $i = 1(M)N$

3.5.17.7 Design Requirements

One column of [B] and one GINØ buffer must fit in core.

3.5.17.8 Diagnostic Messages

See GFBS (Section 3.5.19).

3.5.18 SSG3A (Driver for FBS).

3.5.18.1 Entry Point: SSG3A.

3.5.18.2 Purpose

To solve [A] [X] = [B] using [A] = [L] $[L]^T$. On option to compute the residual matrix [RES] = [A] [X] - [B].

3.5.18.3 Calling Sequence

CALL SSG3A(FILEA,FILEL,FILELT,FILEB,FILEX,SCR1,SCR2,IRES,FILER)

FILEA - GINØ file name of [A] - integer - input.

FILEL - GINØ file name of [L] - integer - input.

FILELT - GINØ file name of $[L]^T$ - integer - input.

FILEB - GINØ file name of [B] - integer - input.

FILEX - GINØ file name of [X] - integer - input.

SCR1 - GINØ name of scratch file - integer - input.

SCR2 - GINØ name of scratch file - integer - input.

IRES - Option for residual vector - integer - input. IRES = 0 suppresses calculation of residual vector.

FILER - GINØ file name of residual vector - integer - input.

3.5.18.4 Method

/FBSX/ is set to compute [A] [X] = [B].

SSG2B is called to compute [RES] = [A] [X] - [B] (see section 3.5.17.3).

For each column of [X], $\{X_i\}$, ε_i is computed.

$$\varepsilon_i = \{X_i\}^T\{RES_i\}/\{B_i\}^T\{X_i\}$$

3.5.18.5 Design Requirements

Open core at /SSGA3/.

3.5.19 GFBS (General Forward - Backward Substitution).

3.5.19.1 Entry Point: GFBS.

3.5.19.2 Purpose

Given the decomposition of a general square matrix [A] = [L] [U], GFBS will solve the system of equations [A] [X] = [L] [U] [X] = $\pm$ [B]

3.5.19.3 Calling Sequence

```
CALL GFBS (Z,Z)

COMMON/GFBSX/L(7),U(7),B(7),X(7),NZ,PREC,ISIGN
```

L,U,B,X - Matrix control blocks for the matrices [L], [U], [B], and [X].

X(5) - Desired output type for [X].

NZ - Number of computer words available at Z.

PREC - $\begin{cases} 1, \text{ use single precision arithmetic} \\ 2, \text{ use double precision arithmetic} \end{cases}$

ISIGN - $\begin{cases} 1, \text{ solve [A] [X] = } \pm \text{ [B].} \\ -1, \text{ solve [A] [X] = -[B].} \end{cases}$

Z - An area of working storage.

3.5.19.4 Method

1. Mathematical Considerations. Given [L], [U] (n by n lower and upper triangular matrices) and [B] (a n by m matrix) GFBS solves the two systems of equations

$$[L]\,[Y] = \pm\,[B]$$

and

$$[U]\,[X] = [Y]$$

Elements of [Y] and [X] are given by

$$y_{ij} = b_{ij} - \sum_{k=1}^{i-1} \ell_{ik} y_{kj} \qquad (1)$$

$$x_{ij} = [y_{ij} - \sum_{b=i+1}^{n} u_{ik} x_{kj}]/u_{ii} \qquad (2)$$

2. Initialization Phase. The type of arithmetic to be performed is computed as a function of the type of [L], [B], and the precision requested by the calling routine. Corresponding transfer vectors are set up to transfer control to the proper arithmetic computation. Core storage is filled with as many columns of [B] as possible.

3. Forward Pass. The intermediate values of [Y] are computed directly over the columns of [B] currently in core. This is a forward pass on [L] since it is read sequentially forward. Interpretation of Equation 1 shows that y_{1j} is complete after the first column of [L] has been read, y_{2j} after column 2, etc. Elements of [L] are read one at a time via INTPK and the appropriate term subtracted off.

4. Backward Pass. Elements of [X] are computed by processing [U] in the reverse order. Reading the last column of [U] completes $x_{n,j}$, the n-1 column of [U] gives $x_{n-1,j}$, etc. In order to facilitate the reading of [U], it was written in the reverse order by DECØMP, allowing a forward pass to be made in actuality.

5. Output Phase. The finished columns of [X] are packed and output via PACK. If more columns of [B] still exist, core is once again filled with vectors of [B] and the process repeated until all columns of [X] have been computed.

3.5.19.5 Design Requirements

At least one column of [B] must be unpacked in core, along with one GINØ buffer.

3.5.19.6 Diagnostic Messages

If insufficient core is available for GFBS, fatal message 3008 occurs.

If a diagonal term does not exist for a column of [U], fatal message 3005 occurs. This is noramlly detected in DECØMP implying care was not taken in processing singular matrices in the calling routine calling DECØMP.

3.5.20 SØLVER (Simultaneous Equation Solution Routine).

3.5.20.1 Entry Point: SØLVER.

3.5.20.2 Purpose

To perform the following three functions:

1. Solve [A] [X] = -[B] for X where A is a real symmetric matrix which has been decomposed by SDCØMP.
2. Evaluate the matrix equation $[E] = [D] + [B]^T [X]$
3. On option, compute

$$\varepsilon = \frac{||[E]||}{||[D]||}$$

3.5.20.3 Calling Sequence

CALL SØLVER(L,U,X,B,D,E,EPS,FLAG,SCR)

where:

L,U are the GINØ file names of the data blocks containing the lower and upper triangular factors of A, respectively.

X is the GINØ file name of the data block where the solution matrix will be written.

B is the GINØ file name of the data block containing the right hand matrix in [A] [X] = -[B]

D,E are the GINØ file names of the data blocks in Equation (2) above.

EPS is the real single precision result of the division in Equation (3).

SCR is the GINØ file name of a scratch file for use by SØLVER.

FLAG $\begin{cases} \neq 0, \text{ compute } \varepsilon \text{ from Equation (3) above and store in EPS} \\ = 0, \text{ do not compute } \varepsilon \end{cases}$

/SØLVRX/ is open core for SØLVER

Note:

1. L must be output from subroutine SDCØMP.
2. If D = A, then E is the error residual matrix.

3.5.20.4 Method

/FBSX/ is initialized and FBS is called to solve [A] [X] = -[B].

/MPYADX/ is initialized and MPYAD is called to compute [E] = [D] + $[B]^T$ [A]. FLAG is tested. If FLAG = 0, return is made. Otherwise, INTPK is called to unpack and interpret each non-zero term of E. The cumulative sum of the absolute value of all non-zero terms of E is formed in double precision. This operation is then performed on D. Finally ε is the division of these two quantities and is stored in EPS in single precision.

3.5.20.5 Design Requirements

/SØLVRX/ must be inserted at the end of the overlay segment containing SØLVER.

3.5.20.6 Diagnostic Messages

The following system fatal message may be issued by SØLVER:

3001

3.5.21 DMPY (Multiply a Diagonal Matrix by an Arbitrary Matrix).

3.5.21.1 Entry Point: DMPY.

3.5.21.2 Purpose

To pre or post multiply an abritrary matrix [B] by a diagonal matrix, i.e. [C] = [D][B] or [C] = [B][D].

3.5.21.3 Calling Sequence

```
CALL DMPY(Z,Z)

CØMMØN/DMPYX/D(7),B(7),C(7),NZ,FLAG,SIGN
```

Z - An area of working storage.

NZ - The number of computer words at Z.

D - Matrix control block for the diagonal matrix.

B - Matrix control block for the general matrix.

C - Matrix control block for the product matrix.

C(1) must contain the GINØ file name prior to entry.

C(5) must contain the arithmetic type of the elements of C.

DMPY will accumulate C(2) and C(6) and set C(7) = 0.

C(3) and C(4) may be set by the user before or after the call.

FLAG - $\begin{cases} = 0, \text{ pre-multiply B by D.} \\ \neq 0, \text{ post-multiply B by D.} \end{cases}$

SIGN - $\begin{cases} +1, \text{ form positive product.} \\ -1, \text{ form negative product.} \end{cases}$

3.5.21.4 Method

The type of arithmetic is determined (real or complex). The elements of the diagonal matrix, D, are unpacked at Z. INTPK is used to read and interpret the non-zero elements of B, column by column. The following equations are used:

Pre-multiplication: $c_{ij} = d_i b_{ij}$

Post-multiplication: $c_{ij} = b_{ij} d_j$

3.5.21.5 Design Requirements

Double precision arithmetic is used throughout.

The amount of core at Z must be sufficient to hold the unpacked diagonal terms of D and two GINØ buffers.

The dimensions of D and B must be compatible although this is not checked.

3.5.21.6 Diagnostic Messages

The following system fatal messages may be issued by DMPY:

3001

3002

3.5.22 ELIM (Perform a Matrix Reduction).

3.5.22.1 Entry Point: ELIM.

3.5.22.2 Purpose

To perform a matrix reduction on the structural model by computing the matrix equation:

$$[K_{ii}] = [\overline{K}_{ii}] + [\overline{K}_{ji}]^T [G_j] + [G_j]^T [\overline{K}_{ji}] + [G_j]^T [\overline{K}_{jj}] [G_j]$$

3.5.22.3 Calling Sequence

CALL ELIM(KIIB,KJIB,KJJB,GJ,KII,SCR1,SCR2,SCR3)

where KIIB, KJIB, KJJB, GJ and KII are the GINØ file names of each of the matrices in the above equation. SCR1, SCR2 and SCR3 are GINØ file names of three scratch files used by ELIM.

Open core for ELIM is defined by /ELIMX/.

3.5.22.4 Method

ELIM computes the above matrix equation by three successive calls to MPYAD. These are as follows:

$$[SCR1] = [\overline{K}_{jj}] [G_j] + [\overline{K}_{ji}]$$

$$[SCR2] = [\overline{K}_{ji}]^T [G_j] + [\overline{K}_{ii}]$$

$$[K_{ii}] = [G_j]^T [SCR1] + [SCR2]$$

3.5.22.5 Design Requirements

/ELIMX/ must be included at the end of the segment in which ELIM resides.

3.5.23 FACTØR (Decompose a Matrix Into Triangular Factors).

3.5.23.1 Entry Point: FACTØR.

3.5.23.2 Purpose

To decompose a symmetric matrix into its two triangular factors.

3.5.23.3 Calling Sequence

CALL FACTØR (A,L,U,SCR1,SCR2)

where A, L, U are the GINØ file names of the data blocks for the symmetric matrix to be decomposed, its lower triangular factor and its upper triangular factor, respectively. If U is negative, FACTØR will decompose the symmetric matrix [A] on file A such that

$$[A] = [C][C]^T ,$$

where the Cholesky decomposition is used. [C] will be written on U as a lower triangular matrix. L will contain the lower triangular factor of a standard non-Cholesky decomposition. SCR1 and SCR2 are GINØ file names of two scratch files for use by FACTØR. The common block /FACTRX/ is open core for FACTØR.

3.5.23.4 Method

FACTØR initializes /SFACT/ and calls SDCØMP to accomplish the decomposition.

3.5.23.5 Design Requirements

/FACTRX/ must be included at the end of the segment which contains FACTØR.

3.5.23.6 Diagnostic Messages

The following system fatal message may be issued by FACTØR:

3005

3.5.24 TRANP1 (Driver for TRNSP).

3.5.24.1 Entry Point: TRANP1.

3.5.24.2 Purpose

To drive TRNSP to compute $[B] = [A]^T$.

3.5.24.3 Calling Sequence

CALL TRANP1(FILEA,FILAT,NSCRTH,SCR1,SCR2,SCR3,SCR4,SCR5,SCR6,SCR7,SCR8).

FILEA - GINØ name of [A] - integer - input.

FILAT - GINØ name of $[A]^T$ - integer - input.

NSCRTH- Number of scratch files - integer - input.

SCR1, ... , SCR8 - GINØ names of scratch files - integer - input.

3.5.24.4 Method

/TRNSPX/ is set based on the trailer of FILEA.

3.5.24.5 Design Requirements

Open core at /DTRANX/.

3.5.25 TRNSP (Matrix Transpose).

3.5.25.1 Entry Point: TRNSP.

3.5.25.2 Purpose

To compute $[A]^T$ given [A].

3.5.25.3 Calling Sequence

CALL TRNSP(Z)

Z - Array of core.

CØMMØN/TRNSPX/MCBA(7),MCBAT(7),LCØRE,NSCRTH,SCR(8)

MCBA - Matrix control block for [A] - input.

MCBAT - Matrix control block for $[A]^T$ - input.

LCØRE - Length of Z array - integer - input.

NSCRTH - Number of scratch files available - integer - input. $1 \leq NSCRTH \leq 8$.

SCR - List of GINØ names of scratch files - integer - input.

3.5.25.4 Method

Three methods are possible:

Method 1 - In-core matrices.

If the full matrix can be held in core, [A] is unpacked into core, and packed out onto $[A]^T$.

Method 2 - Simple sub-matrices.

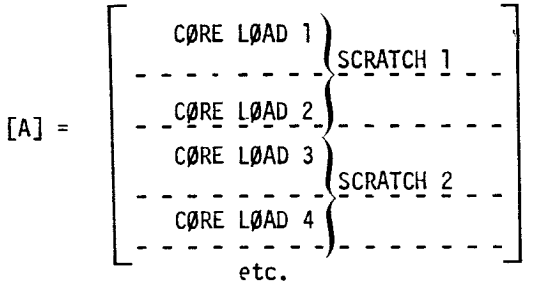
The matrix [A] is broken up one column at a time into submatrices. The submatrices are written on scratch files, read in and transposed one at a time. The break-up of [A] can be pictured as follows:

$$[A] = \begin{bmatrix} \text{SCRATCH 1} \\ \hline \text{SCRATCH 2} \\ \hline \text{SCRATCH 3} \\ \hline \text{etc.} \end{bmatrix}$$

If insufficient scratch files are available to hold [A], multiple passes may be made

Method 3 - Multiple passes on submatrices.

If multiple passes on [A] are necessary in Method 2, it may be more efficient to create larger submatrices and pass each submatrix several times rather than several passes on [A]. The break-up of [A] can be pictured as follows:



TRNSP will choose between the methods to minimize running time.

3.5.25.5 Design Requirements

Methods 2 and 3 require at least one scratch file.

Neither [A] nor $[A]^T$ may be purged.

One unpacked column of [A] and NSCRTH+1 GINØ buffers must fit into core.

3.5.25.6 Diagnostic Messages

A message indicating insufficient core is produced if the third of the above requirements is not satisfied. Either reduce the number of scratch files or increase the open core available to TRNSP.

3.5.26 SADD (Matrix Addition Routine)

3.5.26.1 Entry Point: SADD

3.5.26.2 Purpose

To compute $[X] = \alpha[A] + \beta[B] + \gamma[C] + \delta[D] + \varepsilon[E]$

3.5.26.3 Calling Sequence

```
CALL SADD (Z,Z)
```

Z -- Array of core

```
CØMMØN/SADDX/NØMAT,LCØRE,MCBA(7),TYPA,ALPHA(4),MCBB(7),TYPB,
      BETA(4),MCBC(7),TYPC,GAMMA(4),MCBD(7),TYPD,DELTA(4),
      MCBE(7),TYPE,EPSLN(5),MC(7)
```

NØMAT - Number of matrices to be added - integer - input.

LCØRE - Length of Z array - integer - input.

MCBA - Matrix Control Block for [A] - input

TYPA - Type of ALPHA - integer - input

1 - real single precision

2 - real double precision

3 - complex single precision

4 - complex double precision

ALPHA - α - input - type depends on TYPA

MCBB - Matrix Control Block for [B] - input

TYPB - Type of BETA - integer - input

BETA - β - input - type depends on TYPB

MCBC - Matrix Control Block for [C] - input

TYPC - Type of GAMMA - integer - input

GAMMA - γ - input - type depends on TYPC

MCBD - Matrix Control Block for [D] - input

TYPD - Type of DELTA - integer - input

DELTA - δ - input - type depends on TYPD

MCBE - Matrix Control Block for [E] - input

TYPE - Type of EPSLN - integer - input

EPSLN - ε - input - type depends on TYPE

MC - Matrix Control Block for [X] - input

3.5.26.4 Method

The type of arithmetic is determined to be the maximum type of [A], [B], [C], [D], [E], α, β, γ, δ, ε.

Initially a column of [X] is zeroed out. Each non zero element of [A] is obtained by ZNTPKI, multiplied by α, and added into a corresponding position of [X]. After processing a complete column of [A], columns from matrices [B], [C], etc., are treated in a similar manner. When the contribution from the last matrix has been added in, a complete column of [X] is output via PACK. This procedure is repeated until all columns of [X] are output.

3.5.26.5 Design Requirements

Z must be sufficient to hold one unpacked column of [X] plus n GINØ buffers (where n = NØMAT+1).

3.5.27 RSPSDC (Real Single Precision Symmetric Decomposition)

3.5.27.1 Entry Point: RSPSDC

3.5.27.2 Purpose

To decompose a real symmetric matrix [A] into the form [A] = [L] [D] $[L]^T$ where [L] is a unit lower triangular matrix and [D] is a diagonal matrix stored in place of the unit elements on the diagonal of [L]. On option, the Cholesky decomposition [A] = [C] $[C]^T$ is done for a real, positive definite matrix, with only the lower triangle [C] being output. RSPSDC will also compute the determinant of [A].

3.5.27.3 Calling Sequence

CALL RSPSDC ($\$n_1$,Z,Z,Z)

CØMMØN/SFACT/A(7),L(7),C(7),SCR1,SCR2,NZ,DET,PØWER,CHLSKY

A(7) - Matrix control block for [A].

L(7) - Matrix control block for [L].

C(7) - Matrix control block for $[L]^T$ or [C].

SCR1, SCR2 - Two scratch files.

NZ - The number of computer words at Z.

DET - Double precision cell where the scaled value of the determinant of [A] will be stored.

PØWER - Scale factor to be applied to DET (Determinant = DET*10**PØWER).

CHLSKY - When CHLSKY = 1, form [C]

Z - An area of working storage.

n_1 - Statement number to which control is transferred if the decomposition fails.

3.5.27.4 Method

The method used by RSPSDC is identical to that used by SDCØMP (Section 3.5.14) except that all computations are done in single precision.

3.5.27.5 Auxiliary Subroutines

Subroutine Name: RSPLØØ

Purpose: To compute the inner arithmetic loop of RSPSDC.

3.5.27.6 Design Requirements

The input matrix [A] should be well conditioned or positive definite as the decomposition is done without pivoting.

Core storage requirements depend on the parameters B and C. For a given B and C, Areas II, III, IV, and V must reside in core along with a minimum of two columns of Area I and 5 GINØ buffers.

Files containing [L] and $[L]^T$ should be used as input only to FBS as they are not in standard NASTRAN format.

3.5.27.7 Information Messages

1. CØNMSG is called at entry and exit from RSPSDC. The line

xxxx RSPSDC

will appear twice per decomposition. The execution time of RSPSDC will be the difference in the times (where xxxxx = time in seconds).

2. Message 3023 gives the values of the parameters, B, C, and R chosen for the decomposition.

3. Message 3027 gives the estimated time in seconds to do the decomposition.

4. Message 3024 indicates that a matrix has scattered terms way off the diagonal (i.e., a large bandwidth). Instead of searching all combinations of B and C, the search is started at the maximum bandwidth.

3.5.27.8 Diagnostic Messages

1. If RSPSDC was unable to find a combination of B and C which would meet core restrictions, fatal message 3008 occurs.

2. In a coding sense, message 3025 is possible. However, it violates the design of RSPSDC and therefore, if obtained, should indicate an obscure program design error, or machine error.

3. Message 3026 indicates that sufficient space was not reserved for the generation of the B vs. C vector. RSPSDC should be recompiled to increase BMAX and CMAX.

3.5.28 CSPSDC (Complex Single Precision Symmetric Decomposition)

3.5.28.1 Entry Point: CSPSDC

3.5.28.2 Purpose

To decompose a complex symmetric matrix [A] into the form [A] = [L] [D] $[L]^T$ where [L] is a unit lower triangular matrix and [D] a diagonal matrix stored in place of the unit elements on the diagonal of [L]. CSPSDC will also compute the determinant of [A].

3.5.28.3 Calling Sequence:

```
CALL CSPSDC
CALL SDCØMP($n1,Z,Z,Z)
CØMMØN/SDCCSP/A(7),L(7),C(7),SCR1,SCR2,NZ,DET,PØWER,CHLSKY
```

A(7) - Matrix control block for [A].

L(7) - Matrix control block for [L].

C(7) - Matrix control block for $[L]^T$ or [C].

SCR1, SCR2 - Two scratch files.

NZ - The number of computer words at Z.

DET - Double precision cell where the scaled value of the determinant of [A] will be stored.

PØWER - Scale factor to be applied to DET (Determinant = DET*10**PØWER).

CHLSKY - When CHLSKY = 1, form [C]

Z - An area of working storage.

n_1 - Statement number to which control is transferred if the decomposition fails.

3.5.28.4 Method

The method used by CSPSDC is identical to that used by RSPSDC (Section 3.5.27).

3.5.28.5 Auxiliary Subroutines

Subroutine Name: CSPLØØ

Purpose: To compute the inner arithmetic loop of CSPSDC.

3.5.28.6 Design Requirements

The input matrix [A] should be well conditioned or positive definite as the decomposition is done without pivoting.

Core storage requirements depend on the parameters B and C. For a given B and C, Areas II, III, IV, and V must reside in core along with a minimum of two columns of Area I and 5 GINØ buffers.

Files containing [L] and $[L]^T$ should be used as input only to CXFBS as they are not in standard NASTRAN format.

3.5.28.7 Information Messages

1. CØNMSG is called at entry and exit from CSPSDC. The line

xxxx CSPSDC

will appear twice per decomposition. The execution time of CSPSDC will be the difference in the times (where xxxxx = time in seconds).

2. Message 3023 gives the values of the parameters, B, C, and R chosen for the decomposition.

3. Message 3027 gives the estimated time in seconds to do the decomposition.

4. Message 3024 indicates that a matrix has scattered terms way off the diagonal (i.e., a large bandwidth). Instead of searching all combinations of B and C, the search is started at the maximum bandwidth.

3.5.28.8 Diagnostic Messages

1. If CSPSDC was unable to find a combination of B and C which would meet core restrictions, fatal message 3008 occurs.

2. In a coding sense, message 3025 is possible. However, it violates the design of CSPSDC and therefore, if obtained, should indicate an obscure program design error, or machine error.

3. Message 3026 indicates that sufficient space was not reserved for the generation of the B vs. C vector. CSPSDC should be recompiled to increase BMAX and CMAX.

3.5.29 CXFBS (Forward - Backward Substitution).

3.5.29.1 Entry Point: CXFBS

3.5.29.2 Purpose

Given the decomposition of a complex symmetric matrix [A] = [L] [D] $[L]^T$ CXFBS will perform the forward-backward pass necessary to solve the system of linear equations [A] [X] = [B].

3.5.29.3 Calling Sequence

```
CALL CXFBS
COMMON/FBSXCX/L(7),U(7),B(7),X(7),NZ,PREC,SIGN
```

L,U - Matrix control blocks for the lower and upper triangular factors output from SDCOMP.

B,X - Matrix control blocks for the matrices [B] and [X].

NZ - Number of computer words at Z.

PREC - 1, solve [A] [X] = [B].
2, perform arithmetic in double precision.

SIGN - +1, solve [A] [X] = [B].
-1, solve [A] [X] = -[B].

Z - An area of working storage.

3.5.29.4 Method

Mathematical considerations. Given the unit upper and lower triangular matrices [L] and $[L]^T$, with the diagonal matrix [D] stored over their diagonals, CXFBS solves the two systems of equations given by

$$[L]\,[Y] = \pm [B]$$

and

$$[L]^T\,[X] = [D]^{-1}[Y]$$

Elements of [Y] and [X] are given by

$$y_{ij} = b_{ij} - \sum_{k=1}^{i-1} \ell_{ki}\, y_{kj}$$

$$x_{ij} = y_{ij}/d_i - \sum_{k=i+1}^{n} \ell_{ki} x_{ij}$$

Program Flow. Overall program flow is identical to that of GFBS (see Section 3.5.19). The only difference in the two routines is that CXFBS uses the decomposed matrices output from SCDCØMP, while GFBS uses those output by CDCØMP. Likewise, the computed equations differ slightly.

3.5.29.5 Design Requirements

One column of [B] and one GINØ buffer must fit in core.

3.5.29.6 Diagnostic Messages

See GFBS (Section 3.5.19).

4.1 GENERAL COMMENTS AND INDEXES

The NASTRAN modules (a module is a logical group of subroutines) documented in this section have been classified into 7 categories: 1) Executive Preface modules, 2) Executive modules, 3) Executive DMAP instructions, 4) Executive DMAP modules, 5) functional modules, 6) output modules, and 7) matrix modules.

Executive Preface modules are those which are executed prior to the execution of the first module in a DMAP sequence. They consist of: 1) XCSA (Executive Control Section Analysis), which processes the NASTRAN Executive Control Deck; 2) IFP1 (Input File Processor, Part 1), which processes the NASTRAN Case Control Deck; 3) XSØRT (Executive Bulk Data Card Sort), which sorts the NASTRAN Bulk Data Deck; 4) IFP (Input File Processor), which processes the sorted Bulk Data Deck; 5) IFP3, IFP4 and IFP5 (Input File Processor 3, 4 and 5), which process bulk data cards unique to an axisymmetric conical shell, hydroelastic, or acoustic problem; 6) XGPI (Executive General Problem Initialization), the heart of the Preface, which a) translates (compiles) a DMAP sequence into an internal form, the ØSCAR, - see Section 2.4.2.1, and b) for problem restarts, initializes data blocks and labeled common blocks; and 7) UMFEDIT (User Master File Editor), which creates and manipulates User Master Files.

The only module classified as an Executive module, per se, is XSFA (Executive Segment File Allocator), which is the "administrative manager" of files for NASTRAN.

Executive DMAP instructions documented in this section are REPT, JUMP, CØND, EXIT and END. The DMAP instructions BEGIN, LABEL and FILE are not allocated a separate section, and therefore brief explanations follow.

1. The BEGIN DMAP instruction is a declarative DMAP instruction which denotes the beginning of a DMAP sequence. It is analogous to a computer operating system control card which calls a compiler of the system.

2. The FILE DMAP instruction is a declarative DMAP instruction which alters the normal attributes of a data block in an ØSCAR entry (see an explanation of the attributes AP, LTU, TP, NTU of a data block in the Data Section Format for functional modules section in the description of the ØSCAR, section 2.4.2.1). These attributes of a data block are used by the Executive Segment File Allocator (XSFA) module in performing its task.

3. The LABEL DMAP instruction is used to label a location in a DMAP sequence so that the location may be referenced by the DMAP instructions JUMP, CØND and REPT.

A more detailed description of these three Executive DMAP instructions can be found in section 5 of the User's Manual.

Executive DMAP modules consist of CHKPNT, SAVE, PURGE, EQUIV, PARAM and SETVAL. In addition to the descriptions in this section, the reader is referred to section 5 of the User's Manual, where further explanations of the uses of EQUIV, PURGE and CHKPNT can be found.

Functional modules comprise the bulk of the descriptions in this section. Functional modules perform the actual structural problem solution. The reader is referred to section 5 of the User's Manual for a) general comments on DMAP rules and b) the syntactical rules of the DMAP calling sequences referring to functional modules.

Output modules are those whose entire output is directed a) to the system output file and/or b) to a tape which will drive a plotting device.

Matrix modules are those which, although no different operationally from functional modules, are most likely to be used by the program user who wishes to take advantage of the Direct Matrix Abstraction capabilities of NASTRAN; therefore, they are separately categorized.

4.1.1 Use of Module Functional Descriptions

Each module documented by means of a Module Functional Description (MFD) has been assigned an integer i, and its MFD is documented in section 4.i. For functional modules, a consistent numbering scheme has been followed, wherever possible, in the MFD's. For a functional module whose assigned integer is i, then,

4.i Title

4.i.1 Entry Point

4.i.2 Purpose

4.i.3 DMAP Calling Sequence

4.i.4 Input Data Blocks

4.i.5 Output Data Blocks

4.i.6 Parameters

4.i.7 Method

4.i.8 Subroutines

4.i.9 Design Requirements

4.i.10 Diagnostic Messages

comprises this numbering scheme. The title: a) classifies the module into one of the seven categories defined in the first paragraph of section 4.1; b) defines the module name, which, if it is a DMAP module (one which is called by a DMAP instruction), is the name by which it must be called in the DMAP calling sequence; and c) defines, parenthetically, the phrase from which the name was derived. Comments on the remaining sections follow.

1. Entry Point

This section defines the entry point of the module. A module's entry point usually agrees with the module name, but there are exceptions. For example, the READ (Real Eigenvalue Analysis Displacement) module has the entry point REIG (the entry point READ is a subroutine in the GINØ collection of routines).

2. Purpose

A brief description of the purpose of the module is given. The casual or first-time reader will perhaps go no further than read the purpose.

3. DMAP Calling Sequence

The DMAP calling sequence as it appears in a Rigid Format is given (see section 3 of the User's Manual for a detailed description of the Rigid Formats in NASTRAN). DMAP calling sequences for Executive DMAP instructions and for Executive DMAP modules follow no fixed format. Refer to the individual Module Functional Descriptions for details on their DMAP calling sequences. Functional modules, which are always "called" via a DMAP calling sequence, do have a fixed format. Consider the following DMAP calling sequence for functional module SMA2, which generates the mass matrix, $[M_{gg}]$, and the damping matrix, $[B_{gg}]$:

```
SMA2    CSTM,MPT,ECPT,GPCT,DIT/MGG,BGG/V,Y,WTMASS = 1.0/V,N,NØMGG/V,N,NØBGG/V,Y,
        CØUPBAR = -1  $
```

SMA2 is the module name. The name of a module must begin with an alphabetic character

followed by up to seven additional alphanumeric characters. Following the name is a blank field. Following this blank field is the list {CSTM,MPT,ECPT,GPCT,DIT} of data blocks input to the module. The list is terminated by a slash (/). Each item in this list is separated by a comma. Note that the number of commas for this list is one less than the number of input data blocks. The second slash terminates the list {MGG,BGG} of data blocks output from the module. The rule for naming input and output data blocks is the same as for module names. Each subsequent slash terminates a parameter field. Each parameter field contains three parts separated by commas. The first part is either the letter "V" or the letter "C", defining the parameter as a variable or as a constant respectively. The second part is either the letter "Y" or the letter "N". "Y" implies "yes" the value of the parameter may be specified on a PARAM bulk data card, and "N" implies "no" the value of the parameter may not be specified on a PARAM bulk data card. The third part may be either: (a) the name of the parameter, (b) the value of the parameter, or (c) the name and the value of the parameter. A variable parameter must have a name, hence a variable parameter may not be specified only by its value. The rule governing the names of parameters is the same as that for module names. The value of a parameter may be complex double precision, complex single precision, double precision, real, integer or BCD. In the example given, the name of the first parameter is WTMASS, and its initial value (which can be overridden by a value on a PARAM card because of "Y" prior to the name) is 1.0. Note that the slash terminating the last parameter field is omitted. Although one can terminate the last parameter field with a slash, this final slash is usually omitted. A dollar sign, "$", terminates a DMAP statement.

4. Input Data Blocks

A short description of each of the module's input data blocks is given along with notes explaining what the module's design requires about the status (purged or not purged) of the data blocks. Detailed data block descriptions are found in section 2 of the Programmer's Manual.

5. Output Data Blocks

A short description of each of the module's output data blocks and an explanation of the action taken when an output data block has been pre-purged are given in this section. An output data block is said to be pre-purged if the data block has been

explicitly purged in a previous PURGE DMAP instruction, or if the data block does not appear in the DMAP calling sequence for the module.

6. Parameters

The order of DMAP parameters in a DMAP calling sequence is the same as the order of the FØRTRAN variables corresponding to the parameters in blank common at module execution time. Each variable DMAP parameter is defined as whether a) it is input data into, or output data from, the module, or both (e.g., a DMAP loop counter which is incremented within the module); b) the type of the parameter: integer, real, double precision, complex single precision, complex double precision, or BCD; and c) the default value of the parameter as defined either i) in the Module Properties List (MPL) Executive table, ii) by means of a PARAM or SETVAL DMAP instruction, or iii) by means of the DMAP statement itself. An example of the third type of default value is

```
MØDULEA    A,B,C/D,E/V,N,UVW/V,Y,XYZ=-1 $.
```

The parameter XYZ is set to -1 by the above statement. For further information on DMAP parameters see paragraph 3 above, section 2.4.2.2 in the Programmer's Manual and section 5 of the User's Manual.

7. Method

A discussion of the method used by the module writer to achieve the purpose of the module is given in this section.

8. Subroutines

The subroutines which comprise the module are described in this section. However, not all subroutines capable of being called by a module are listed here. Utility routines and matrix routines that are in the root segment are not listed in this section. These inlcude: MAPFNS, all the GINØ routines (ØPEN, WRITE, CLØSE, READ, FWDREC, BCKREC, REWIND, EØF, SKPFIL, XGINØ, GINØ, ØPNCØR), FREAD, GØPEN, WRTTRL, FNAME, CLSTAB, PRELØC, PEXIT, TMTØGØ, MESAGE, and the matrix packing and unpacking routines (BLDPK, PACK, INTPK, UNPACK). Descriptions for these routines are found in section 3.

9. Design Requirements

Design requirements peculiar to the module are presented.

10. Diagnostic Messages

Diagnostic messages unique to the module are given in this section. A detailed list of NASTRAN diagnostic messages can be found in section 6 of the User's Manual.

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		4.33	MCE1
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4.10	CHKPNT	**	MØDA
4.13	CØND	**	MØDB
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**	DDR	4.79	MPYAD
4.67	DDR1	4.57	MTRXIN
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**	DUMMØD1	4.102	ØUTPUT3
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* Executive System Internal Module
** Dummy Module
*** Executive System Instruction (No Module Functional Description)

Alphabetical Index of Module Functional Descriptions (Continued)

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* Executive System Internal Module
** Dummy Module
*** Executive System Instruction (No Module Functional Description)

4.1.3 Alphabetical Index of Entry Points in Module Functional Descriptions

Names listed under entry point which end in the characters "BD" are block data subprograms.

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4.31.1	GP4	GP4	4.31-1
4.31.8.1	GP4PRT	GP4	4.31-5
4.41.11.16	GRAV	SSG1	4.41-20
4.41.11.5	GRAVL1	SSG1	4.41-16
4.41.11.6	GRAVL2	SSG1	4.41-16
4.41.11.29	GRAVL3	SSG1	4.41-24
4.41.11.40	HBDY	SSG1	4.41-28
4.27.8.45	HHBDY	SMA1	4.27-21a
4.27.8.46	HRING	SMA1	4.27-21b
4.46.8	IFAC	SDR2	4.46-7
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4.5.7.9	IFPDCØ	IFP	4.5-7
4.3.1	IFP1	IFP1	4.3-1
4.3.7.1	IFP1B	IFP1	4.3-2
4.3.7.2	IFP1C	IFP1	4.3-3

Section Number	Entry Point	Module Name	Page Number
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4.71.1	MATPRN	MATPRN	4.71-1
4.73.8.2	MATPRT	MATPRT	4.73-2
4.65.8.6	MATVEC	TRD	4.65-14
4.28.8.8	MBAR	SMA2	4.28-6
4.28.8.9	MCBAR	SMA2	4.28-6
4.33.1	MCE1	MCE1	4.33-1
4.33.8.1	MCE1A	MCE1	4.33-2
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4.34.1	MCE2	MCE2	4.34-1
4.28.8.11	MCØNE	SMA2	4.28-6
4.28.8.10	MCØNMX	SMA2	4.28-6
4.28.8.18	MCRØD	SMA2	4.28-8
4.84.1	MERGE1	MERGE	4.84-1
4.28.8	MFAC	SMA2	4.28-3
4.28.8.23	MFLUD2	SMA2	4.28-8a
4.28.8.24	MFLUD3	SMA2	4.28-8b
4.28.8.25	MFLUD4	SMA2	4.28-8b
4.28.8.26	MFREE	SMA2	4.28-8b
4.24.8.13	MINMAX	PLØT	4.24-11
4.7.5.11	MPLPRT	XGPI	4.7-6
4.41.11.24	MPYL	SSG1	4.41-23
4.41.11.25	MPYLT	SSG1	4.41-23
4.28.8.21	MQDPLT	SMA2	4.28-8a
4.28.8.5	MRØD	SMA2	4.28-5
4.28.8.27	MSLØT	SMA2	4.28-8b
4.28.8.28	MSØLID	SMA2	4.28-8b
4.48.8.11	MTIMSU	READ	4.48-10
4.28.8.15	MTØRDR	SMA2	4.28-7
4.28.8.14	MTRAPR	SMA2	4.28-7
4.28.8.19	MTRBSC	SMA2	4.28-8
4.28.8.22	MTRIQD	SMA2	4.28-8a
4.28.8.13	MTRIRG	SMA2	4.28-7
4.28.8.20	MTRPLT	SMA2	4.28-8a
4.57.1	MTRXIN	MTRXIN	4.57-1
4.28.8.6	MTUBE	SMA2	4.28-5
4.41.11.20	NØRM	SSG1	4.41-21

Section Number	Entry Point	Module Name	Page Number
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4.48.8.39	WILVEC	READ	4.48-19e
4.76.8.2	WRTMSG	PRTMSG	4.76-2
4.24.8.17	WRTPRT	PLØT	4.24-12a
4.4.5.5	XBCDBI	XSØRT	4.4-4
4.7.62	XBSBD	XGPI	4.7-7
4.11.1	XCEI	REPT	4.11-1
4.11.6	XCEI	REPT	4.11-2
4.12.1	XCEI	JUMP	4.12-1
4.13.1	XCEI	CØND	4.13-1
4.14.1	XCEI	EXIT	4.14-1
4.18.1	XCEI	END	4.18-1
4.10.1	XCHK	XCHK	4.10-1
4.9.5.2	XCLEAN	XSFA	4.9-4
4.2.1	XCSA	XCSA	4.2-1
4.9.5.4	XDPH	XSFA	4.9-6
4.17.1	XEQUIV	EQUIV	4.17-1
4.4.5.4	XFADJ	XSØRT	4.4-4
4.4.5.10	XFADJ1	XSØRT	4.4-5
4.9.5.7	XFILPS	XSFA	4.9-7
4.7.5.9	XFLDEF	XGPI	4.7-5
4.7.5.8	XFLØRD	XGPI	4.7-5
4.7.1	XGPI	XGPI	4.7-1
4.7.6.2	XGPIBD	XGPI	4.7-7
4.7.5.2	XGPIBS	XGPI	4.7-3
4.7.5.1	XGPIDG	XGPI	4.7-3
4.7.5.1	XGPIMW	XGPI	4.7-3
4.7.5.5	XIPFL	XGPI	4.7-4
4.7.5.4	XLNKHD	XGPI	4.7-4
4.7.6.2	XMPLBD	XGPI	4.7-7
4.7.5.5	XØPFL	XGPI	4.7-4
4.7.5.3	XØSGEN	XGPI	4.7-3
4.7.5.6	XPARAM	XGPI	4.7-4
4.9.5.6	XPLEQK	XSFA	4.9-6
4.9.5.5	XPØLCK	XSFA	4.9-6
4.4.5.6	XPRETY	XSØRT	4.4-4
4.9.5.3	XPUNP	XSFA	4.9-5
4.16.1	XPURGE	XPURGE	4.16-1
4.4.5.1	XRECPS	XSØRT	4.4-3

4.2 EXECUTIVE PREFACE MODULE XCSA (EXECUTIVE CONTROL SECTION ANALYSIS)

4.2.1 Entry Point: XCSA

4.2.2 Purpose

To process the NASTRAN Executive Control Deck.

4.2.3 Calling Sequence

CALL XCSA. XCSA is called only by subroutine SEMINT.

4.2.4 Method

The cards of the Executive Control Deck are read and processed with checks being made for illegal formats, duplication and errors peculiar to the particular card being processed. When all of the control cards have been processed (i.e., CEND control card found), the Executive Control Table (XCSA) is written on the Problem Tape and XCSA returns to the calling routine.

4.2.5 Subroutines

4.2.5.1 Subroutine Name: XRGDFM

1. Entry Point: XRGDFM
2. Purpose: To select a rigid format based on the SØL card in the Executive Control Deck.
3. Calling Sequence: CALL XRGDFM (NEWSØL,ØLDSØL,IAPP)

   NEWSØL - Two-word array containing solution and subset numbers taken from SØL control card.

   ØLDSØL - Two-word array containing solution and subset numbers taken from the Old Problem Tape if the problem is a restart. If not a restart, ØLDSØL = 0.

   IAPP - Approach code (1 = FØRCE, 2 = DISPL, 3 = DMAP) taken from the APP card in the Executive Control Deck.

4. Method: If the problem is being restarted, a check is made for a solution (Rigid Format) change. If the solution has been changed, a bit is set in table MEDMSK in named common block /XMDMSK/.

A check is made for a legal solution number, and, if acceptable, a branch is made on the solution number, and subroutine LDi (i = solution number) is called to create the DMAP and MED records for the XCSA table. XRGDFM then returns to the calling routine XCSA.

4.2.5.2 Subroutine Name: LDi, where i = solution number, i = 01, 02, ..., 12.

1. Entry Points: LDi

2. Purpose: To write the DMAP sequence and MED records of the XCSA Executive Table for solution (Rigid Format) i (see XCSA Executive Control Table description, Section 2.4.2.5).

3. Calling Sequence: CALL LDi (SUBSET)

SUBSET - Solution subset number from the SØL control card.

4. Method: The packed DMAP program is generated, and then subroutine XSBSET is called to select the proper solution subset for the DMAP program by altering the ISl array. Upon return from XSBSET the arrays ISl, JNM and INM (see 4.2.6.2 below) are written on the New Problem Tape to complete the MED record for Executive Table XCSA. LDi then returns to calling routine.

4.2.5.3 Subroutine Name: XSBSET

1. Entry Point: XSBSET

2. Purpose: To eliminate DMAP instructions not belonging to the specified subset by altering the ISl array.

3. Calling Sequence: CALL XSBSET (ID1,NSS,SUBSET,IS1,NDI,NWPI)

ID1 - Table containing DMAP instruction numbers of those instructions that are not part of the specified subset.

NSS - Number of subsets in table ID1.

SUBSET - Subset to be selected from table ID1.

IS1 - Module execution decision table.

NDI - Number of DMAP instructions in DMAP program.

NWPI - Number of words per IS1 entry.

4. Method: Table ID1 is searched and the proper subset is selected. Each DMAP instruction has a corresponding entry in table IS1. If the IS1 entry for an instruction is zero, then the instruction is eliminated from the DMAP program. Therefore zeroing the IS1 entries of those instructions specified in table ID1 yields the proper subset. XSBSET then returns to the calling routine.

4.2.6 Design Requirements

4.2.6.1 Use of Open Core

Open core is used for GINØ buffers, for generating the XPTDIC Executive Table (see section 2.4) on restarts, and for storing user generated DMAP programs. Named common block /XCSABF/ defines the beginning of open core for module XCSA. Since XPTDIC is not stored permanently in open core and because the use of open core to store a DMAP program and a call to LDi are mutually exclusive, the LDi subroutines can be origined for overlay purposes at the same location as /XCSABF/.

4.2.6.2 Restart Tables Initialized in the Routines

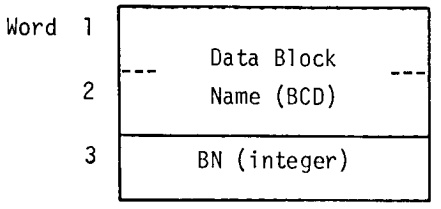
The following tables are initialized by the LDi (i = solution number) subroutine or its associated Block Data program and are used to aid module XGPI in restarting a problem which uses Rigid Format i.

1. IS1 - Module Execution Decision Table: This table when used in conjunction with table MEDMSK in named common block /XMDMSK/ will provide module XGPI with the information needed to decide whether or not to set the execute flag in an ØSCAR entry. Each DMAP instruction

in a Rigid Format has a corresponding entry in ISl. An entry in ISl can be one to five words in length, and only bits 1 through 31 are used to form a truth table. Note that if an ISl entry is zero, the corresponding DMAP instruction is unconditionally excluded from the Rigid Format DMAP program being compiled by module XGPI.

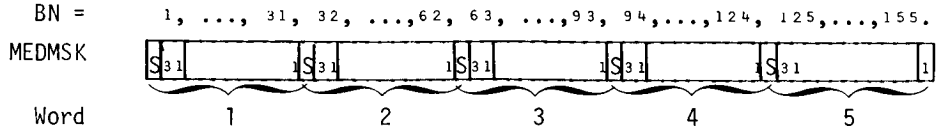
2. JNM - File Name Restart Table: The JNM table provides module XGPI with the capability of regenerating data blocks which are missing in the restart dictionary and which are needed to restart the problem. Note that the restart must be a modified restart. If a data block is missing, the JNM table will indicate which bit to set in table MEDMSK. MEDMSK is then used with ISl to determine which DMAP modules must be re-executed in order to correctly regenerate the missing data block.

Sample JNM Entry:



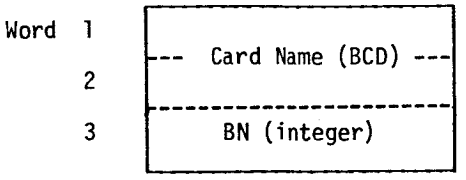
BN is the bit number of the bit which is to be set in table MEDMSK to regenerate the specified data block. The usable bits (bits 1-31) of MEDMSK are numbered sequentially starting from bit 31 of the first word. MEDMSK is five words long.

Example:



3. INM - Card Name Restart Table: When the problem is being restarted and input data (Bulk Data and/or Case Control Data) has been modified, table INM tells module XGPI whether or not the modifications affect the compilation of the DMAP program associated with the Rigid Format. Table MJCD in named common block /IFPX1/ and table MJMSK in named common block /IFPXO/ indicate which cards have been modified. If INM has an entry for a modified card, the INM entry will indicate which bit to set in table MEDMSK. MEDMSK is then used with ISl to determine which DMAP modules must be re-executed.

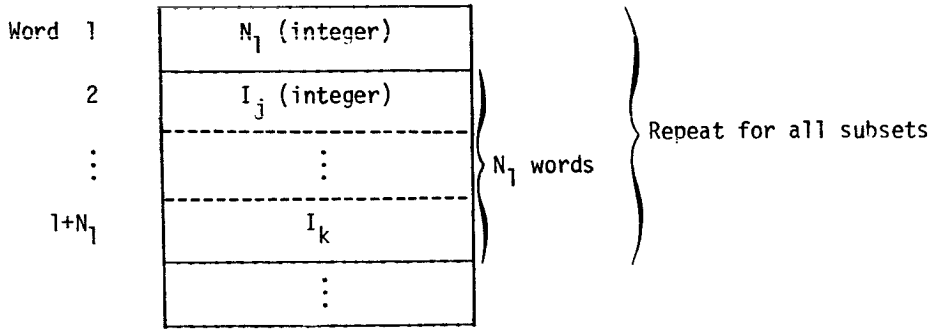
Sample INM Entry:



BN is the number of the bit which is to be set in table MEDMSK if the associated card name has been modified. See sample JNM entry for further description of BN.

4. ID1 - Subset Table: DMAP instructions in a DMAP program are numbered sequentially starting with "BEGIN" as instruction number 1. Table ID1 contains the instruction numbers of those instructions that are not to be included in a subset.

Sample ID1 Entry:



N_1 = number of instructions to delete in subset 1. ($N_1 \geq 0$).

I_j - I_k = DMAP instruction numbers of instructions to be deleted.

4.2.7 Diagnostic Messages

Every effort is made to get through module XCSA so that the modules IFP1 and IFP can process the Case Control Deck and the Bulk Data Deck. XCSA sets the NØGØ flag in named common block /SYSTEM/ according to the severity of the errors found.

NØGØ = 0 - no errors found.

1 - job will terminate after module XGPI.

2 - job will terminate after IFP modules.

3 - job terminates in XCSA.

See diagnostic message section of User's Manual (section 6.2) for a detailed discussion of XCSA error messages. XCSA messages include numbers 501 thru 526.

4.3 EXECUTIVE PREFACE MODULE IFP1 (INPUT FILE PROCESSOR, PART 1)

4.3.1 Entry Point: IFP1

4.3.2 Purpose

To process the Case Control Deck. See section 2.3 of the User's Manual for a discussion of the Case Control Deck.

4.3.3 Calling Sequence

CALL IFP1. IFP1, a Preface module, is called only by subroutine SEMINT.

4.3.4 Input Data

The input data consists of the Case Control Deck and the CASECC data block from the Old Problem Tape if the problem is a restart.

4.3.5 Output Data Blocks

CASECC - Case Control Data Table.

PCDB - Plot Control Data Table (for the structure plotter).

XYCDB - XY output Control Data Block.

Notes:

1. CASECC will always exist.
2. PCDB will exist only if a structure plotter package is included in the Case Control Deck.
3. XYCDB will exist only if a XYØUT plotter package is included in the Case Control Deck.

4.3.6 Method

The Case Control Cards are read and stored on a scratch file for later use. The title cards are abstracted to form page headings. Title card abstraction is stopped by a SYM, SUBCASE, SYMCØM or REPCASE card. IFP1 is stopped by a BEGIN BULK card.

The construction of CASECC is as follows:

1. The scratch tape is read one card at a time, and subroutine XRCARD is called to translate the card.

2. The first four characters beginning with a non-blank are identified in a key word table, and card type dependent routines are executed. (See Case Control Deck in User's Manual).

3. When "SUBCASE" type cards are encountered, a CASECC record is written out.

4. If the card ØUTPUT (PLØT) is encountered,XRCARD images of succeeding cards are written on PCDB.

5. If the card ØUTPUT (XYØUT) is encountered,IFP1XY processes the succeeding cards into the XYCDB.

The module conclusion is as follows:

1. A copy of CASECC is placed on the NPTP for use in restart.

2. If this run is a restart, IFP1B is called to analyze CASECC changes and set modify flags for later use in Executive Preface module XGPI (see section 4.7).

4.3.7 Subroutines

4.3.7.1 Subroutine Name: IFP1B

1. Entry Point: IFP1B

2. Purpose: To set modify flags for use in modified restart.

3. Calling Sequence: CALL IFP1B (ICASE,ØPTP,CASECC,IBUF1,IBUF2,LENCC)

   ICASE - A two-dimensional array (LENCC,2) for storage of both copies of CASECC - array - input.

   ØPTP - GINØ file name of the Old Problem Tape - BCD - input.

   CASECC - GINØ file name of CASECC - BCD - input.

   IBUF1, IBUF2 - GINØ buffer pointers - integer - input.

   LENCC - Row dimension of ICASE - integer - input.

CØMMØN/IFPXO/SPACE(3),NWØRDS

NWØRDS - Pointer into /IFPXO/ such that IFP1 modify flags are in SPACE(NWØRDS).

4. Method:

CASECC and the copy of CASECC on the ØPTP are compared according to the following scheme. The local array IWØRD classifies each word in CASECC into 0 and 1. 0 words: If the CASECC word is non-zero and IBIT is non-zero in this position, the IBIT bit is turned on in /IFPXO/. 1 word: If the CASECC word is different from the ØPTP word and IBIT is non-zero in this position, the IBIT is turned on in /IFPXO/.

IFP1B also determines the loop nature of the problem. The looping rules are as follows:

a. The current problem will loop under the following conditions: SPC set changes; MPC set changes; direct input matrix changes; transfer function set changes; transient load changes; frequency set changes; differential stiffness coefficient set is greater than zero; and Piecewise Linear coefficient set is greater than zero. If any of the above conditions are met. LØØP$ is turned on in /IFPXO/.

b. The old problem might have been a looping problem if the above conditions were present in the ØPTP CASECC. If the old problem was a looping problem as determined in (a) and the number of records in CASECC changes, LØØP1$ is set (this should force the re-execution of the entire loop).

c. If the problem is not a looping problem, NØLØØP$ is set.

4.3.7.2 Subroutine Name: IFP1C

1. Entry Point: IFP1C

2. Purpose: To construct set lists from SET cards.

3. Calling Sequence: CALL IFP1C (ISUB,I81,CØRE,SCR1,NWPC,ICC,NZ,THRU,NSET)

ISUB - 1 - master set. 2 - set belongs to a subcase - integer - input.

I81 - Pointer to storage for set in core - integer - input/output.

CØRE - Open core array.

SCR1 - GINØ file number of scratch file containing card images - integer - input.

NWPC - Number of words per card - integer - input.

ICC - Current line count of Case Control card echo - integer - input/output.

NZ - Length of open core - integer - input/output.

THRU - BCD value "THRU" - BCD - input.

NSET - Number of sets found to current set - integer - input.

4.3.7.3 Subroutine Name: IFP1D

1. Entry Point: IFP1D

2. Purpose: To write user diagnostic messages from IFP1.

3. Calling Sequence: CALL IFP1D (MSGN)

MSGN - User message number - integer - input.

4.3.7.4 Subroutine Name: IFP1E

1. Entry Point: IFP1E

2. Purpose: To write out CASECC and update sets.

3. Calling Sequence: CALL IFP1E (CASE,ISUBC,SYMSEQ,NWDSC,I81)

CASE - Array containing Case Control record to be written out (CASE (LENCC,2)).

ISUBC - Five word BCD array containing current subcase number - BCD - output.

SYMSEQ - Symmetry coefficient array - real - input.

NWDSC - Pointer to beginning of set lists - integer - input/output.

I81 - Pointer to end of set list - integer - output.

4.3.7.5 Subroutine Name: IFP1F

1. Entry Point: IFP1F

2. Purpose: To find the first four characters beginning with a non-blank on one input card.

3. Calling Sequence: CALL IFP1F ($n,IWØRD,IS,IBEN,II)

$n - FØRTRAN statement number which defines the return to be taken if the entire card is blank.

IWØRD - First four characters beginning with a non-blank, left justified - BCD - output.

IS - Number of bits/character times (number of characters/word-1) - integer - input.

IBEN - Mask used to determine if character is blank 'b000' - input.

II - Pointer to word in which IWØRD begins - integer - output.

CØMMØN/IFP1X/CØRE(20)

IFP1X - 20-word array holding card image - BCD - input.

CØMMØM/IFP1A/

IFP1A - See /IFP1A/ description under Design Requirements (section 4.3.8).

4.3.7.6 Subroutine Name: IFP1G

1. Entry Point: IFP1G

2. Purpose: To find an equal sign and copy the remainder of the data into a specified arrays

3. Calling Sequence: CALL IFP1G (ITYPE,CASE,ISUB1)

ITYPE - Indicates area in which to store data.

1. TITLE
2. SUBTITLE
3. LABEL
4. HEAD1
5. HEAD2
6. HEAD3
7. PLØTID

} of /ØUTPUT/

8. First 32 words of CASE

- integer - input.

CASE - Case control array (132,2) unless ITYPE = 8, when it may be only 32 word array.

ISUB1 - Subcase number -1 or 2 of CASE array.

CØMMØN/IFP1X/CØRE(20)

IFP1X - 20-word array holding card image.

CØMMØN/ØUTPUT/

ØUTPUT - Output common block - holds BCD titles for NASTRAN pages.

CØMMØN/IFP1A/

IFP1A - See /IFP1A/ description under Design Requirements (section 4.3.8).

4.3.7.7 Subroutine Name: SWSRT

1. Entry Point: SWSRT

2. Purpose: To check set lists for duplicates and overlapping intervals. SWSRT also sorts lists into increasing order.

3. Calling Sequence: CALL SWSRT (LIST,ISTØR,NLIST)

LIST - Array of set members.

ISTØR - Scratch space of length NLIST.

NLIST - Number of members in LIST.

4.3.7.8 Subroutine Name: IFP1XY

1. Entry Point: IFP1XY

2. Purpose: To construct the XYCDB data block.

3. Calling Sequence: CALL IFP1XY (FLAG)

FLAG - 0, first entry for initialization; 1, data entry; -1, last entry. FLAG is set to 1 on return from the first entry - integer - input/output.

CØMMØN/IFP1X/CARD(20), CARD1(20)

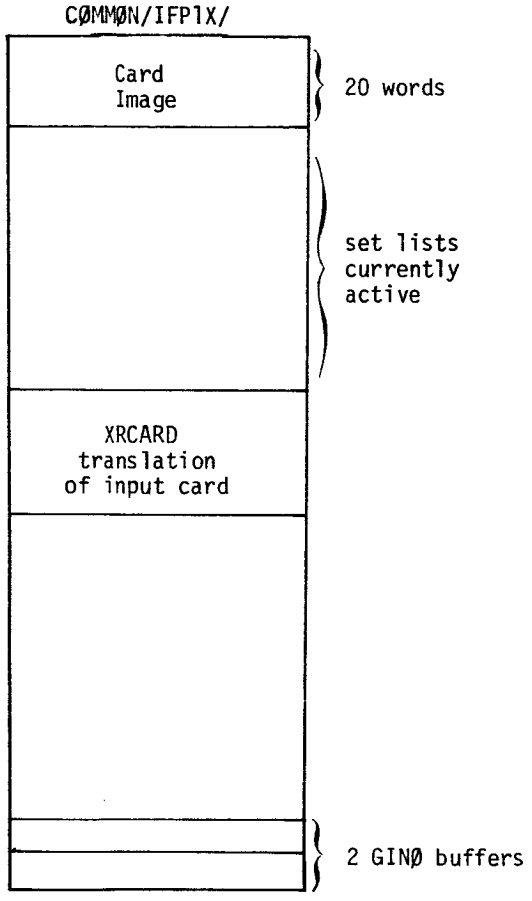
CARD - Contains card data as read from the input file.

CARD1 - Contains XRCARD translation of CARD unless CARD(1) contains 'XTIT', 'YTIT', 'TCUR', 'YTTI' or 'YBTI'. In this case CARD1 (20) contains BCD data occurring after the equal sign.

4.3.8 Design Requirements

1. One scratch file.

2. Open core at /IFP1X/.



3. Common block IFP1A.

Name	Length	Meaning	Initialized to
NAME	2	Name of data block for error messages.	CASE CC
SUBC	1	Subcase key word	SUBC
SET	1	Set key word	SETb
SYMS	1	Symmetry sequence key word	SYMS
TSTE	1	Time step card selection key word	TSTE
LABE	1	Label key word	LABE
SUBT	1	Subtitle key word	SUBT
SCR1	1	GINØ file number of scratch file	301
CASECC	1	GINØ file name of CASECC	CASE
BLANK	1	Blank word	bbbb

Name	Length	Meaning	Initialized to
CARD	1	Heading word card	CARD
CØUN	1	Heading word CØUNT	CØUN
T	1		T
BEGI	1	Begin bulk key word	BEGI
TITL	1	Title key word	TITL
CASEN	11	Case Control page heading	Case Control Deck echo
SPCF	1	Forces of constraint key word	SPCF
VELØ	1	Velocity key word	VELØ
ACCE	1	Acceleration key word	ACCE
ELFØ	1	Element forces key word	ELFØ
STRE	1	Element stress key word	STRE
DISP	1	Displacement key word	DISP
ØUTP	1	Øutput key word	ØUTP
SYM	1	Symmetry subcase key word	SYM
FREQ	1	Frequency set key word	FREQ
DLØA	1	Dynamic loading key word	DLØA
TEMP	1	Temperature field key word	TEMP
DEFØ	1	Deformation set key word	DEFØ
TIME	1	Time key word	TIME
SPC	1	Single-point constraint set key word	SPC
MAXL	1	Maximum number of output lines key word	MAXL
IC	1	Initial condition set selection id	IC
METH	1	Real eigenvalue or buckling method selection key word	METH
LØAD	1	Load set selection key word	LØAD
MPC	1	Multipoint set selection key word	MPCb
STIF	1	Stiffness thermal field key word	STIF
ALL	1	ALL key word	ALLb
THRU	1	THRU key word	THRU
SØRT	1	Sorted echo key word	SØRT
UNSØ	1	Unsorted echo key word	UNSØ

EXECUTIVE PREFACE MODULE IFP1 (INPUT FILE PROCESSOR, PART 1)

Name	Length	Meaning	Initiated to
ECHØ	1	Bulk data echo key word	ECHØ
PLØT	1	Plot key word	PLØT
MØDE	1	Modes key word	MØDE
PUNC	1	Punch key word	PUNC
PRIN	1	Print key word	PRIN
NWPC	1	Number of words per card	20
NCPW	1	Number of characters per word (NASTRAN)	4
BØTH	1	Echo-sorted and unsorted	BØTH
NØNE	1	None key word	NØNE
PCDB	1	Plot control data GINØ file name	PCDB
NAME	2	GINØ error message for PCDB file	PCDB bbbb
VECT	1	Alternate displacement key word	VECT
SYMC	1	Symcom key word	SYMC
EQUAL1	1	Equal sign left adjusted	=bbb
NMØDES	1	Value of modes card	1
IBØB	1	Structure plot flag 0, not currently in structure plot mode 1, in structure plot mode	0
IEND	1		0
ISYMCM	1	Symcom flag	0
LØADN	1	Current Subcase ID number	1
IØUT2	1		0
ICC	1	Printed card count	1
NSET	1	Number of current set lists	0
NSYM	1	Number of 'SYM' subcases	1
INØMØR	1	Flag to turn off Title card search	0
NPTP	1	GINØ file name of the New Problem Tape	NPTP
ØPTP	1	GINØ file name of the Old Problem Tape	ØPTP
DØL	1	Dollar sign	$bbbb
ZZZZBB	1	Hollerith zeros	0000bb

Name	Length	Meaning	Initiated to
ISTR	1	Storage flag for IFP1G titles	1
ISUB	1	Subcase or master CASECC pointer	1
K2PP	1	Key words for direct input matrix selection	K2PP
B2PP	1		B2PP
M2PP	1		M2PP
DSCØ	1	Key word for differential stiffness set selection	DSCØ
REPC	1	Key word for repeat subcase subcase	REPC
LENCC	1	Length of Case Control Record	166
LINE	1	Key word for LINE/page count	LINE
ØM	1	Word to distinguish between SUBCØM SUBCASE	ØMbb
TFL	1	Key word for transfer function set selection	TFL
DEFA	1	Key word for default specification	DEFA
ELST	1	Key word for element stress set selection	ELST
MAT	1	Key word for thermal material set selection	MATE
ØFRE	1	Key word for output frequency set selection	ØFRE
IMAG	1	Key word for real/imaginary printout	IMAG
PHAS	1	Key word for magnitude/phase printout	PHAS
REAL	1	Key word for real or real/imaginary printout	REAL
CMET	1	Key word for complex eigenvalue set selection	CMET
SDAM	1	Key word for Structural Damping Table for use in modal formulation	SDAM
INER	1	Key word for Inertia Relief Element set selection	INER
ADIS	1	Key word for solution set displacement selection	SDIS
AVEL	1	Key word for solution set velocity selection	SVEL
AACC	1	Key word for solution set acceleration selection	SACC
NØNL	1	Key word for non-linear load set selection	NØNL
CØNF	1	Not used	
XYPL	1	Key word for XYPLØT packet delimiter	XYPL
PLCØ	1	Key word for Piecewise Linear set selection	PLCØ

Name	Length	Meaning	Initiated to
AXIS	1	Key word for selection of Axis symmetric boundary condition	AXIS
NLLØ	1	Key word for non-linear output set selection	NLLØ
DELE	1	Key word for element deletion set selection	DELE
XYCB	1	GINØ file name of XY control data block	XYCB
ØNEB	1	BCD one	1bbb
HARM	1	Key word for harmonic output control	HARM
SINE	1	Key word for sine boundary conditions	SINE
CØSI	1	Key word for cosine boundary conditions	CØSI
FLUID	1	Key word for fluid boundary conditions	FLUI
SUBS	1	Key word for SUBSEQ	SUBS
AVEC	1	Key word for solution set vector output	SVEC
FØRC	1	Not used	
RAND	1	Key word for random set selection	RAND
XYØU	1	Key word for XYPLØT packet delimiter	XYØU
ØLØA	1	Key word for output load set selection	ØLØA
PLT1	1	GINØ file name of BCD plot tape	PLT1
PLT2	1	GINØ file name of binary plot tape	PLT2
XTIT	1	Key words for XY output titles	XTIT
YTIT	1		YTIT
TCUR	1		TCUR
YTTI	1		YTTI
YBTI	1		YBTI
IBEN		Right shifted blank '000b'	----
EQUAL		Right shifted equal '000='	----
PRES	1	Alternate displacement key word	PRES
TEMP	1	Alternate displacement key word	TEMP

4. Interface with /SYSTEM/ (See Section 2.4).

   IFP1 can set the following cells of SYSTEM:

   a. NØGØ - (NØGØ flag). If a fatal error is detected.
   b. NLPP - (Number of lines per page). If a LINE card is supplied by the user.
   c. STFTEM - (Material Temperature Set ID). If a TEMP(MATE) card is supplied.

d. ECHØ - (Echo flag). If an ECHØ request is made.

5. Interface with /ØUTPUT/.

IFP1 supplies the problem title, subtitle, and label as well as the Plot ID.

4.3.9 Diagnostic Messages

IFP1 makes every attempt to process the entire Case Control Deck so that the complete Preface will run. Hence all fatal messages only cause the NØGØ flag to turn on.

IFP1 causes messages 601-699. For the exact nature of these messages, refer to the Diagnostic Message section of the User's Manual.

4.4 EXECUTIVE PREFACE MODULE XSØRT (EXECUTIVE BULK DATA CARD SØRT)

4.4.1 Entry Point: XSØRT

4.4.2 Purpose

The function of XSØRT is to prepare a file on the New Problem Tape containing the sorted bulk data. The operation of XSØRT is influenced by the type of run. If a cold start, the bulk data is read from the system input stream (or the User's Master File), sorted and written on the New Problem Tape. If an unmodified restart, the bulk data is copied from the Old Problem Tape onto the New Problem Tape. If a modified restart, the bulk data is read from the Old Problem Tape, and cards are deleted and/or added in accordance with cards in the system input stream. Additionally, flags are set within restart tables for each card type changed in any way. Again, the sorted bulk data is written onto the New Problem Tape. A print of the unsorted and/or sorted bulk data is made on request. XSØRT processes all data cards between the BEGIN BULK and ENDDATA cards in the input stream. Both cards must be present to properly bracket the NASTRAN Bulk Data Deck.

4.4.3 Calling Sequence

CALL XSØRT. XSØRT, a Preface module, is called only by the Preface driver, SEMINT.

4.4.4 Method

If the input is to be from a User Master File, XSØRT begins by positioning the file to the beginning of the proper subset of bulk data cards. INITCØ is then called to initialize machine dependent masks and constants. The open core below XSØRT (/ESØRT/) is divided into 5 GINØ buffers and a work buffer. This work buffer will contain each data card and a chaining pointer to indicate its sorted position. That is, the cards will be placed into the work buffer in the same order as read, but their sorted order will be shown by a chaining word with each card pointing to the position of the next card in alphanumeric sort. If the work buffer is unable to hold all of the bulk data cards, each subset that fills the buffer is unchained and written in sorted order onto a scratch file. This writing onto a scratch file frees the work buffer for another subset of data cards.

Three scratch files may become involved in sorting a large number of bulk data cards. After the first two scratches are filled with sorted subsets, they are merged, while maintaining the sorted order, onto a third scratch. From this point, after each new subset is written onto a scratch, it is merged with the scratch containing all previous subsets. As an example, assume three scratches are named A, B, and C. Scratch A is written with the first subset of data from a filled work buffer. Scratch B is written with the second subset. Scratch A and B are then merged to form scratch C. This frees scratch A and B. Scratch A is then written with the third subset of data. A and C are merged to form a new B. A is then written with the fourth subset. A and B are merged to form a new C. This process continues until all bulk data has been sorted. Following the final merge, one of the scratch files will contain all of the sorted bulk data cards.

As the sort and merge operations are being performed, any continuation cards or delete cards encountered are written onto separate holding files. After all data cards in the input stream have been processed, each of these holding files is processed. The delete card values are placed in ascending order and any overlaps or redundancies are removed. The continuation cards are checked for duplication and an in-core dictionary of their connection words is formed.

XSØRT may now make a pass through the scratch file containing all of the sorted bulk data cards within the input stream. During this pass, the User Master File (UMF) or the Old Problem Tape (ØPTP) data cards are merged with those from the input stream. Both the UMF and ØPTP data cards were properly sorted during their preparation. As this merge progresses, any data cards designated for removal by delete control cards are discarded. If the NASTRAN run for which XSØRT is operating is a restart, all data cards within the input stream plus any deleted from the ØPTP will cause data card type flags to be set within restart tables. This entire pass is not performed if the run does not require either a UMF or ØPTP.

Now a final pass of the resulting sorted data is made to introduce any continuation cards and write the completed Bulk Data Deck onto the New Problem Tape. The continuation cards are connected to the sorted data cards by matching connection words. Continuation cards can in no way affect the sorted order. If a print of the resulting sorted deck is requested, it is performed during this pass.

During any sort collation the data cards are ordered by comparing half-fields from left to right. Each bulk data card may contain up to ten, eight column (character) fields.

Because of computer word size constraints, each data card is stored into twenty memory words, four characters (half a card field) per word. Sorting proceeds by comparing the first words (4 characters) from each card. If an order cannot be established, i.e., the words are equal, the second words from each card are compared, and so on, until an order is established or total duplication is determined. Each field (8 characters) is left (BCD) or right (integer) justified prior to sorting to eliminate leading or trailing blanks. The characters within the first field of each card are converted to a special internal character set prior to comparing to eliminate machine dependent collation sequences which might order the same cards differently on different machines. This internal set forces the collation order to be ascending from blank through all numbers then all letters. A flowchart is given in Figure 1.

4.4.5 Subroutines

In the following, note that XRECPS, RPAGE, INITCØ, XFADJ, XBCDBI, XPRETY, CRDFLG, EXTINT, and INTEXT are secondary entry points in XRECPS.

4.4.5.1 Subroutine Name: XRECPS

1. Entry Point: XRECPS

2. Purpose: Positions the continuation card file to the proper record (card image) as determined from the in-core continuation card dictionary.

3. Calling Sequence: CALL XRECPS (NEW, ØLD)

Where: NEW = the file position being requested

ØLD = the file position last requested.

Both arguments are integer record numbers.

4.4.5.2 Subroutine Name: RPAGE

1. Entry Point: RPAGE

2. Purpose: Counts output print lines for XSØRT, and performs the necessary interface with the system subroutine PAGE.

3. Calling Sequence: CALL RPAGE (NLINE)

Where: NLINE = integer number of lines being output. If NLINE $\geq$ 100 a page eject is

forced and the line count is set to NLINE - 100.

4.4.5.3 Subroutine Name: INITCØ

1. Entry Point: INITCØ

2. Purpose: Initializes machine dependent masks and constants within XSØRT.

3. Calling Sequence: CALL INITCØ

4.4.5.4 Subroutine Name: XFADJ

1. Entry Point: XFADJ

2. Purpose: Adjusts four character fields, left or right, two or four fields at a time. If the fields contain only integers, the shift is right, otherwise the shift will be left. This routine determines only the direction of shift required. Actual shifting is performed by XFADJ1.

3. Calling Sequence: CALL XFADJ (BUF,SD,K)

Where: BUF = field array to be shifted

SD = {0, shift two fields at a time
     {1, shift four fields at a time

K = {0, returned if right shift was done.
    {1, returned if left shift was done.

4.4.5.5 Subroutine Name: XBCDBI

1. Entry Point: XBCDBI

2. Purpose: Converts two, four character BCD integer fields (right adjusted in the left most four characters of the computer word) into a single binary integer (right adjusted in the second of the two input words).

3. Calling Sequence: CALL XBCDBI (BUF)

Where: BUF = two word array to be converted.

4.4.5.6 Subroutine Name: XPRETY

1. Entry Point: XPRETY

2. Purpose: "Pretties-up" printed output by left adjusting all fields to eliminate any leading zeros introduced when integer fields are right adjusted.

3. Calling Sequence: CALL XPRETY (BUF)

Where: BUF = card image array.

4.4.5.7 Subroutine Name: CRDFLG

1. Entry Point: CRDFLG

2. Purpose: Sets the card type flags within the restart tables.

3. Calling Sequence: CALL CRDFLG (CARD)

Where: CARD = first of two word card type field.

4.4.5.8 Subroutine Name: EXTINT

1. Entry Point: EXTINT

2. Purpose: Converts card type field from the machine dependent character code to an internal machine independent code.

3. Calling Sequence: CALL EXTINT (CTYBF)

Where: CTYBF = first of two word card type field.

4.4.5.9 Subroutine Name: INTEXT

1. Entry Point: INTEXT

2. Purpose: Converts the card type field from an internal machine independent code to the machine dependent character code.

3. Calling Sequence: CALL INTEXT (CTYBF)

Where: CTYBF = first of two word card type field.

4.4.5.10 Subroutine Name: XFADJ1

1. Entry Point: XFADJ1

2. Purpose: Adjust four character fields left or right, two or four fields at a time. This routine performs actual shifting with the direction of shift controlled through the

calling sequence. (Note entry point XFADJ).

3. Calling Sequence: CALL XFADJ1 (BUF,SHIFT,SD)

Where: BUF = Field Array to be shifted.

SHIFT = Function LSHIFT or RSHIFT.

SD = {0, shift two fields at a time.
{1, shift four fields at a time.

4.4.5.11 Function Name: ISFT

1. Entry Point: ISFT

2. Purpose: Performs special shifting functions for subroutine XFAJ1.

3. Calling Sequence: CALL ISFT

RESULT = ISFT(BUF,SFTCNT,J)

where: BUF = Word to be shifted.

SFTCNT = Bits to be shifted.

J = Shift direction control; 3 = right, 4 = left.

4.4.6 Design Requirements

1. Data cards operated upon by XSØRT must conform to the NASTRAN format for bulk data cards (ten, eight character fields per card). See section 2 of the User's Manual for details.

2. Data cards must contain only valid BCD key punch codes or blanks. Non-standard multi-punched code (e.g., some IBM EBCDIC) will cause unpredictable results.

3. XSØRT requires sufficient open core to contain five GINØ buffers and a work buffer for at least ten data cards. (Each data card requires twenty-one core locations). Sort efficiency increases in proportion to the size of the work buffer.

4. The continuation card dictionary must fit into the core work buffer during the final pass. Each continuation card requires two dictionary locations.

5. XSØRT logic is biased toward input that is already sorted. That is, the program will operate at a much greater speed if verifying a sort rather than producing a sort.

4.4.7 Diagnostic Messages

XSØRT can produce two catagories of diagnostic messages. The first are termed USER messages and deal with bulk data card errors. The second are termed SYSTEM messages which are generally fatal in nature and indicate serious I/Ø malfunctions.

XSØRT message numbers includes 201 through 216. All messages are listed and explained in section 6 of the User's Manual.

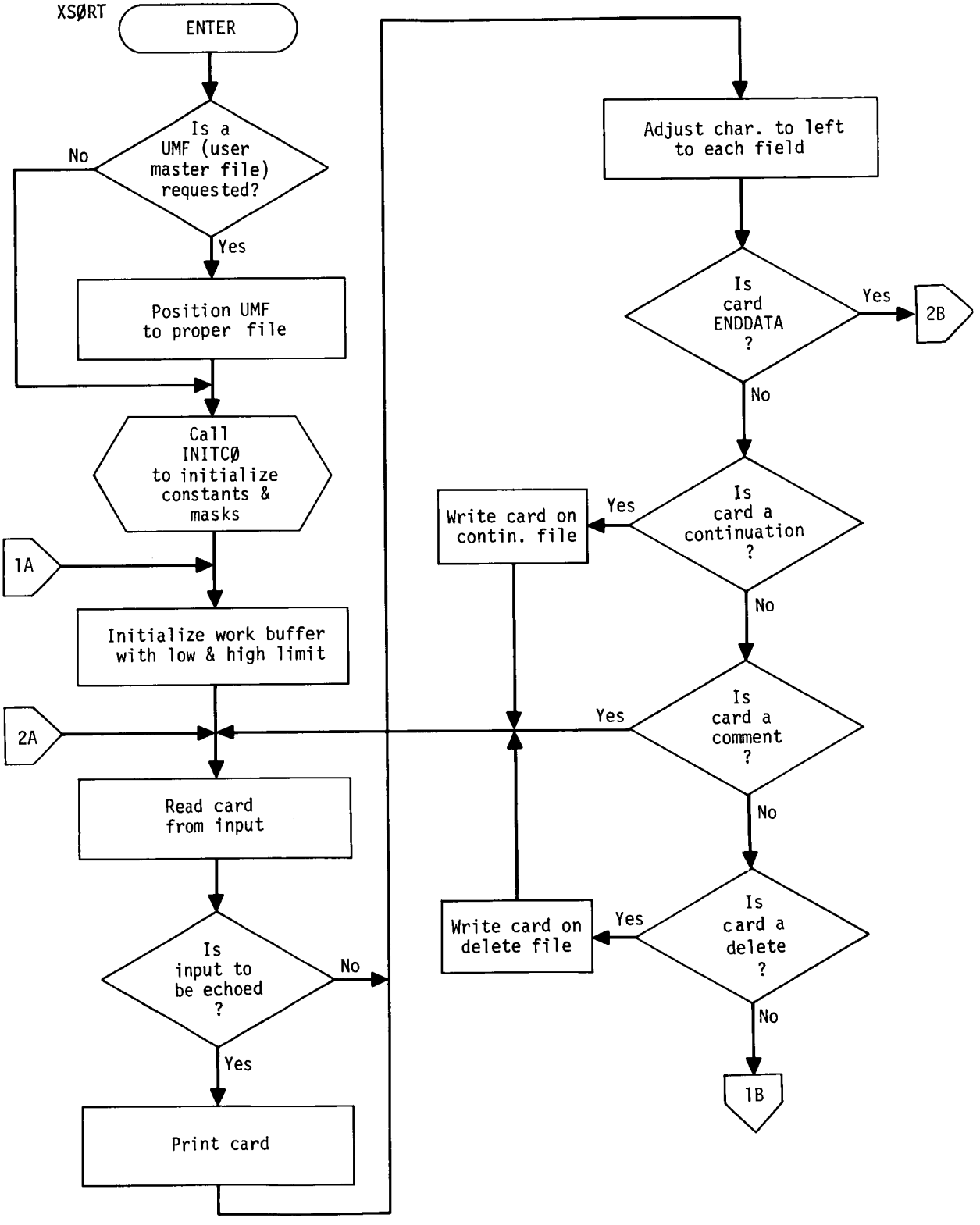


Figure 1.(a) Flowchart for module XSØRT.

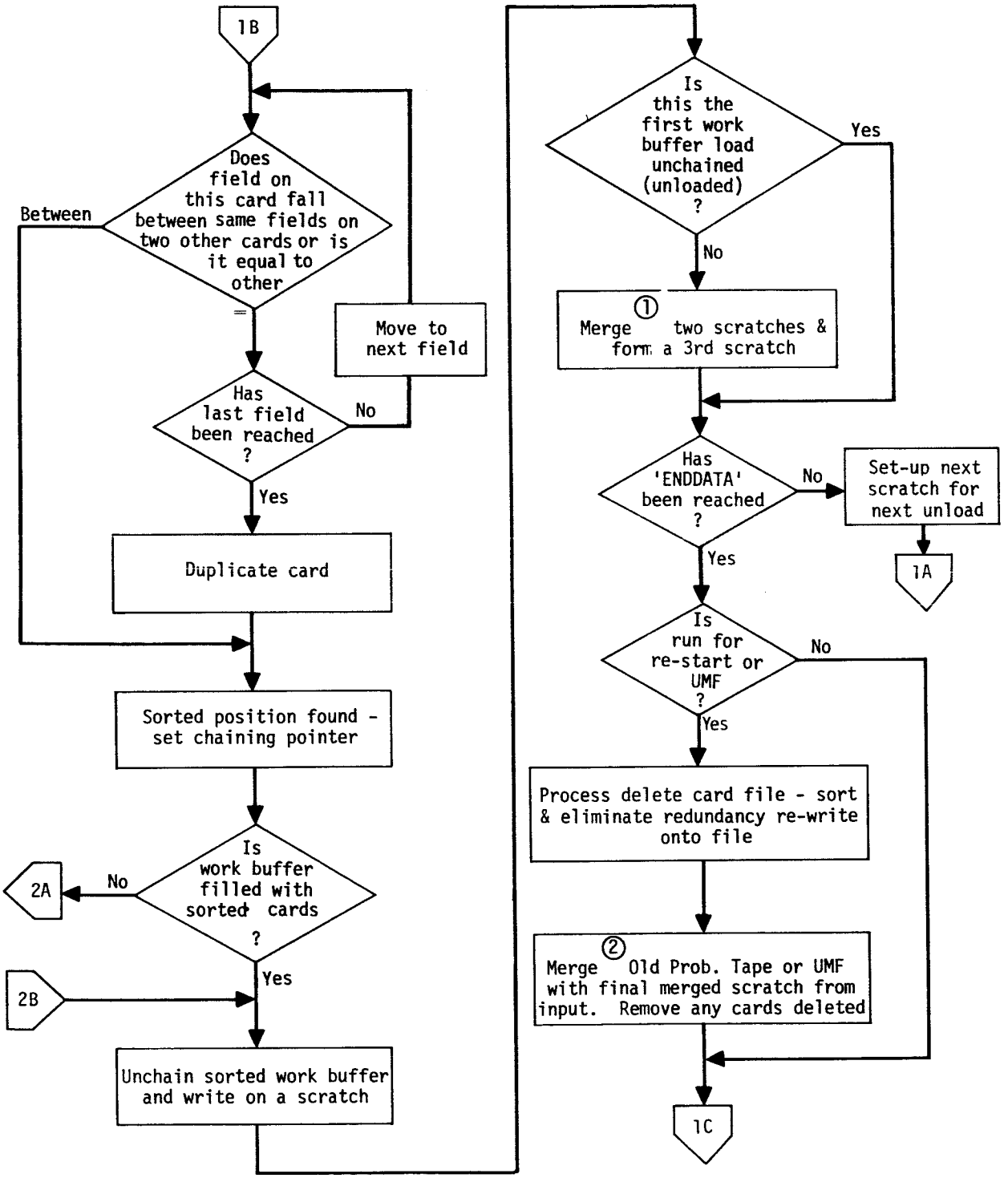


Figure 1.(b) Flowchart for module XSØRT.

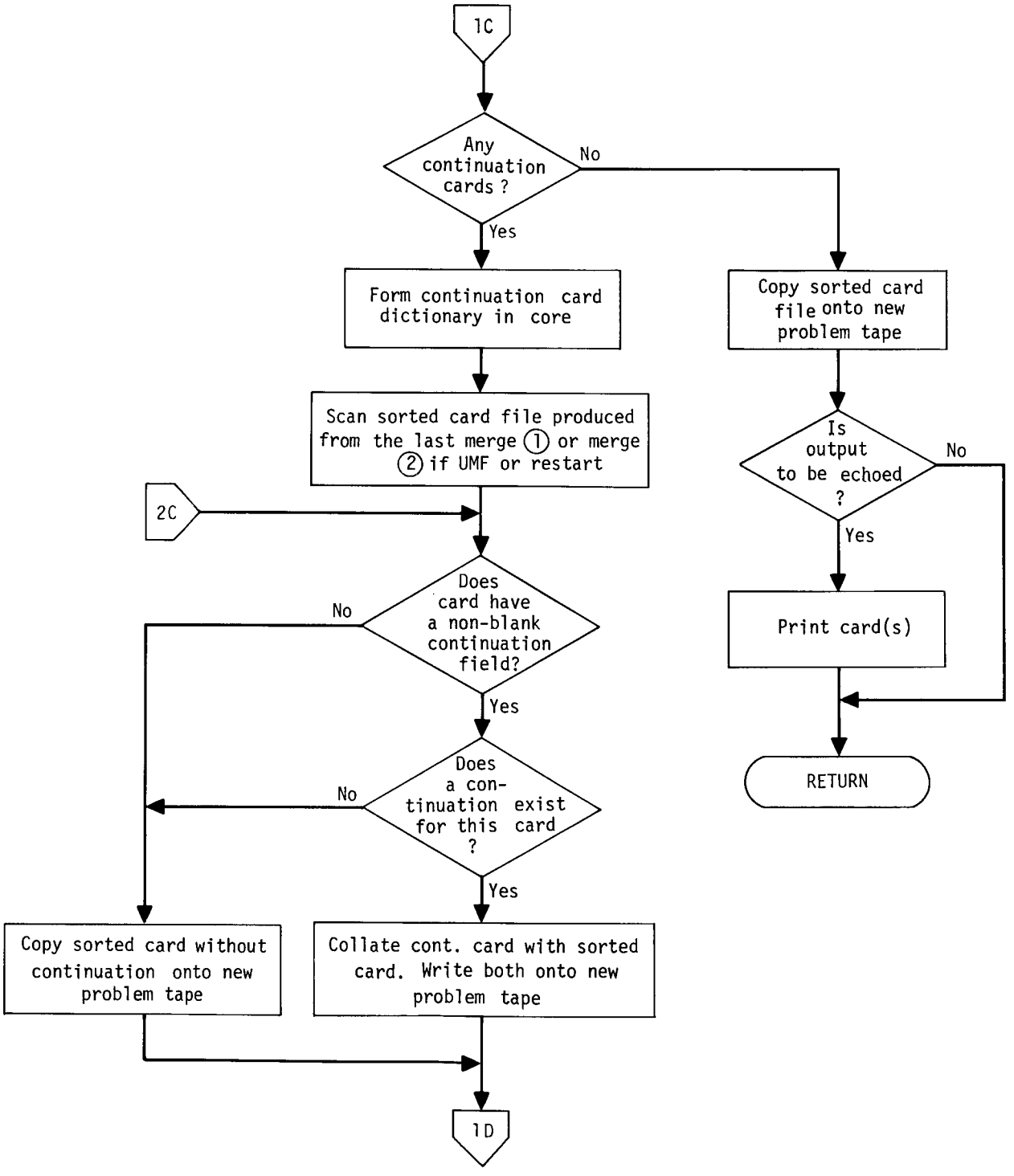


Figure 1.(c) Flowchart for module XSØRT.

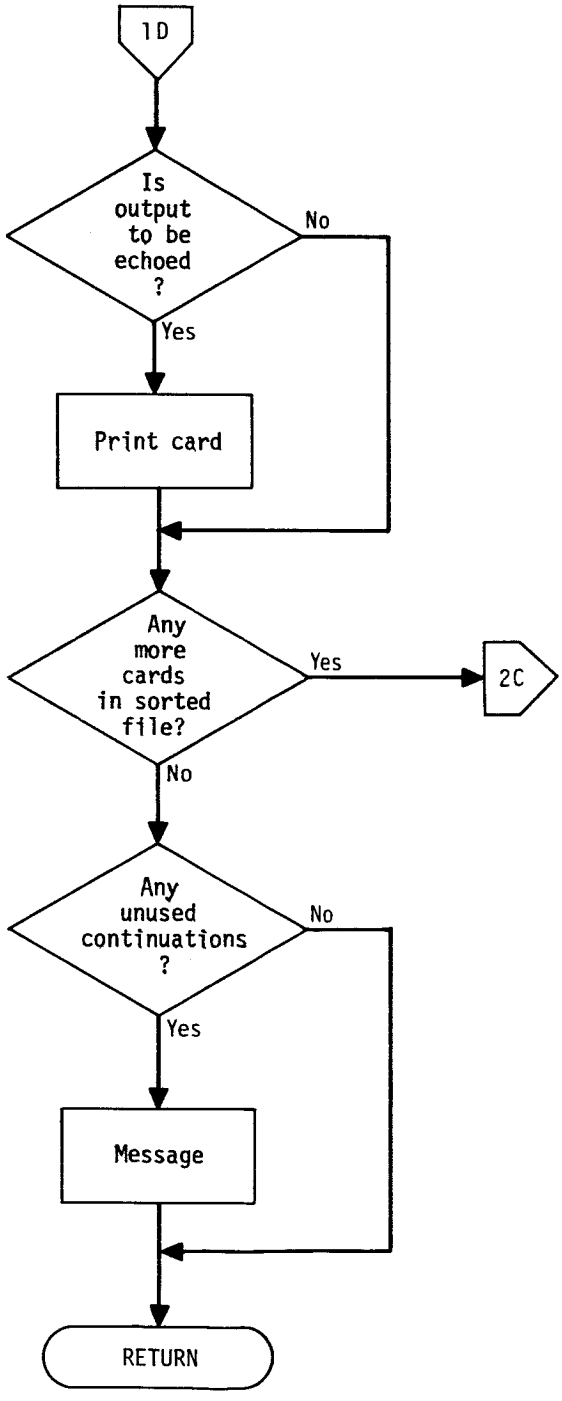


Figure 1.(d) Flowchart for module XSØRT.

4.5 EXECUTIVE PREFACE MODULE IFP (INPUT FILE PROCESSOR)

4.5.1 Entry Point: IFP

4.5.2 Purpose

To process the Bulk Data Deck sorted by Executive Preface module, XSØRT. This task is accomplished as follows: 1) the sorted Bulk Data Deck is read from the New Problem Tape (NPTP) card-by-card; 2) the contents of each field of each card are validated (see section 2.4 of the User's Manual for detailed descriptions of each bulk data card); 3) card images or modified card images are written on data blocks or the NPTP or the Data Pool File (see section 2.3.2 of the Programmer's Manual for details on the formats of these data blocks).

4.5.3 Calling Sequence

CALL IFP. IFP, an Executive Preface module, is called only by the Preface driver, subroutine SEMINT.

4.5.4 Input

The input to IFP consists of the Bulk Data Deck sorted by Executive Preface module XSØRT.

4.5.5 Output

The output of IFP consists of: 1) data blocks used in Rigid Formats; 2) the AXIC data block, which is processed by Executive Preface Modules IFP3, IFP4 and IFP5 and is present only if the NASTRAN run is a conical shell (a unique structural elemtn) problem, a hydroelastic problem, or an acoustic cavity problem; 3) the PVT Executive table, which contains the names and values of all DMAP parameters input by means of the PARAM bulk data card, and which is written on the New Problem Tape to be processed by Executive Preface module XGPI; and 4) DMI's (Direct Matrix Inputs) and DIT's (Direct Table Inputs), each of which is written on the Data Pool File as a data block and is indistinguishable from any matrix data block or table data block pooled by the Executive Segment File Allocator (XSFA) module.

4.5.5.1 Output Data Blocks Used in Rigid Formats

GEØM1 - Grid point, coordinate system, and sequence data.

GEØM2 - Element connection data.

GEØM3 - Static loads and temperature data.

GEØM4 - Displacement set definitions data.

EPT - Element Property Table.

MPT - Material Property Table.

DIT - Direct Input Tables.

EDT - Element Deformation Table.

DYNAMICS - Collection of bulk data cards for a dynamics problem.

MATPØØL - Data block containing matrices input on DMIG bulk data cards.

Note: Do not confuse the DTI (Direct Table Input) bulk data card and the DIT (Direct Input Table) data block.

4.5.6 Method

4.5.6.1 General Comments

The bulk data cards processed by IFP are classified into five categories. Listed below is a brief explanation of each with a few examples.

1. Closed End Cards (Fixed Length Card)

Cards such as CQUAD2 and PRØD go through all the standard bulk data card checks (see 4.5.6.2) before being processed by the card dependent subroutines within IFP, (IFSiP, i = 1, 2, 3, 4, 5). These closed end cards are output to one of the standard GINØ files.

2. Open Ended Cards (Variable Length Cards)

In cards such as SPC1 and PLFACT, since the length and therefore the formats are not known, the bulk data checks using the data initialized in the block data subprograms must be made in the card dependent subroutines. Also, since the length is not known, a flag is placed at the end of the information for that card before being written on the file in order that routines reading an open ended card will be signaled as to an end-of-card condition.

3. GRDSET and BARØR Cards

Special cards such as GRDSET and BARØR are not output to a GINØ data block, but are stored in local variables, and provide default values for the GRID and CBAR cards.

4. DMI and DTI Cards

DMI and DTI cards are unique in the manner in which they are used by the user and processed by IFP. The DMI card enables the user to define matrix data blocks directly, while the DTI card gives the user the capability to input his own table data blocks directly. The user must write a DMAP sequence or use the ALTER feature - see section 2.2 of the User's Manual - in the Executive Control Deck to alter the Rigid Format chosen in order to use the DMI or DTI feature since he is defining his own data blocks. Both DMI and DTI cards are written directly onto the Data Pool File.

5. PARAM Cards

PARAM bulk data cards are stored in open core by IFP until the entire Bulk Data Deck has been processed. PARAM cards are then written as the PVT (Parameter Value Table) on the NPTP for subsequent processing by the Executive Preface module XGPI.

4.5.6.2 Card Processing

1. IFP searches the NPTP for the Bulk Data Deck and extracts it in 20 word (one physical card) segments. Each card is passed to subroutine RCARD, which takes the BCD card images and converts the fields thereon to values, and identifies the values as to type: blank data field, integer data field, real single precision data field, BCD data field, real double precision data field or a data field which is in error.

IFP always has two physical bulk data cards in internal storage areas: the "current" card and the "next" card. M is the local FØRTRAN array where the values of the current bulk data card are located, and M1 the local FØRTRAN array where the values of the next card are located. After the current card is processed, the data in M1 are transferred into M, and new card values for M1 are input from the NPTP. When the values from M1 are transferred to M, the first two words (the card mnemonic) are stripped off. M1(3) is stored in M(1), M1(4) is stored in M(2), and so on.

2. /IFPX1/ is referenced to verify the admissibility of the name (mnemonic) of the particular card taken from the NPTP.

3. The approach acceptability flag is checked. This flag is defined as follows:

0 = OK for any approach;

1 = Not used by displacement approach;

2 = Illegal for displacement approach.

The approach flag (DISPL, DMAP) is found in /SYSTEM/.

4. The proper output files are established. See Table 1 or Table 2 for the output file on which the various bulk data cards will reside.

5. Uniqueness flags, which reside in CØMMØN/IFPX5/, are defined for each card type as follows:

0 - No check is made;

1 - A check is made;

2 - A special check is made.

For example, on the bulk data card CØNRØD, field 2 is the EID, and it must be unique with respect to all other CØNRØD EID's.

6. The next physical card is read from the NPTP. This will be the next card to be processed.

7. A check for too many continuation cards is made. This check is made on fixed length cards only.

8. A check is made for the minimum and maximum number of words for a logical bulk data card.

9. A check for the proper types of values for the fields on a card is made by referencing /IFPX7/, which contains format codes for each card type as follows:

0 = Blank

1 = Integer

2 = Real

3 = BCD

4 = Double Precision

5 = Anything.

When RCARD passes format values to IFP, a format code of 0 will override this check. In the card dependent code check (step 10), the value will be looked at to see if it is in error.

10. An auxiliary subroutine IFSiP, i = 1, 2, 3, 4, 5, is called to execute card dependent code.

11. If the input card passes the tests in the card dependent code, the data are written on the appropriate GINØ output file.

4.5.6.3 Module Conclusion

When the sorted Bulk Data Deck has been exhausted, the following steps are carried out.

1. The appropriate trailer codes are written for each data block. For listings of trailer information reference section 2.3.2.

2. The PVT is written on the NPTP.

3. Restart flags are set in /IFPXO/.

4.5.7 Subroutines

IFP uses the utility routine RCARD described in section 3.4.20.

4.5.7.1 Block Data Subprogram: IFX1BD

Purpose: To initialize /IFPX1/, which is used by IFP to validate card names. All bulk data card names must appear in this table.

4.5.7.2 Block Data Subprogram: IFX2BD

Purpose: To initialize /IFPX2/. This table contains two words per entry (two words per card type): the first gives the GINØ output file number, and the second gives the approach acceptability flag.

4.5.7.3 Block Data Subprogram: IFX3BD

Purpose: To initialize /IFPX3/. This table contains two words per entry (two words per card type): the first word is used as the Conical Shell Problem flag, and the second word is used internally to store the number of words to be output to the GINØ output file.

4.5.7.4 Block Data Subprogram: IFX4BD

Purpose: To initialize /IFPX4/. This table contains two words per entry (two words per card type): the first is the minimum number of words allowable, the second is the maximum number of words allowable. The first word of an entry being negative implies the card is open ended.

4.5.7.5 Block Data Subprogram: IFX5BD

Purpose: To initialize /IFPX5/. This table contains two words per entry (two words per card type): the first is a pointer into /IFPX7/, the second is the field 2 uniqueness check flag.

4.5.7.6 Block Data Subprogram: IFX6BD

Purpose: To initialize /IFPX6/. This table contains two words per entry (two words per card type): the first is header word 1 (card type), the second is header word 2 (trailer bit position) of the three word header information of each logical record, which corresponds to all the data of particular bulk data card type. See section 2.3.2 for details.

4.5.7.7 Block Data Subprogram: IFX7BD

Purpose: To initialize /IFPX7/. Each entry contains the admissible sequence of format codes for that card type (see step 9 in section 4.5.6.2 above).

4.5.7.8 Subroutine Name: IFSiP, i = 1, 2, 3, 4, 5

1. Entry Point: IFSiP, i = 1, 2, 3, 4, 5

2. Purpose: These are the four subroutines that the module driver IFP calls to execute card dependent code.

3. Calling Sequence: CALL IFSiP (n_1,n_2,n_3)

   n_1 - FØRTRAN statement number defining the return taken in the event of a format or data error.

   n_2 - FØRTRAN statement number defining the return taken when local variables are set to provide default values for appropriate cards.

   n_3 - FØRTRAN statement number defining the return taken in the event of a data error.

4.5.7.9 Subroutine Name: IFPDCØ

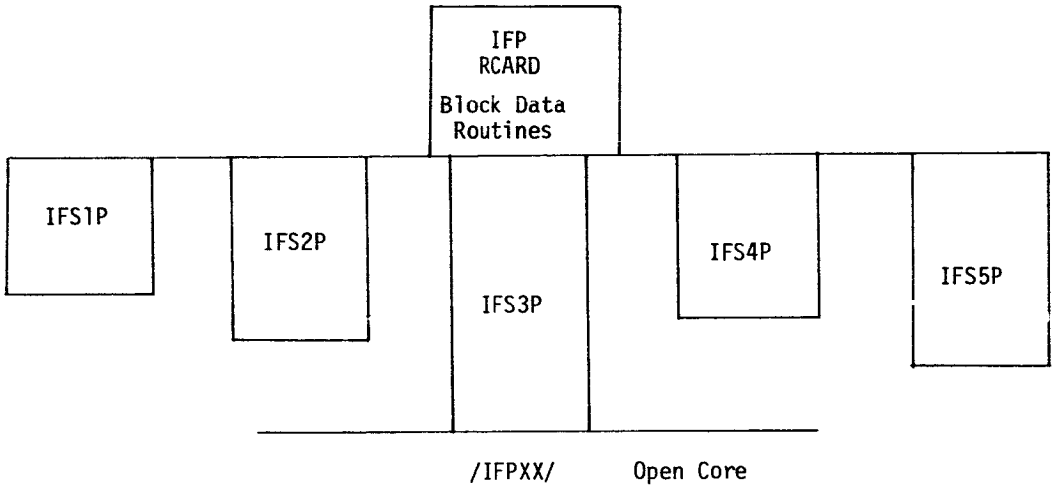
1. Entry Point: IFPDCØ

2. Purpose: LØGICAL FUNCTIØN IFPDCØ decodes packed component code and returns .FALSE. if no errors are detected and .TRUE. if any errors are detected. The decoded results are stored in labeled common block /IFPDTA/ . This subroutine is also used by the Preface Module IFP3.

4.5.8 Design Requirements

Open core is defined in /IFPXX/. Open core is used to store all PARAM cards until the Bulk Data Deck has been exhausted, at which time the PARAM cards are written on the NPTP as the PVT Executive table.

IFP has a compilation-dependent overlay structure as shown in the sketch below.



The open core (common block /IFPXX/ must be located below the longest of the IFSiP segments. This is automatically done on the Univac 1108 but must be done by the programmer on the other machines.

4.5.9 Diagnostic Messages

If a fatal error is detected during any phase of the processing of module IFP, the NØGØ flag will be set, and the error message will be printed out. IFP will continue processing data cards until all are processed.

Table 1(a). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

The following list gives an explanation of the column headings on the following pages of Table 1.

A = Internal IFP Bulk Data Card Number

B = Bulk Data Card Name (an asterisk following a name implies the card is not available)

C = Internal IFP GINØ Output File Number

D = Data Block Name

E = Approach Acceptance Indicator

-2 = Illegal for the Force Approach

-1 = Not Used by the Force Approach

0 = OK for any Approach

1 = Not Used by the Displacement Approach

2 = Illegal for the Displacement Approach

F = Minimum Number of Words Allowed Per Logical Card (F negative implies an open ended card)

G = Maximum Number of Words Allowed Per Logical Card

H = Format Check Pointer Into IFX7BD

I = Field 2 Uniqueness Check Flag

0 = No Check is Made

1 = Check is Made

2 = Special

J = Subroutine LØCATE Code for Card on Output Data Block

K = Trailer Bit Position

L = Pointer to Secondary (Card Dependent) Code

S1 = Subroutine IFS1P

S2 = Subroutine IFS2P

S3 = Subroutine IFS3P

S4 = Subroutine IFS4P

S5 = Subroutine IFS5P

M = FØRTRAN Statement Number in the Card Dependent Subroutines

N = Conical Shell Problem Flag

-1 = Illegal for Shell Mode

Table 1(b). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

0 = OK for Shell Mode

1 = Puts Card Into Different Data Block

0 = Users Map for Data Blocks IFX2BD,...,IFX6BD

Values for I = 1,2 or 3

J = 1,2 or 3

H = A,B,C,D or E

K = 1,2,3,4,5 or 6

I = Is Data Statement in the Block Data Program

J = The Group of A Through E Continuation Card Blocks Within the Ith Data Statement

H = Alphabetic Character in Col 6 (Continuation Column) in the Jth Group

K = The Pair Number on Line H Where the Actual Data is located.

Table 1(c). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
1	GRID	1	GEØM1	0	4	12	1	1	4501	45	S3	100	-1	11A1
2	GRDSET	1	GEØM1	0	4	12	13	2	0	0	S3	200	-1	11A2
3	ADUM1	1	GEØM1	0	8	8	537	0	0	0	S5	100	0	11A3
4	SEQGP	1	GEØM1	-1	4	8	37	0	5301	53	S1	40	-1	11A4
5	CØRD1R	1	GEØM1	0	4	8	37	0	1801	18	S1	500	-1	11A5
6	CØRD1C	1	GEØM1	0	4	8	37	0	1701	17	S1	600	-1	11A6
7	CØRD1S	1	GEØM1	0	4	8	37	0	1901	19	S1	700	-1	11B1
8	CØRD2R	1	GEØM1	0	12	16	45	1	2101	21	S1	800	-1	11B2
9	CØRD2C	1	GEØM1	0	12	16	45	1	2001	20	S1	900	-1	11B3
10	CØRD2S	1	GEØM1	0	12	16	45	1	2201	22	S1	1000	-1	11B4
11	PLØTEL	8	GEØM2	0	4	8	505	0	5201	52	S1	1111	-1	11B5
12	SPC1	10	GEØM4	-2	-4	9	-1	0	5481	58	S3	3980	-1	11B6
13	SPCADD	10	GEØM4	-2	4	8	-1	1	5491	59	S3	4020	1	11C1
14	SUPØRT	10	GEØM4	-2	4	8	37	0	5601	56	S1	1400	-1	11C2
15	ØMIT	10	GEØM4	-2	4	8	37	0	5001	50	S1	1400	-1	11C3
16	SPC	10	GEØM4	-2	4	8	101	0	5501	55	S1	1600	-1	11C4
17	MPC	10	GEØM4	-2	4	8	-1	0	4901	49	S3	1700	-1	11C5
18	FØRCE	9	GEØM3	0	8	12	109	0	4201	42	S1	1800	1	11C6
19	MØMENT	9	GEØM3	0	8	12	109	0	4801	48	S1	1800	1	11D1
20	FØRCE1	9	GEØM3	0	8	12	121	0	4001	40	S1	2000	-1	11D2
21	MØMENT1	9	GEØM3	0	8	12	121	0	4601	46	S1	2000	-1	11D3
22	FØRCE2	9	GEØM3	0	8	12	133	0	4101	41	S1	2200	-1	11D4
23	MØMENT2	9	GEØM3	0	8	12	133	0	4701	47	S1	2200	-1	11D5
24	PLØAD	9	GEØM3	0	8	12	145	0	5101	51	S1	2400	-1	11D6
25	SLØAD	9	GEØM3	-2	4	8	157	0	5401	54	S1	2500	-1	11E1
26	GRAV	9	GEØM3	0	8	12	165	1	4401	44	S1	2600	1	11E2
27	TEMP	9	GEØM3	0	4	8	157	0	5701	57	S1	2500	-1	11E3
28	GENEL	8	GEØM2	-2	-4	9	-1	1	4301	43	S3	2800	-1	11E4
29	PRØD	2	EPT	0	4	12	165	1	902	9	S1	2900	-1	11E5
30	PTUBE	2	EPT	0	4	12	177	1	1602	16	S1	2920	-1	11E6
31	PVISC	2	EPT	-2	4	8	189	0	1802	18	S1	310	-1	12A1
32	ADUM2	1	GEØM1	0	8	8	537	0	10	0	S5	200	0	12A2
33	PTRIA1	2	EPT	0	4	16	221	1	1202	12	S1	2980	-1	12A3
34	PTRIA2	2	EPT	0	4	8	237	0	1302	13	S1	3000	-1	12A4
35	PTRBSC	2	EPT	0	4	12	257	1	1102	11	S1	3020	-1	12A5
36	PTRPLT	2	EPT	0	4	12	257	1	1502	15	S1	3020	-1	12A6
37	PTRMEM	2	EPT	0	4	8	237	0	1402	14	S1	3000	-1	12B1
38	PQUAD1	2	EPT	0	4	16	221	1	702	7	S1	2980	-1	12B2
39	PQUAD2	2	EPT	0	4	8	237	0	802	8	S1	3000	-1	12B3
40	PQDPLT	2	EPT	0	4	12	257	0	602	6	S1	3020	-1	12B4
41	PQDMEM	2	EPT	0	4	8	237	0	502	5	S1	3000	-1	12B5
42	PSHEAR	2	EPT	0	4	8	237	0	1002	10	S1	3000	-1	12B6
43	PTWIST	2	EPT	0	4	8	237	0	1702	17	S1	3000	-1	12C1
44	PMASS	2	EPT	-2	4	8	269	0	402	4	S1	3200	-1	12C2
45	PDAMP	2	EPT	-2	4	8	269	0	402	2	S1	3200	-1	12C3
46	PELAS	2	EPT	-2	4	8	497	0	302	3	S1	3240	-1	12C4
47	CØNRØD	8	GEØM2	0	8	12	277	1	1601	16	S1	3260	-1	12C5
48	CRØD	8	GEØM2	0	4	8	37	0	3001	30	S1	3281	-1	12C6
49	CTUBE	8	GEØM2	0	4	8	37	0	3701	37	S1	3282	-1	12D1
50	CVISC	8	GEØM2	-2	4	8	37	0	3901	39	S1	3283	-1	12D2
51	ADUM3	1	GEØM1	0	8	8	537	0	10	0	S5	300	0	12D3
52	CTRIA1	8	GEØM2	0	8	12	313	1	3301	33	S1	3360	-1	12D4
53	CTRIA2	8	GEØM2	0	8	12	313	1	3401	34	S1	3360	-1	12D5
54	CTRBSC	8	GEØM2	0	8	12	313	1	3201	32	S1	3360	-1	12D6
55	CTRPLT	8	GEØM2	0	8	12	313	1	3601	36	S1	3360	-1	12E1
56	CTRMEM	8	GEØM2	0	8	12	313	1	3501	35	S1	3360	-1	12E2
57	CQUAD1	8	GEØM2	0	8	12	325	1	2801	28	S1	3460	-1	12E3
58	CQUAD2	8	GEØM2	0	8	12	325	1	2901	29	S1	3460	-1	12E4

Table 1(d). Bulk Data Cards Processed by IFP Sorted by Internal Code Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
59	CQDPLT	8	GEØM2	0	8	12	325	1	2701	27	S1	3460	-1	12E5
60	CQDMEM	8	GEØM2	0	8	12	325	1	2601	26	S1	3460	-1	12E6
61	CSHEAR	8	GEØM2	0	8	12	337	1	3101	31	S1	3540	-1	13A1
62	CTWIST	8	GEØM2	0	8	12	337	1	3801	38	S1	3540	-1	13A2
63	CØNM1	8	GEØM2	0	8	28	349	1	1401	14	S1	3580	-1	13A3
64	CØNM2	8	GEØM2	0	8	20	377	1	1501	15	S1	3600	-1	13A4
65	CMASS1	8	GEØM2	-2	4	12	337	1	1001	10	S1	3620	-1	13A5
66	CMASS2	8	GEØM2	-2	4	12	397	1	1101	11	S1	3623	-1	13A6
67	CMASS3	8	GEØM2	-2	4	8	37	0	1201	12	S1	3674	-1	13B1
68	CMASS4	8	GEØM2	-2	4	8	409	0	1301	13	S1	3697	-1	13B2
69	CDAMP1	8	GEØM2	-2	4	12	337	1	201	2	S1	3620	-1	13B3
70	CDAMP2	8	GEØM2	-2	4	12	397	1	301	3	S1	3623	-1	13B4
71	CDAMP3	8	GEØM2	-2	4	8	37	0	401	4	S1	3675	-1	13B5
72	CDAMP4	8	GEØM2	-2	4	8	409	0	501	5	S1	3698	-1	13B6
73	CELAS1	8	GEØM2	-2	4	12	337	1	601	6	S1	3620	-1	13C1
74	CELAS2	8	GEØM2	-2	4	12	417	1	701	7	S1	3800	-1	13C2
75	CELAS3	8	GEØM2	-2	4	8	37	0	801	8	S1	3676	-1	13C3
76	CELAS4	8	GEØM2	-2	4	8	409	0	901	9	S1	3699	-1	13C4
77	MAT1	3	MPT	0	4	20	429	1	103	1	S1	3860	0	13C5
78	MAT2	3	MPT	0	8	20	449	1	203	2	S1	3880	0	13C6
79	CTRIARG	8	GEØM2	-2	8	12	738	1	1708	17	S4	790	-1	13D1
80	CTRAPRG	8	GEØM2	-2	8	12	737	1	1808	18	S4	800	-1	13D2
81	DEFØRM	4	EDT	-2	4	8	157	0	104	1	S1	2500	-1	13D3
82	PARAM	6	PVT	0	-5	16	-1	2	0	0	S3	3960	0	13D4
83	MPCADD	10	GEØM4	-2	4	8	-1	1	4891	60	S3	4020	1	13D5
84	LØAD	9	GEØM3	0	4	8	-1	1	4551	61	S3	4060	1	13D6
85	EIGR	7	DYNAMICS	-2	14	18	469	1	307	3	S2	850	0	13E1
86	EIGB	7	DYNAMICS	-2	14	18	469	1	107	1	S2	850	0	13E2
87	EIGC	7	DYNAMICS	-2	-4	10	-1	1	207	2	S2	870	0	13E3
88	ADUM4	1	GEØM1	0	8	8	537	0	0	0	S5	400	0	13E4
89		1	GEØM1	0	8	8	-1	2	0	0	S2	890	0	13E5
90	MATS1	3	MPT	-2	4	16	545	1	503	5	S4	900	-1	13E6
91	MATT1	3	MPT	0	4	16	545	1	703	7	S4	900	0	21A1
92	ØMIT1	10	GEØM4	-2	-4	9	-1	0	4951	63	S3	3981	-1	21A2
93	TABLEM1	5	DIT	0	-4	16	-1	1	105	1	S2	930	0	21A3
94	TABLEM2	5	DIT	0	-4	16	-1	1	205	2	S2	930	0	21A4
95	TABLEM3	5	DIT	0	-4	16	-1	1	305	3	S2	930	0	21A5
96	TABLEM4	5	DIT	0	-4	16	-1	1	405	4	S2	960	0	21A6
97	TABLES1	5	DIT	-2	-4	16	-1	1	3105	31	S2	930	-1	21B1
98	TEMPD	9	GEØM3	0	4	12	269	0	5641	65	S4	980	1	21B2
99	ADUM5	1	GEØM1	0	8	8	537	0	320	0	S5	500	0	21B3
100	ADUM6	1	GEØM1	0	8	8	537	0	0	0	S5	600	0	21B4
101	ADUM7	1	GEØM1	0	8	8	537	0	0	0	S5	700	0	21B5
102	MATT2	3	MPT	0	4	16	525	1	803	8	S4	1020	-1	21B6
103	ADUM8	1	GEØM1	0	8	8	537	0	0	0	S5	800	0	21C1
104	CTØRDRG	8	GEØM2	-2	4	12	750	1	1908	19	S4	1040	-1	21C2
105	SPØINT	8	GEØM2	-2	-4	9	794	0	5551	49	S4	1050	-1	21C3
106	ADUM9	1	GEØM1	0	8	8	537	0	0	0	S5	900	0	21C4
107	CDUM1	8	GEØM2	0	8	24	925	1	6108	61	S5	1000	0	21C5
108	CDUM2	8	GEØM2	0	8	24	925	1	6208	62	S5	1100	0	21C6
109	CDUM3	8	GEØM2	0	8	24	925	1	6308	63	S5	1200	0	21D1
110	CDUM4	8	GEØM2	0	8	24	925	1	6408	64	S5	1300	0	21D2
111	CDUM5	8	GEØM2	0	8	24	925	1	6508	65	S5	1400	0	21D3
112	CDUM6	8	GEØM2	0	8	24	925	1	6608	66	S5	1500	0	21D4
113	CDUM7	8	GEØM2	0	8	24	925	1	6708	67	S5	1600	0	21D5
114	CDUM8	8	GEØM2	0	8	24	925	1	6808	68	S5	1700	0	21D6
115	CDUM9	8	GEØM2	0	8	24	925	1	6908	69	S5	1800	0	21E1
116	PDUM1	2	EPT	0	4	24	925	1	6102	61	S5	1900	0	21E2

Table 1(e). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
117	PDUM2	2	EPT	0	4	24	925	1	6202	62	S5	2000	0	21E3
118	PDUM3	2	EPT	0	4	24	925	1	6302	63	S5	2100	0	21E4
119	DMI	12	PØØL	0	-4	16	-1	0	0	0	S2	1190	0	21E5
120	DMIG	14	MATPØØL	-2	-4	12	-1	0	114	1	S2	1200	0	21E6
121	PTØRDRG	2	EPT	-2	4	8	237	0	2102	21	S1	3000	-1	22A1
122	MAT3	3	MPT	-2	4	20	449	1	1403	14	S4	1220	-1	22A2
123	DLØAD	7	DYNAMICS	-2	4	8	-1	1	57	5	S3	4060	0	22A3
124	EPØINT	7	DYNAMICS	-2	-4	9	794	0	707	7	S4	1050	0	22A4
125	FREQ1	7	DYNAMICS	-2	4	8	705	0	1007	10	S1	1250	0	22A5
126	FREQ	7	DYNAMICS	-2	4	8	-1	1	1307	13	S3	1260	0	22A6
127	NØLIN1	7	DYNAMICS	-2	8	12	725	0	3107	31	S1	1270	0	22B1
128	NØLIN2	7	DYNAMICS	-2	8	12	725	0	3207	32	S1	1280	0	22B2
129	NØLIN3	7	DYNAMICS	-2	8	12	725	0	3307	33	S1	1290	0	22B3
130	NØLIN4	7	DYNAMICS	-2	8	12	725	0	3407	34	S1	1290	0	22B4
131	RLØAD1	7	DYNAMICS	-2	8	8	337	1	5107	51	S3	1310	0	22B5
132	RLØAD2	7	DYNAMICS	-2	8	8	337	1	5207	52	S3	1310	0	22B6
133	TABLED1	5	DIT	-2	-4	16	-1	1	1105	11	S2	930	0	22C1
134	TABLED2	5	DIT	-2	-4	16	-1	1	1205	12	S2	930	0	22C2
135	SEQEP	7	DYNAMICS	-1	4	8	37	0	5707	57	S1	40	-1	22C3
136	TF	7	DYNAMICS	-2	8	12	-1	0	6207	62	S1	1360	0	22C4
137	TIC	7	DYNAMICS	-2	4	12	713	0	6607	66	S1	1370	0	22C5
138	TLØAD1	7	DYNAMICS	-2	8	8	681	1	7107	71	S3	1380	0	22C6
139	TLØAD2	7	DYNAMICS	0	8	16	689	1	7207	72	S3	1390	0	22D1
140	TABLED3	5	DIT	0	-4	16	-1	1	1305	13	S2	930	0	22D2
141	TABLED4	5	DIT	0	-4	16	-1	1	1405	14	S2	960	0	22D3
142	TSTEP	7	DYNAMICS	0	4	8	-1	1	8307	83	S1	1420	0	22D4
143	DSFACT	3	MPT	0	4	8	-1	1	53	10	S3	1430	0	22D5
144	AXIC	15	AXIC	-2	4	8	93	0	515	5	S3	1440	0	22D6
145	RINGAX	15	AXIC	-2	4	12	245	1	5615	56	S3	1450	0	22E1
146	CCØNEAX	15	AXIC	-2	4	8	645	1	2315	23	S3	1460	0	22E2
147	PCØNEAX	2	EPT	-2	4	28	653	1	152	19	S3	1470	0	22E3
148	SPCAX	15	AXIC	-2	4	12	485	0	6215	62	S3	1480	0	22E4
149	MPCAX	15	AXIC	-2	4	8	-1	0	4015	40	S3	1490	0	22E5
150	ØMITAX	15	AXIC	-2	4	8	337	0	4315	43	S3	1500	0	22E6
151	SUPAX	15	AXIC	-2	4	8	337	0	6415	64	S3	1500	0	23A1
152	PØINTAX	15	AXIC	-2	4	8	517	1	4915	49	S3	1520	0	23A2
153	SECTAX	15	AXIC	-2	4	12	177	1	6015	60	S3	1530	0	23A3
154	PRESAX	15	AXIC	-2	4	12	61	0	5215	52	S3	1540	0	23A4
155	TEMPAX	15	AXIC	-2	4	8	237	0	6815	68	S3	1550	0	23A5
156	FØRCEAX	15	AXIC	-2	-4	13	109	0	2115	21	S3	1560	0	23A6
157	MØMAX	15	AXIC	-2	-4	13	109	0	3815	38	S3	1560	0	23B1
158	EIGP	7	DYNAMICS	-2	4	8	561	0	257	4	S1	1580	0	23B2
159	PDUM4	2	EPT	0	4	24	925	1	6402	64	S5	2200	0	23B3
160	PDUM5	2	EPT	0	4	24	925	1	6502	65	S5	2300	0	23B4
161	PDUM6	2	EPT	0	4	24	925	1	6602	66	S5	2400	0	23B5
162	TABDMP1	5	DIT	-2	-4	16	-1	1	15	21	S2	930	0	23B6
163	PDUM7	2	EPT	0	4	24	925	1	6702	67	S5	2500	0	23C1
164	PDUM8	2	EPT	0	4	24	925	1	6802	68	S5	2600	0	23C2
165	PDUM9	2	EPT	0	4	24	925	1	6902	69	S5	2700	0	23C3
166	FREQ2	7	DYNAMICS	-2	4	8	705	0	1107	11	S1	1660	0	23C4
167	U1SET	10	GEØM4	0	8	8	37	0	110	41	S5	2800	0	23C5
168	U2SET	10	GEØM4	0	8	8	37	0	210	2	S5	2900	0	23C6
169	U3SET	10	GEØM4	0	8	8	37	0	310	3	S5	3000	0	23D1
170	U4SET	10	GEØM4	0	8	8	37	0	410	4	S5	3100	0	23D2
171	U5SET	10	GEØM4	0	8	8	37	0	500	5	S5	3200	0	23D3
172	U6SET	10	GEØM4	0	8	8	37	0	610	6	S5	3300	0	23D4
173	U7SET	10	GEØM4	0	8	8	37	0	710	7	S5	3400	0	23D5
174	U8SET	10	GEØM4	0	8	8	37	0	810	8	S5	3500	0	23D6

Table 1(f). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
175	U9SET	10	GEØM4	0	8	8	37	0	910	9	S5	3600	0	23E1
176	U1SET1	10	GEØM4	0	-4	9	-1	0	1110	11	S5	3700	0	23E2
177	U2SET1	10	GEØM4	0	-4	9	-1	0	1210	12	S5	3800	0	23E3
178	U3SET1	10	GEØM4	0	-4	9	-1	0	1310	13	S5	3900	0	23E4
179	BARØR	8	GEØM2	0	4	12	25	2	0	0	S1	100	-1	23E5
180	CBAR	8	GEØM2	0	8	20	73	1	2408	24	S1	200	-1	23E6
181	PBAR	2	EPT	0	4	24	621	1	52	20	S1	300	-1	31A1
182	DAREA	7	DYNAMICS	-2	4	8	101	0	27	17	S3	1820	0	31A2
183	DELAY	7	DYNAMICS	-2	4	8	101	0	37	18	S3	1820	0	31A3
184	DPHASE	7	DYNAMICS	-2	4	8	101	0	77	19	S3	1820	0	31A4
185	PLFACT	3	MPT	-2	4	8	-1	1	1103	11	S3	1420	-1	31A5
186	U4SET1	10	GEØM4	0	-4	9	-1	0	1410	14	S5	4000	0	31A6
187	U5SET1	10	GEØM4	0	-4	9	-1	0	1510	15	S5	4100	0	31B1
188	U6SET1	10	GEØM4	0	-4	9	-1	0	1610	10	S5	4200	0	31B2
189	MATT3	3	MPT	-2	4	16	525	1	1503	15	S4	1020	-1	31B3
190	RFØRCE	9	GEØM3	-2	8	12	109	0	5509	55	S1	1900	1	31B4
191	TABRND1	5	DIT	-2	-4	16	-1	1	55	25	S2	930	0	31B5
192	U7SET1	10	GEØM4	0	-4	9	-1	0	1710	17	S5	4300	0	31B6
193	U8SET1	10	GEØM4	0	-4	9	-1	0	1810	18	S5	4400	0	31C1
194	U9SET1	10	GEØM4	-0	-4	9	-1	0	1910	19	S5	4500	0	31C2
195	RANDPS	7	DYNAMICS	-2	4	12	782	0	2107	21	S4	1950	-1	31C3
196	RANDT1	7	DYNAMICS	-2	4	8	752	0	2207	22	S4	1960	-1	31C4
197	RANDT2*	7	DYNAMICS	-2	-4	8	-1	1	2307	23	S9		-1	31C5
198	PLØAD1*	9	GEØM3	-2	0	0	0	0	6909	69	S9		-1	31C6
199	PLØAD2	9	GEØM3	-2	-4	9	774	0	6802	68	S4	1990	-1	31D1
200	DTI	12	PØØL	0	-4	16	-1	0	0	0	S2	2000	0	31D2
201	TEMPP1	9	GEØM3	-2	-4	10	-1	0	8109	81	S4	2100	-1	31D3
202	TEMPP2	9	GEØM3	-2	-4	10	-1	0	8209	82	S4	2200	-1	31D4
203	TEMPP3	9	GEØM3	-2	-4	10	-1	0	8309	83	S4	2300	-1	31D5
204	TEMPRB	9	GEØM3	-2	-4	10	-1	0	8409	84	S4	2400	-1	31D6
205	GRIDB	15	AXIC	-2	8	12	1	1	8115	81	S4	3100	-1	31E1
206	FSLIST	15	AXIC	-2	-4	10	-1	0	8215	82	S4	3200	-1	31E2
207	RINGFL	15	AXIC	-2	4	8	497	1	8315	83	S4	3300	-1	31E3
208	PRESPT	15	AXIC	-2	4	8	834	0	8415	84	S4	3400	-1	31E4
209	CFLUID2	15	AXIC	-2	8	8	845	1	8515	85	S4	3500	-1	31E5
210	CFLUID3	15	AXIC	-2	8	8	853	1	8615	86	S4	3600	-1	31E6
211	CFLUID4	15	AXIC	-2	8	8	861	1	8715	87	S4	3700	-1	32A1
212	AXIF	15	AXIC	-2	-8	10	-1	0	8815	88	S4	3800	-1	32A2
213	BDYLIST	15	AXIC	-2	-4	10	-1	0	8915	89	S4	3900	-1	32A3
214	FREEPT	15	AXIC	-2	4	8	834	0	9015	90	S4	4000	-1	32A4
215	ASET	10	GEØM4	-2	4	8	37	0	5561	76	S1	1400	-1	32A5
216	ASET1	10	GEØM4	-2	-4	9	-1	0	5571	77	S3	3981	-1	32A6
217	CTETRA	8	GEØM2	-2	8	8	337	1	5508	55	S4	4100	-1	32B1
218	CWEDGE	8	GEØM2	-2	8	8	525	1	5608	56	S4	4200	-1	32B2
219	CHEXA1	8	GEØM2	-2	16	16	531	1	5708	57	S4	4300	-1	32B3
220	CHEXA2	8	GEØM2	-2	16	16	531	1	5808	58	S4	4400	-1	32B4
221	DMIAX	14	MATPØØL	-2	-4	9	-1	0	214	2	S4	4500	-1	32B5
222	FLSYM	15	AXIC	-2	4	10	826	0	9115	91	S4	4600	-1	32B6
223	AXSLØT	15	AXIC	-2	8	8	869	1	1115	11	S1	4100	0	32C1
224	CAXIF2	8	GEØM2	-2	8	8	877	1	2108	21	S1	4200	0	32C2
225	CAXIF3	8	GEØM2	-2	8	8	877	1	2208	22	S1	4300	0	32C3
226	CAXIF4	8	GEØM2	-2	8	8	877	1	2308	23	S1	4400	0	32C4
227	CSLØT3	8	GEØM2	-2	8	8	877	1	4408	44	S1	4500	0	32C5
228	CSLØT4	8	GEØM2	-2	8	16	877	1	4508	45	S1	4600	0	32C6
229	GRIDF	15	AXIC	-2	4	8	885	1	1215	12	S1	4700	0	32D1
230	GRIDS	15	AXIC	-2	4	8	893	1	1315	13	S1	4800	0	32D2
231	SLBDY	15	AXIC	-2	-4	8	-1	0	1415	14	S1	4900	0	32D3
232	CHBDY	8	GEØM2	0	9	9	901	1	4208	42	S1	5000	-1	32D4

Table 1(g). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
233	QHBDY	9	GEØM3	0	9	9	901	0	4309	43	S1	5100	-1	32D5
234	MAT4	3	MPT	0	4	8	317	1	2103	21	S1	3900	-1	32D6
235	MAT5	3	MPT	0	8	8	82	1	2203	22	S1	4000	-1	32E1
236	SAME	11	GEØM5	-2	-4	9	-1	0	1110	11	S5	5	-1	32E2
237	SAME1	11	GEØM5	-2	-8	9	-1	0	1210	12	S5	5	-1	32E3
238	INPUT	11	GEØM5	0	17	17	909	0	1310	13	S5	5	-1	32E4
239	ØUTPUT	11	GEØM5	0	17	17	909	0	1410	14	S5	5	-1	32E5

Table 2(a). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

The following list gives an explanation of the column headings on the following pages of Table 2.

A = Internal IFP Bulk Data Card Number

B = Bulk Data Card Name (an asterisk following a name implies the card is not available)

C = Internal IFP GINØ Output File Number

D = Data Block Name

E = Approach Acceptance Indicator

-2 = Illegal for the Force Approach

-1 = Not Used by the Force Approach

0 = OK for any Approach

1 = Not Used by the Displacement Approach

2 = Illegal for the Displacement Approach

F = Minimum Number of Words Allowed Per Logical Card (F negative implies an open ended card)

G = Maximum Number of Words Allowed Per Logical Card

H = Format Check Pointer Into IFX7BD

I = Field 2 Uniqueness Check Flag

0 = No Check is Made

1 = Check is Made

2 = Special

J = Subroutine LØCATE Code for Card on Output Data Block

K = Trailer Bit Position

L = Pointer to Secondary (Card Dependent) Code

S1 = Subroutine IFS1P

S2 = Subroutine IFS2P

S3 = Subroutine IFS3P

S4 = Subroutine IFS4P

S5 = Subroutine IFS5P

M = FØRTRAN Statement Number in the Card Dependent Subroutines

N = Conical Shell Problem Flag

-1 = Illegal for Shell Mode

Table 2(b). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

0 = OK for Shell Mode

1 = Puts Card Into Different Data Block

0 = Users Map for Data Blocks IFX2BD,...,IFX6BD

Values for I = 1,2 or 3

J = 1,2 or 3

H = A,B,C,D or E

K = 1,2,3,4,5 or 6

I = Is Data Statement in the Block Data Program

J = The Group of A Through E Continuation Card Blocks Within the Ith Data Statement

H = Alphabetic Character in Col 6 (Continuation Column) in the Jth Group

K = The Pair Number on Line H Where the Actual Data is located.

Table 2(c). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
89		1	GEØM1	0	8	8	-1	2	0	0	S2	890	0	13E5
3	ADUM1	1	GEØM1	0	8	8	537	0	0	0	S5	100	0	11A3
32	ADUM2	1	GEØM1	0	8	8	537	0	10	0	S5	200	0	12A2
51	ADUM3	1	GEØM1	0	8	8	537	0	10	0	S5	300	0	12D3
88	ADUM4	1	GEØM1	0	8	8	537	0	0	0	S5	400	0	13E4
99	ADUM5	1	GEØM1	0	8	8	537	0	320	0	S5	500	0	21B3
100	ADUM6	1	GEØM1	0	8	8	537	0	0	0	S5	600	0	21B4
101	ADUM7	1	GEØM1	0	8	8	537	0	0	0	S5	700	0	21B5
103	ADUM8	1	GEØM1	0	8	8	537	0	0	0	S5	800	0	21C1
106	ADUM9	1	GEØM1	0	8	8	537	0	0	0	S5	900	0	21C4
215	ASET	10	GEØM4	-2	4	8	37	0	5561	76	S1	1400	-1	32A5
216	ASET1	10	GEØM4	-2	-4	9	-1	0	5571	77	S3	3981	-1	32A6
144	AXIC	15	AXIC	-2	4	8	93	0	515	5	S3	1440	0	22D6
212	AXIF	15	AXIC	-2	-8	10	-1	0	8815	88	S4	3800	-1	32A2
223	AXSLØT	15	AXIC	-2	8	8	869	1	1115	11	S1	4100	0	32C1
179	BARØR	8	GEØM2	0	4	12	25	2	0	0	S1	100	-1	23E5
213	BDYLIST	15	AXIC	-2	-4	10	-1	0	8915	89	S4	3900	-1	32A3
224	CAXIF2	8	GEØM2	-2	8	8	877	1	2108	21	S1	4200	0	32C2
225	CAXIF3	8	GEØM2	-2	8	8	877	1	2208	22	S1	4300	0	32C3
226	CAXIF4	8	GEØM2	-2	8	8	877	1	2308	23	S1	4400	0	32C4
180	CBAR	8	GEØM2	0	8	20	73	1	2408	24	S1	200	-1	23E6
146	CCØNEAX	15	AXIC	-2	4	8	645	1	2315	23	S3	1460	0	22E2
69	CDAMP1	8	GEØM2	-2	4	12	337	1	201	2	S1	3620	-1	13B3
70	CDAMP2	8	GEØM2	-2	4	12	397	1	301	3	S1	3623	-1	13B4
71	CDAMP3	8	GEØM2	-2	4	8	37	0	401	4	S1	3675	-1	13B5
72	CDAMP4	8	GEØM2	-2	4	8	409	0	501	5	S1	3698	-1	13B6
107	CDUM1	8	GEØM2	0	8	24	925	1	6108	61	S5	1000	0	21C5
108	CDUM2	8	GEØM2	0	8	24	925	1	6208	62	S5	1100	0	21C6
109	CDUM3	8	GEØM2	0	8	24	925	1	6308	63	S5	1200	0	21D1
110	CDUM4	8	GEØM2	0	8	24	925	1	6408	64	S5	1300	0	21D2
111	CDUM5	8	GEØM2	0	8	24	925	1	6508	65	S5	1400	0	21D3
112	CDUM6	8	GEØM2	0	8	24	925	1	6608	66	S5	1500	0	21D4
113	CDUM7	8	GEØM2	0	8	24	925	1	6708	67	S5	1600	0	21D5
114	CDUM8	8	GEØM2	0	8	24	925	1	6808	68	S5	1700	0	21D6
115	CDUM9	8	GEØM2	0	8	24	925	1	6908	69	S5	1800	0	21E1
73	CELAS1	8	GEØM2	-2	4	12	337	1	601	6	S1	3620	-1	13C1
74	CELAS2	8	GEØM2	-2	4	12	417	1	701	7	S1	3800	-1	13C2
75	CELAS3	8	GEØM2	-2	4	8	37	0	801	8	S1	3676	-1	13C3
76	CELAS4	8	GEØM2	-2	4	8	409	0	901	9	S1	3699	-1	13C4
209	CFLUID2	15	AXIC	-2	8	8	845	1	8515	85	S4	3500	-1	31E5
210	CFLUID3	15	AXIC	-2	8	8	853	1	8615	86	S4	3600	-1	31E6
211	CFLUID4	15	AXIC	-2	8	8	861	1	8715	87	S4	3700	-1	32A1
232	CHBDY	8	GEØM2	0	9	9	901	1	4208	42	S1	5000	-1	32D4
219	CHEXA1	8	GEØM2	-2	16	16	531	1	5708	57	S4	4300	-1	32B3
220	CHEXA2	8	GEØM2	-2	16	16	531	1	5808	58	S4	4400	-1	32B4
65	CMASS1	8	GEØM2	-2	4	12	337	1	1001	10	S1	3620	-1	13A5
66	CMASS2	8	GEØM2	-2	4	12	397	1	1101	11	S1	3623	-1	13A6
67	CMASS3	8	GEØM2	-2	4	8	37	0	1201	12	S1	3674	-1	13B1
68	CMASS4	8	GEØM2	-2	4	8	409	0	1301	13	S1	3697	-1	13B2
63	CØNM1	8	GEØM2	0	8	28	349	1	1401	14	S1	3580	-1	13A3
64	CØNM2	8	GEØM2	0	8	20	377	1	1501	15	S1	3600	-1	13A4
47	CØNRØD	8	GEØM2	0	8	12	277	1	1601	16	S1	3260	-1	12C5
6	CØRD1C	1	GEØM1	0	4	8	37	0	1701	17	S1	600	-1	11A6
5	CØRD1R	1	GEØM1	0	4	8	37	0	1801	18	S1	500	-1	11A5
7	CØRD1S	1	GEØM1	0	4	8	37	0	1901	19	S1	700	-1	11B1
9	CØRD2C	1	GEØM1	0	12	16	45	1	2001	20	S1	900	-1	11B3
8	CØRD2R	1	GEØM1	0	12	16	45	1	2101	21	S1	800	-1	11B2
10	CØRD2S	1	GEØM1	0	12	16	45	1	2201	22	S1	1000	-1	11B4

Table 2(d). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
60	CQDMEM	8	GEØM2	0	8	12	325	1	2601	26	S1	3460	-1	12E6
59	CQDPLT	8	GEØM2	0	8	12	325	1	2701	27	S1	3460	-1	12E5
57	CQUAD1	8	GEØM2	0	8	12	325	1	2801	28	S1	3460	-1	12E3
58	CQUAD2	8	GEØM2	0	8	12	325	1	2901	29	S1	3460	-1	12E4
48	CRØD	8	GEØM2	0	4	8	37	0	3001	30	S1	3281	-1	12C6
61	CSHEAR	8	GEØM2	0	8	12	337	1	3101	31	S1	3540	-1	13A1
227	CSLØT3	8	GEØM2	-2	8	8	877	1	4408	44	S1	4500	0	32C5
228	CSLØT4	8	GEØM2	-2	8	16	877	1	4508	45	S1	4600	0	32C6
217	CTETRA	8	GEØM2	-2	8	8	337	1	5508	55	S4	4100	-1	32B1
104	CTØRDRG	8	GEØM2	-2	4	12	750	1	1908	19	S4	1040	-1	21C2
80	CTRAPRG	8	GEØM2	-2	8	12	737	1	1808	18	S4	800	-1	13D2
54	CTRBSC	8	GEØM2	0	8	12	313	1	3201	32	S1	3360	-1	12D6
52	CTRIA1	8	GEØM2	0	8	12	313	1	3301	33	S1	3360	-1	12D4
53	CTRIA2	8	GEØM2	0	8	12	313	1	3401	34	S1	3360	-1	12D5
79	CTRIARG	8	GEØM2	-2	8	12	738	1	1708	17	S4	790	-1	13D1
56	CTRMEM	8	GEØM2	0	8	12	313	1	3501	35	S1	3360	-1	12E2
55	CTRPLT	8	GEØM2	0	8	12	313	1	3601	36	S1	3360	-1	12E1
49	CTUBE	8	GEØM2	0	4	8	37	0	3701	37	S1	3282	-1	12D1
62	CTWIST	8	GEØM2	0	8	12	337	1	3801	38	S1	3540	-1	13A2
50	CVISC	8	GEØM2	-2	4	8	37	0	3901	39	S1	3283	-1	12D2
218	CWEDGE	8	GEØM2	-2	8	8	525	1	5608	56	S4	4200	-1	32B2
182	DAREA	7	DYNAMICS	-2	4	8	101	0	27	17	S3	1820	0	31A2
81	DEFØRM	4	EDT	-2	4	8	157	0	104	1	S1	2500	-1	13D3
183	DELAY	7	DYNAMICS	-2	4	8	101	0	37	18	S3	1820	0	31A3
123	DLØAD	7	DYNAMICS	-2	4	8	-1	1	57	5	S3	4060	0	22A3
119	DMI	12	PØØL	0	-4	16	-1	0	0	0	S2	1190	0	21E5
221	DMIAX	14	MATPØØL	-2	-4	9	-1	0	214	2	S4	4500	-1	32B5
120	DMIG	14	MATPØØL	-2	-4	12	-1	0	114	1	S2	1200	0	21E6
184	DPHASE	7	DYNAMICS	-2	4	8	101	0	77	19	S3	1820	0	31A4
143	DSFACT	3	MPT	0	4	8	-1	1	53	10	S3	1430	0	22D5
200	DTI	12	PØØL	0	-4	16	-1	0	0	0	S2	2000	0	31D2
86	EIGB	7	DYNAMICS	-2	14	18	469	1	107	1	S2	850	0	13E2
87	EIGC	7	DYNAMICS	-2	-4	10	-1	1	207	2	S2	870	0	13E3
158	EIGP	7	DYNAMICS	-2	4	8	561	0	257	4	S1	1580	0	23B2
85	EIGR	7	DYNAMICS	-2	14	18	469	1	307	3	S2	850	0	13E1
124	EPØINT	7	DYNAMICS	-2	-4	9	794	0	707	7	S4	1050	0	22A4
222	FLSYM	15	AXIC	-2	4	10	826	0	9115	91	S4	4600	-1	32B6
18	FØRCE	9	GEØM3	0	8	12	109	0	4201	42	S1	1800	1	11C6
20	FØRCE1	9	GEØM3	0	8	12	121	0	4001	40	S1	2000	-1	11D2
22	FØRCE2	9	GEØM3	0	8	12	133	0	4101	41	S1	2200	-1	11D4
156	FØRCEAX	15	AXIC	-2	-4	13	109	0	2115	21	S3	1560	0	23A6
214	FREEPT	15	AXIC	-2	4	8	834	0	9015	90	S4	4000	-1	32A4
126	FREQ	7	DYNAMICS	-2	4	8	-1	1	1307	13	S3	1260	0	22A6
125	FREQ1	7	DYNAMICS	-2	4	8	705	0	1007	10	S1	1250	0	22A5
166	FREQ2	7	DYNAMICS	-2	4	8	705	0	1107	11	S1	1660	0	23C4
206	FSLIST	15	AXIC	-2	-4	10	-1	0	8215	82	S4	3200	-1	31E2
28	GENEL	8	GEØM2	-2	-4	9	-1	1	4301	43	S3	2800	-1	11E4
26	GRAV	9	GEØM3	0	8	12	165	1	4401	44	S1	2600	1	11E2
2	GRDSET	1	GEØM1	0	4	12	13	2	0	0	S3	200	-1	11A2
1	GRID	1	GEØM1	0	4	12	1	1	4501	45	S3	100	-1	11A1
205	GRIDB	15	AXIC	-2	8	12	1	1	8115	81	S4	3100	-1	31E1
229	GRIDF	15	AXIC	-2	4	8	885	1	1215	12	S1	4700	0	32D1
230	GRIDS	15	AXIC	-2	4	8	893	1	1315	13	S1	4800	0	32D2
238	INPUT	11	GEØM5	0	17	17	909	0	1310	13	S5	5	-1	32E4
84	LØAD	9	GEØM3	0	4	8	-1	1	4551	61	S3	4060	1	13D6
77	MAT1	3	MPT	0	4	20	429	1	103	1	S1	3860	0	13C5
78	MAT2	3	MPT	0	8	20	449	1	203	2	S1	3880	0	13C6
122	MAT3	3	MPT	-2	4	20	449	1	1403	14	S4	1220	-1	22A2

Table 2(e). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
234	MAT4	3	MPT	0	4	8	317	1	2103	21	S1	3900	-1	32D6
235	MAT5	3	MPT	0	8	8	82	1	2203	22	S1	4000	-1	32E1
90	MATS1	3	MPT	-2	4	16	545	1	503	5	S4	900	-1	13E6
91	MATT1	3	MPT	0	4	16	545	1	703	7	S4	900	0	21A1
102	MATT2	3	MPT	0	4	16	525	1	803	8	S4	1020	-1	21B6
189	MATT3	3	MPT	-2	4	16	525	1	1503	15	S4	1020	-1	31B3
157	MØMAX	15	AXIC	-2	-4	13	109	0	3815	38	S3	1560	0	23B1
19	MØMENT	9	GEØM3	0	8	12	109	0	4801	48	S1	1800	1	11D1
21	MØMENT1	9	GEØM3	0	8	12	121	0	4601	46	S1	2000	-1	11D3
23	MØMENT2	9	GEØM3	0	8	12	133	0	4701	47	S1	2200	-1	11D5
17	MPC	10	GEØM4	-2	4	8	-1	0	4901	49	S3	1700	-1	11C5
83	MPCADD	10	GEØM4	-2	4	8	-1	1	4891	60	S3	4020	1	13D5
149	MPCAX	15	AXIC	-2	4	8	-1	0	4015	40	S3	1490	0	22E5
127	NØLIN1	7	DYNAMICS	-2	8	12	725	0	3107	31	S1	1270	0	22B1
128	NØLIN2	7	DYNAMICS	-2	8	12	725	0	3207	32	S1	1280	0	22B2
129	NØLIN3	7	DYNAMICS	-2	8	12	725	0	3307	33	S1	1290	0	22B3
130	NØLIN4	7	DYNAMICS	-2	8	12	725	0	3407	34	S1	1290	0	22B4
15	ØMIT	10	GEØM4	-2	4	8	37	0	5001	50	S1	1400	-1	11C3
92	ØMIT1	10	GEØM4	-2	-4	9	-1	0	4951	63	S3	3981	-1	21A2
150	ØMITAX	15	AXIC	-2	4	8	337	0	4315	43	S3	1500	0	22E6
239	ØUTPUT	11	GEØM5	0	17	17	909	0	1410	14	S5	5	-1	32E5
82	PARAM	6	PVT	0	-5	16	-1	2	0	0	S3	3960	0	13D4
181	PBAR	2	EPT	0	4	24	621	1	52	20	S1	300	-1	31A1
147	PCØNEAX	2	EPT	-2	4	28	653	1	152	19	S3	1470	0	22E3
45	PDAMP	2	EPT	-2	4	8	269	0	402	2	S1	3200	-1	12C3
116	PDUM1	2	EPT	0	4	24	925	1	6102	61	S5	1900	0	21E2
117	PDUM2	2	EPT	0	4	24	925	1	6202	62	S5	2000	0	21E3
118	PDUM3	2	EPT	0	4	24	925	1	6302	63	S5	2100	0	21E4
159	PDUM4	2	EPT	0	4	24	925	1	6402	64	S5	2200	0	23B3
160	PDUM5	2	EPT	0	4	24	925	1	6502	65	S5	2300	0	23B4
161	PDUM6	2	EPT	0	4	24	925	1	6602	66	S5	2400	0	23B5
163	PDUM7	2	EPT	0	4	24	925	1	6702	67	S5	2500	0	23C1
164	PDUM8	2	EPT	0	4	24	925	1	6802	68	S5	2600	0	23C2
165	PDUM9	2	EPT	0	4	24	925	1	6902	69	S5	2700	0	23C3
46	PELAS	2	EPT	-2	4	8	497	0	302	3	S1	3240	-1	12C4
185	PLFACT	3	MPT	-2	4	8	-1	1	1103	11	S3	1420	-1	31A5
24	PLØAD	9	GEØM3	0	8	12	145	0	5101	51	S1	2400	-1	11D6
198	PLØAD1*	9	GEØM3	-2	0	0	0	0	6909	69	S9		-1	31C6
199	PLØAD2	9	GEØM3	-2	-4	9	774	0	6802	68	S4	1990	-1	31D1
11	PLØTEL	8	GEØM2	0	4	8	505	0	5201	52	S1	1111	-1	11B5
44	PMASS	2	EPT	-2	4	8	269	0	402	4	S1	3200	-1	12C2
152	PØINTAX	15	AXIC	-2	4	8	517	1	4915	49	S3	1520	0	23A2
41	PQDMEM	2	EPT	0	4	8	237	0	502	5	S1	3000	-1	12B5
40	PQDPLT	2	EPT	0	4	12	257	0	602	6	S1	3020	-1	12B4
38	PQUAD1	2	EPT	0	4	16	221	1	702	7	S1	2980	-1	12B2
39	PQUAD2	2	EPT	0	4	8	237	0	802	8	S1	3000	-1	12B3
154	PRESAX	15	AXIC	-2	4	12	61	0	5215	52	S3	1540	0	23A4
208	PRESPT	15	AXIC	-2	4	8	834	0	8415	84	S4	3400	-1	31E4
29	PRØD	2	EPT	0	4	12	165	1	902	9	S1	2900	-1	11E5
42	PSHEAR	2	EPT	0	4	8	237	0	1002	10	S1	3000	-1	12B6
121	PTØRDRG	2	EPT	-2	4	8	237	0	2102	21	S1	3000	-1	22A1
35	PTRBSC	2	EPT	0	4	12	257	1	1102	11	S1	3020	-1	12A5
33	PTRIA1	2	EPT	0	4	16	221	1	1202	12	S1	2980	-1	12A3
34	PTRIA2	2	EPT	0	4	8	237	0	1302	13	S1	3000	-1	12A4
37	PTRMEM	2	EPT	0	4	8	237	0	1402	14	S1	3000	-1	12B1
36	PTRPLT	2	EPT	0	4	12	257	1	1502	15	S1	3020	-1	12A6
30	PTUBE	2	EPT	0	4	12	177	1	1602	16	S1	2920	-1	11E6
43	PTWIST	2	EPT	0	4	8	237	0	1702	17	S1	3000	-1	12C1

Table 2(f). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
31	PVISC	2	EPT	-2	4	8	189	0	1802	18	S1	310	-1	12A1
233	QHBDY	9	GEØM3	0	9	9	901	0	4309	43	S1	5100	-1	32D5
195	RANDPS	7	DYNAMICS	-2	4	12	782	0	2107	21	S4	1950	-1	31C3
196	RANDT1	7	DYNAMICS	-2	4	8	752	0	2207	22	S4	1960	-1	31C4
197	RANDT2*	7	DYNAMICS	-2	-4	8	-1	1	2307	23	S9		-1	31C5
145	RINGAX	15	AXIC	-2	4	12	245	1	5615	56	S3	1450	0	22E1
207	RINGFL	15	AXIC	-2	4	8	497	1	8315	83	S4	3300	-1	31E3
190	RFØRCE	9	GEØM3	-2	8	12	109	0	5509	55	S1	1900	1	31B4
131	RLØAD1	7	DYNAMICS	-2	8	8	337	1	5107	51	S3	1310	0	22B5
132	RLØAD2	7	DYNAMICS	-2	8	8	337	1	5207	52	S3	1310	0	22B6
236	SAME	11	GEØM5	-2	-4	9	-1	0	1110	11	S5	5	-1	32E2
237	SAME1	11	GEØM5	-2	-8	9	-1	0	1210	12	S5	5	-1	32E3
153	SECTAX	15	AXIC	-2	4	12	177	1	6015	60	S3	1530	0	23A3
135	SEQEP	7	DYNAMICS	-1	4	8	37	0	5707	57	S1	40	-1	22C3
4	SEQGP	1	GEØM1	-1	4	8	37	0	5301	53	S1	40	-1	11A4
231	SLBDY	15	AXIC	-2	-4	8	-1	0	1415	14	S1	4900	0	32D3
25	SLØAD	9	GEØM3	-2	4	8	157	0	5401	54	S1	2500	-1	11E1
16	SPC	10	GEØM4	-2	4	8	101	0	5501	55	S1	1600	-1	11C4
12	SPC1	10	GEØM4	-2	-4	9	-1	0	5481	58	S3	3980	-1	11B6
13	SPCADD	10	GEØM4	-2	4	8	-1	1	5491	59	S3	4020	1	11C1
148	SPCAX	15	AXIC	-2	4	12	485	0	6215	62	S3	1480	0	22E4
105	SPØINT	8	GEØM2	-2	-4	9	794	0	5551	49	S4	1050	-1	21C3
151	SUPAX	15	AXIC	-2	4	8	337	0	6415	64	S3	1500	0	23A1
14	SUPØRT	10	GEØM4	-2	4	8	37	0	5601	56	S1	1400	-1	11C2
162	TABDMP1	5	DIT	-2	-4	16	-1	1	15	21	S2	930	0	23B6
133	TABLED1	5	DIT	-2	-4	16	-1	1	1105	11	S2	930	0	22C1
134	TABLED2	5	DIT	-2	-4	16	-1	1	1205	12	S2	930	0	22C2
140	TABLED3	5	DIT	0	-4	16	-1	1	1305	13	S2	930	0	22D2
141	TABLED4	5	DIT	0	-4	16	-1	1	1405	14	S2	960	0	22D3
93	TABLEM1	5	DIT	0	-4	16	-1	1	105	1	S2	930	0	21A3
94	TABLEM2	5	DIT	0	-4	16	-1	1	205	2	S2	930	0	21A4
95	TABLEM3	5	DIT	0	-4	16	-1	1	305	3	S2	930	0	21A5
96	TABLEM4	5	DIT	0	-4	16	-1	1	405	4	S2	960	0	21A6
97	TABLES1	5	DIT	-2	-4	16	-1	1	3105	31	S2	930	-1	21B1
191	TABRND1	5	DIT	-2	-4	16	-1	1	55	25	S2	930	0	31B5
27	TEMP	9	GEØM3	0	4	8	157	0	5701	57	S1	2500	-1	11E3
155	TEMPAX	15	AXIC	-2	4	8	237	0	6815	68	S3	1550	0	23A5
98	TEMPD	9	GEØM3	0	4	12	269	0	5641	65	S4	980	1	21B2
201	TEMPP1	9	GEØM3	-2	-4	10	-1	0	8109	81	S4	2100	-1	31D3
202	TEMPP2	9	GEØM3	-2	-4	10	-1	0	8209	82	S4	2200	-1	31D4
203	TEMPP3	9	GEØM3	-2	-4	10	-1	0	8309	83	S4	2300	-1	31D5
204	TEMPRB	9	GEØM3	-2	-4	10	-1	0	8409	84	S4	2400	-1	31D6
136	TF	7	DYNAMICS	-2	8	12	-1	0	6207	62	S1	1360	0	22C4
137	TIC	7	DYNAMICS	-2	4	12	713	0	6607	66	S1	1370	0	22C5
138	TLØAD1	7	DYNAMICS	-2	8	8	681	1	7107	71	S3	1380	0	22C6
139	TLØAD2	7	DYNAMICS	0	8	16	689	1	7207	72	S3	1390	0	22D1
142	TSTEP	7	DYNAMICS	0	4	8	-1	1	8307	83	S1	1420	0	22D4
167	U1SET	10	GEØM4	0	8	8	37	0	110	41	S5	2800	0	23C5
176	U1SET1	10	GEØM4	0	-4	9	-1	0	1110	11	S5	3700	0	23E2
168	U2SET	10	GEØM4	0	8	8	37	0	210	2	S5	2900	0	23C6
177	U2SET1	10	GEØM4	0	-4	9	-1	0	1210	12	S5	3800	0	23E3
169	U3SET	10	GEØM4	0	8	8	37	0	310	3	S5	3000	0	23D1
178	U3SET1	10	GEØM4	0	-4	9	-1	0	1310	13	S5	3900	0	23E4
170	U4SET	10	GEØM4	0	8	8	37	0	410	4	S5	3100	0	23D2
186	U4SET1	10	GEØM4	0	-4	9	-1	0	1410	14	S5	4000	0	31A6
171	U5SET	10	GEØM4	0	8	8	37	0	500	5	S5	3200	0	23D3
187	U5SET1	10	GEØM4	0	-4	9	-1	0	1510	15	S5	4100	0	31B1
172	U6SET	10	GEØM4	0	8	8	37	0	610	6	S5	3300	0	23D4

Table 2(g). Bulk Data Cards Processed by IFP Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
188	U6SET1	10	GEØM4	0	-4	9	-1	0	1610	10	S5	4200	0	31B2
173	U7SET	10	GEØM4	0	8	8	37	0	710	7	S5	3400	0	23D5
192	U7SET1	10	GEØM4	0	-4	9	-1	0	1710	17	S5	4300	0	31B6
174	U8SET	10	GEØM4	0	8	8	37	0	810	8	S5	3500	0	23D6
193	U8SET1	10	GEØM4	0	-4	9	-1	0	1810	18	S5	4400	0	31C1
175	U9SET	10	GEØM4	0	8	8	37	0	910	9	S5	3600	0	23E1
194	U9SET1	10	GEØM4	-0	-4	9	-1	0	1910	19	S5	4500	0	31C2

4.6 EXECUTIVE PREFACE MODULE IFP3 (INPUT FILE PROCESSOR 3)

4.6.1 Entry Point: IFP3

4.6.2 Purpose

1. To interpret Bulk Data cards unique to an axisymmetric conical shell problem.

2. To generate and distribute to data blocks GEØM1, GEØM2, GEØM3, and GEØM4 data cards for all harmonics specified in the problem.

3. To convert the following input Bulk Data cards to the following output Bulk Data cards.

Input Bulk Data Card Type	Input Data Block	Output Bulk Data Card Type	Output Data Block
AXIC	AXIC	None	
CCØNEAX	AXIC	CCØNE	GEØM2
FØRCEAX	AXIC	FØRCE	GEØM3
FØRCE	AXIC	FØRCE	GEØM3
GRAV	AXIC	GRAV	GEØM3
LØAD	AXIC	LØAD	GEØM3
MØMAX	AXIC	MØMENT	GEØM3
MØMENT	AXIC	MØMENT	GEØM3
MPCADD	AXIC	MPCADD	GEØM4
MPCAX	AXIC	MPC	GEØM4
ØMITAX	AXIC	ØMIT	GEØM4
PØINTAX	AXIC	MPC GRID	GEØM4 GEØM1
PRESAX	AXIC	PRESAX	GEØM3
RINGAX	AXIC	SPC GRID	GEØM4 GEØM1
SECTAX	AXIC	MPC GRID	GEØM4 GEØM1
SEQGP	AXIC	SEQGP	GEØM1
SPCADD	AXIC	SPCADD	GEØM4
SPCAX	AXIC	SPC	GEØM4
SUPAX	AXIC	SUPØRT	GEØM4
TEMPAX	AXIC	TEMP	GEØM3
TEMPD	AXIC	TEMPD	GEØM3

4.6.3 Calling Sequence

CALL IFP3. IFP3, a Preface module, is called only from the Preface driver SEMINT.

4.6.4 Input Data Blocks

AXIC - Bulk Data Deck cards as output from IFP.

4.6.5 Output Data Blocks

GEØM1 - Grid Point Data.

GEØM2 - Element Connection Data.

GEØM3 - Loading Data.

GEØM4 - Constraint Data.

4.6.6 Parameters

Not applicable to IFP3.

4.6.7 Method

In the following a "card" is defined as the type of card image output by IFP, i.e., with the mneumonic stripped off and a card image, in some cases a modified card image, written on the output data block.

4.6.7.1 Initialization and Overall Method

IFP3 first determines the amount of core available, and then allocates three buffers for the SCRATCH, AXIC, and GEØM data blocks. The AXIC data block is opened for input using PRELØC. At this point the 21 types of input Bulk Data cards are found, one type at a time, on the AXIC data block, using the LØCATE routine. The cards of each type are converted and output to a GEØM data block.

To facilitate the operation, all Bulk Data cards causing output to a particular GEØM data block are handled together. Thus the processing is such that all cards affecting GEØM2 are first converted, and following these all those for GEØM3, then GEØM4, and finally GEØM1.

The superscripts s and c in the following refer to the sine and cosine sets respectively.

4.6.7.2 Conversion of Input Bulk Data Cards to Output Bulk Data Cards for GEØM2.

1. AXIC card

-Input Card-

AXIC	Harm	0

-Output Card-
(None)

The AXIC card supplies Harm which is used to compute the number of harmonics, N.

$$N = Harm + 1 \tag{1}$$

2. CCØNEAX card

-Input Card-

CCØNEAX	EL-ID	Prop-ID	$Ring_A$ ID	$Ring_B$ ID

-N Output Cards-

$CCØNE_n$	$EL\text{-}ID_n$	Prop-ID	$Ring_A$ ID_n	$Ring_B$ ID_n

where

$$EL\text{-}ID_n = EL\text{-}ID \times 1000 + n, \tag{2}$$

$$Ring_A\ ID_n = Ring_A\ ID + 1000000 \times n, \tag{3}$$

$$Ring_B\ ID_n = Ring_B\ ID + 1000000 \times n, \tag{4}$$

for n = 1, 2, ..., N.

4.6.7.3 Conversion of Input Bulk Data Cards to Output Cards for GEØM3.

1. FØRCE card and MØMENT card

These two cards are output to GEØM3 as input from AXIC.

2. FØRCEAX card and MØMAX card

-Input Cards-

FORCEAX	Set ID	Ring ID	Harm ID	Factor	F_r	F_ϕ	F_z
MØMAX	Set ID	Ring ID	Harm ID	Factor	M_r	M_ϕ	M_z

-Output Cards-

FØRCE	Set ID	Ring ID_H	0	Factor	F_r	F_ϕ	F_z
MØMENT	Set ID	Ring ID_H	0	Factor	M_r	M_ϕ	M_z

where

$$\text{Ring ID}_H = \text{Ring ID} + (\text{Harm ID} + 1) \times 1000000 \qquad (5)$$

If FØRCE cards and FØRCEAX cards both exist, then the resulting output cards of the FØRCE and FØRCEAX cards are merged in sort on Set ID's. This applies to MØMENT and MØMAX cards also.

3. GRAV card, LØAD card, and TEMPD card

These three cards are output to GEØM3 as they are input from AXIC.

4. PRESAX card

-Input Card-

PRESAX	Set ID	Value	Ring_A ID	Ring_B ID	ϕ_1	ϕ_2

-N Output Cards-

$PRESAX_n$	Set ID	Value	$Ring_A ID_n$	$Ring_B ID_n$	ϕ_1	ϕ_2	n

where

$$Ring_A\ ID_n = Ring_A\ ID + 1000000 \times n \tag{6}$$

$$Ring_B\ ID_n = Ring_B\ ID + 1000000 \times n \tag{7}$$

for n = 1, 2, ..., N.

5. TEMPAX card

-Input Card-

TEMPAX	Set ID	Ring ID	ϕ_1	T_1	ϕ_2	T_2	ϕ_3	T_3

-N x 2 Output Cards -

$N\text{-}TEMP^S_{n+1}$	$Set\ ID^S$	$Ring\ ID_{n+1}$	T^S_n

$N\text{-}TEMP^C_{n+1}$	$Set\ ID^C$	$Ring\ ID_{n+1}$	T^C_n

where

$$Ring\ ID_{n+1} = Ring\ ID + 1000000 \times (n+1) \tag{8}$$

$$Set\ ID^S = Set\ ID + 100000000 \tag{9}$$

$$Set\ ID^C = Set\ ID + 200000000 \tag{10}$$

for n = 0, 1, ..., N-1.

T^S_n and T^C_n are computed as follows. All TEMPAX cards having the same Set ID and Ring ID are gathered together. The angles ϕ_i and temperatures T_i are arrayed into a two-

dimensional matrix.

ϕ_1	T_1
ϕ_2	T_2
⋮	⋮
ϕ_k	T_k

where k is the total number of unique ϕ's, and the ϕ's are converted to radians.

The matrix is sorted on the ϕ column, and duplicate angles are removed.

For n = 0, we have

$$T_o^c = \frac{1}{4\pi} \sum_{i=1}^{k} (T_i + T_{i+1}) (\phi_{i+1} - \phi_i), \tag{11}$$

and

$$T_o^s = 0. \tag{12}$$

For n > 0

$$T_n^c = \frac{1}{\pi} \sum_{i=1}^{k} \frac{1}{(\phi_{i+1} - \phi_i)} \left\{ \frac{(T_i \phi_{i+1} - T_{i+1} \phi_i)}{n} (\sin n\phi_{i+1} - \sin n\phi_i) \right.$$

$$\left. + \frac{T_{i+1} - T_i}{n^2} (\cos n\phi_{i+1} - \cos n\phi_i + n\phi_{i+1} \sin n\phi_{i+1} - n\phi_i \sin n\phi_i) \right\} \tag{13}$$

and

$$T_n^s = \frac{1}{\pi} \sum_{i=1}^{k} \frac{1}{(\phi_{i+1} - \phi_1)} \left\{ \frac{(T_i \phi_{i+1} - T_{i+1} \phi_i)}{n} (-\cos n\phi_{i+1} + \cos n\phi_i) \right.$$

$$\left. + \frac{T_{i+1} - T_i}{n^2} (\sin n\phi_{i+1} - \sin n\phi_i - n\phi_{i+1} \cos n\phi_{i+1} + n\phi_i \cos n\phi_i) \right\} \tag{14}$$

where

$$\phi_{k+1} = \phi_1 + 2\pi , \tag{15}$$

and

$$T_{k+1} = T_1 . \tag{16}$$

4.6.7.4 Conversion of Input Bulk Data Cards to Output Cards for GEØM4

1. SPCADD card

-Input Card-

SPCADD	Set ID	S1	...	S9	-1	} Open-ended

-2 Output Cards-

$SPCADD^S$	$Set\ ID^S$	S1	...	S9	101	-1
$SPCADD^C$	$Set\ ID^C$	S1	...	S9	102	-1

where

$$Set\ ID^S = Set\ ID + 100000000\ , \tag{17}$$

$$Set\ ID^C = Set\ ID + 200000000\ . \tag{18}$$

The following 4 mandatory SPCADD cards are also created and put out on GEØM4 regardless of whether there are or are not SPCADD cards present.

SPCADD	100000101	101	-1
SPCADD	200000102	102	-1
SPCADD	100000000	101	-1
SPCADD	200000000	102	-1

2. MPCADD card

All operations performed for the SPCADD card are performed for the MPCADD card.

3. SPCAX card

-Input Card-

SPCAX	Set ID	Ring ID	Harm ID	Comp	Value

-3 Output Cards-

$SPCADD^S$	$Set\ ID^S$	Set ID	101	-1

$SPCADD^C$	$Set\ ID^C$	Set ID	102	-1

where

$$Set\ ID^S = Set\ ID + 100000000\ , \tag{19}$$

$$Set\ ID^C = Set\ ID + 200000000\ ; \tag{20}$$

and

SPC	Set ID	$Ring\ ID_H$	Comp	Value

where

$$Ring\ ID_H = Ring\ ID + (Harm\ ID + 1) \times 1000000. \tag{21}$$

4. MPCAX card

-Input Card-

MPCAX	Set ID	Ring ID	Harm ID	Comp ID	Value	...	-1	-1	-1	-1	Open Ended

Repeats

-3 Output Cards-

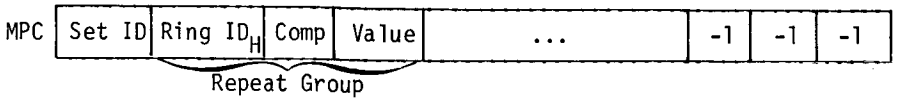
$MPCADD^S$	$Set\ ID^S$	Set ID	101	-1

$MPCADD^C$	$Set\ ID^C$	Set ID	102	-1

$$Set\ ID^S = Set\ ID + 100000000\ , \tag{22}$$

$$Set\ ID^C = Set\ ID + 200000000\ . \tag{23}$$

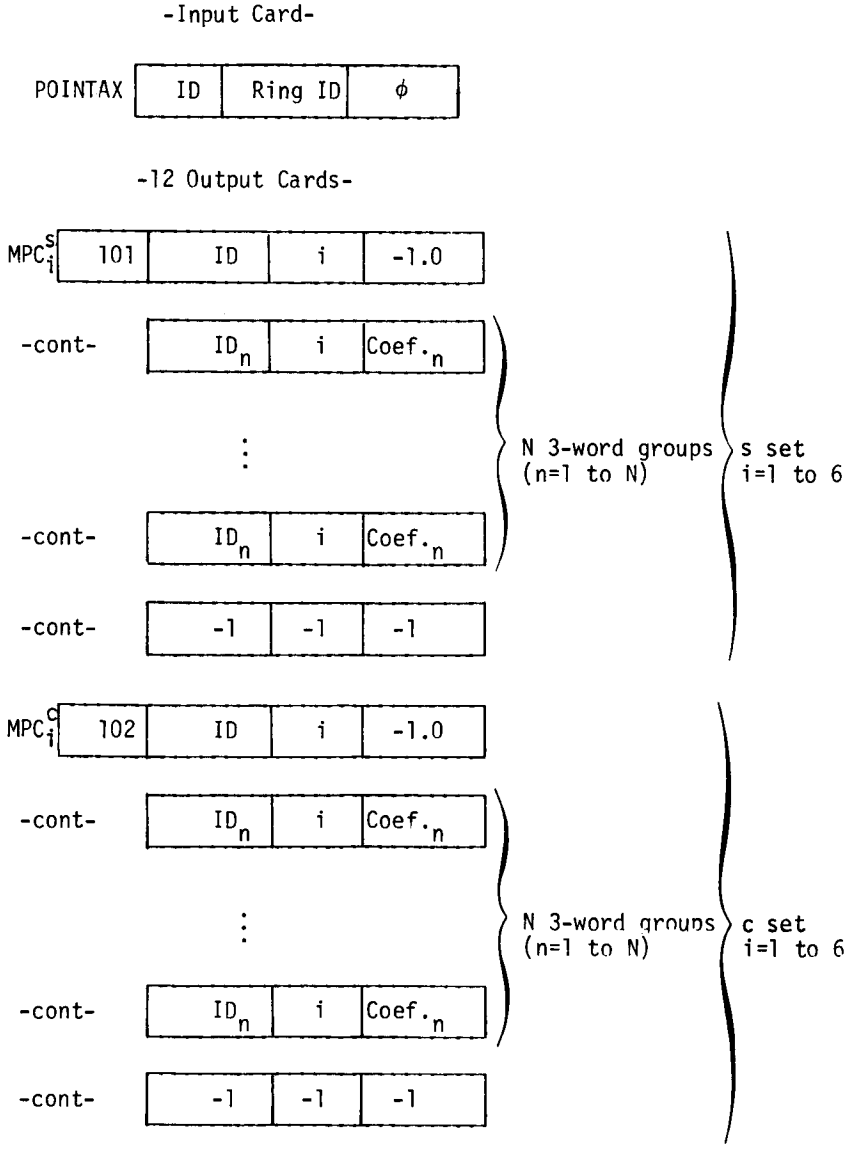
and



For each 3-word group output,

$$\text{Ring ID}_H = \text{Ring ID} + (\text{Harm ID} + 1) \times 1000000. \quad (24)$$

5. PØINTAX card (also processed in GEØM1 section)



where the Coef.$_n$ above are defined by:

i	c set-Coef.$_n$	s set-Coef.$_n$
1 (u_r)	cos (nϕ)	sin (nϕ)
2 (u_ϕ)	sin (nϕ)	-cos (nϕ), = +1, n = 0
3 (u_t)	cos (nϕ)	sin (nϕ)
4 (θ_r)	sin (nϕ)	-cos (nϕ), = +1, n = 0
5 (θ_ϕ)	cos (nϕ)	sin (nϕ)
6 (θ_z)	sin (nϕ)	-cos (nϕ), = +1, n = 0

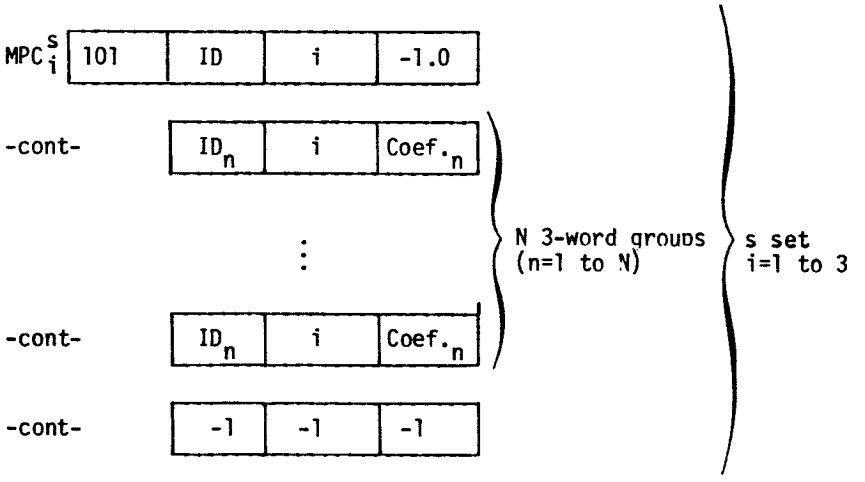
and

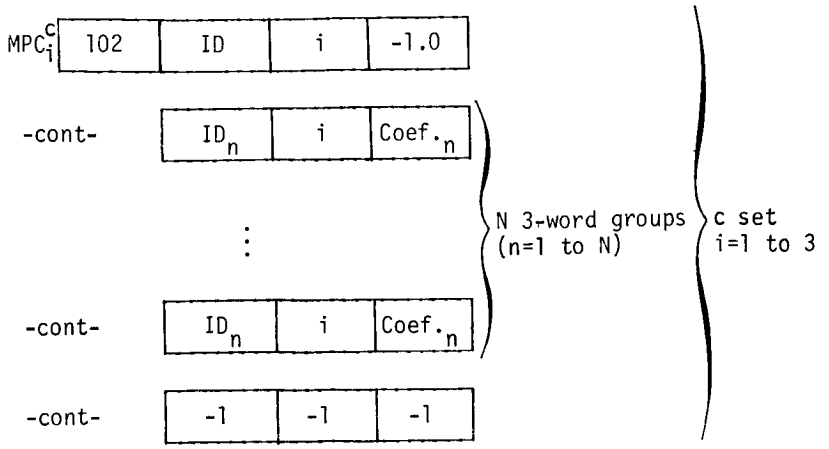
$$ID_n = \text{Ring ID} + (n \times 1000000). \tag{25}$$

6. SECTAX card (also processed in GEØM1 section)

-Input Card-

-6 Output Cards-





where the Coef.$_n$ above are defined by:

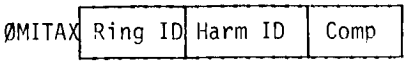
i	c set-Coef.$_n$	s set-Coef.$_n$
1	$\frac{R}{n}(\sin(n\phi_2) - \sin(n\phi_1))$ or $R(\phi_2 - \phi_1)$ for n=0	$-\frac{R}{n}(\cos(n\phi_2) - \cos(n\phi_1))$ or 0 for n=0
2	$-\frac{R}{n}(\cos(n\phi_2) - \cos(n\phi_1))$ or 0 for n=0	$-\frac{R}{n}(\sin(n\phi_2) - \sin(n\phi_1))$ or $R(\phi_2 - \phi_1)$ for n=0
3	$\frac{R}{n}(\sin(n\phi_2) - \sin(n\phi_1))$ or $R(\phi_2 - \phi_1)$ for n=0	$-\frac{R}{n}(\cos(n\phi_2) - \cos(n\phi_1))$ or 0, for n=0

and

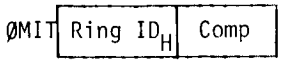
$$ID_n = \text{Ring ID} + (n \times 1000000) \tag{26}$$

7. ØMITAX card

-Input Card-



-Output card-



$$\text{Ring ID}_H = \text{Ring ID} + (\text{Harm ID} + 1) \times 1000000. \tag{27}$$

8. SUPAX card

-Input Card-

SUPAX	Ring ID	Harm ID	Comp

-Output Card-

SUPØRT	Ring ID_H	Comp

$$\text{Ring ID}_H = \text{Ring ID} + (\text{Harm ID} + 1) \times 1000000. \tag{28}$$

9. RINGAX card (also processed in GEØM1 section)

-Input Card-

RINGAX	Ring ID	R	Z	Comp

-2 x N Output Cards-

SPC^S_n	101	Ring ID^S_n	135	0

where

$$\text{Ring ID}^S_n = \text{Ring ID} + 1000000 \times n, \tag{29}$$

for n = 1, 2, ..., N; and

SPC^C_n	102	Ring ID^C_n	246	0

where

$$\text{Ring ID}^C_n = \text{Ring ID} + 1000000 \times n, \tag{30}$$

for n = 1, 2, ..., N.

4.6.7.5 Conversion of Input Bulk Data Cards to Output Cards for GEØM1.

1. PØINTAX card (also processed in GEØM4 section)

-Input Card-

PØINTAX	ID	Ring ID	ϕ

-Output Card-

GRID	ID	0	ϕ	0.0	0.0	0	0	0

2. SECTAX card (also processed in GEØM4 section)

-Input Card-

SECTAX	ID	Ring ID	R	ϕ_1	ϕ_2

-Output Card-

GRID	ID	0	R	ϕ_1	ϕ_2	0	0	0

3. RINGAX card (also processed in GEØM4 section)

-Input Card-

RINGAX	Ring ID	R	Z	Comp

-N Output Cards-

GRID	Ring ID_n	0	R	Z	0.0	0	Comp	0

where

$$\text{Ring ID}_n = \text{Ring ID} + 1000000 \times n, \tag{31}$$

for n = 1, 2, ..., N.

4.6.7.6 Order of Output for Generated Card Images

IFP3 has the responsibility to output cards in the sort order output by IFP. This causes IFP3 to simultaneously process some cards.

4.6.8 Subroutines

4.6.8.1 Subroutine Name: IFP3B

1. Entry Point: IFP3B
2. Purpose: To process the cards causing output to be created for GEØM4 and GEØM1.
3. Calling Sequence: CALL IFP3B

4.6.9 Design Requirements

The design requirements are:

1. To produce card images equivalent to those put out by IFP.
2. To output those images on GEØM1, GEØM2, GEØM3, GEØM4 in the proper sort and order.

The following CØMMØN blocks are required for data interface between subroutines IFP3 and IFP3B.

1. CØMMØN/IFP3LV/

   This CØMMØN block contains local variables common between IFP3 and IFP3B only.

2. CØMMØN/IFP3BD/

   This CØMMØN block contains constants common between IFP3 and IFP3B and is initialized in the Block Data subprogram AXICBD.

3. CØMMØN/IFP3ZZ/

   This CØMMØN block defines the beginning of open-core.

4.6.10 Diagnostic Messages

IFP3 error messages are all user-oriented. They pertain to Bulk Data card errors for the axisymmetric conical shell problem, and are output in summary form by IFP3 on the system output file.

4.7 EXECUTIVE PREFACE MODULE XGPI (EXECUTIVE GENERAL PROBLEM INITIALIZATION).

4.7.1 Entry Point: XGPI

4.7.2 Purpose

To translate (compile) a DMAP program into an internal form (the ØSCAR) for use by the NASTRAN Executive System, and, if restarting the problem, to initialize data blocks and named common blocks for proper restart of the problem. See section 2 for format of the ØSCAR.

4.7.3 Calling Sequence

CALL XGPI. XGPI is called only by subroutine SEMINT, the Preface driver.

4.7.4 Method

XGPI calls XGPIBS to initialize data for the module and to initialize the Link Specification table in named common block /XLINK/. Upon return from XGPIBS, XGPI loads the XCSA Executive Table into core from the Problem Tape. If restarting the problem, XGPI modifies table MEDMSK in named common block /XMDMSK/ if necessary. See discussion of the INM table in the description for the XCSA module, in section 4.2.6.2.

XGPI calls XØSGEN to execute phase 1 of the DMAP program compilation. XØSGEN processes the DMAP instructions and generates the skeleton of the Operation Sequence Control Array (ØSCAR). See section 2.4.2.1 for details on the format of the ØSCAR.

XGPI calls XFLØRD to execute phase 2 of the compilation. XFLØRD fills in the ØSCAR entries with the information needed for allocating files (by SFA) when DMAP modules are executed. If restarting a problem, XFLØRD determines which data blocks are needed from the Old Problem Tape to restart the problem and, when necessary, turns on execute flags for DMAP modules to regenerate missing data blocks.

At this point, XGPI terminates the job if any errors were found in compilation; if not, XGPI writes the ØSCAR onto the Data Pool File. If the problem is a restart, XGPI copies the data blocks specified by XFLØRD from the Old Problem Tape onto the Data Pool File and initializes various named common blocks.

XGPI calls ØSCDMP to print the ØSCAR if requested by the user via the DIAG card in the Executive Control Deck and to position the Data Pool File at the first ØSCAR entry in preparation for executing DMAP modules. If checkpointing is requested by the user, the Problem Tape Dictionary is initialized and written on the Problem Tape. XGPI then returns to the calling routine SEMINT.

4.7.5 Subroutines

The following labeled common blocks are used to communicate data and constants among the complex of XGPI subroutines.

1. CØMMØN/XGPIC/ - Contains 30 individual cells containing various flags, integer and BCD constants, and machine dependent data. Also an additional 40 cell array contains a series of required masks.

2. CØMMØN/XGPID/ - Contains restart type codes and approach type codes plus masks and flags required in ØSCAR generation.

3. CØMMØN/XGPI1/ - Defines the beginning of open core for the XGPI module and contains the ØSCAR as it is generated.

4. CØMMØN/XGPI2/ - Contains the MPL table (see section 2.4.2.2).

5. CØMMØN/XGPI2X/ - Contains the default parameters required by the MPL table.

6. CØMMØN/XGPI3/ - Contains the PVT table (see section 2.4.2.4) prior to it being written on the Problem Tape.

7. CØMMØN/XGPI4/ - Contains individual DMAP cards as they are output from XRCARD plus the various flags and pointers required to process each DMAP instruction.

8. CØMMØN/XGPI5/ - Contains solution, solution subset, approach and start codes along with data pertaining to DMAP ALTER numbers.

9. CØMMØN/XGPI6/ - Contains various pointers into the Module Execution Decision Table, MED (see section 1.10).

10. CØMMØN/XGPI7/ - Contains data pertaining to the IFILE Table (see section 4.7.6.3).

11. CØMMØN/XGPI8/ - Contains pointers into the ICPDPL Table (see section 4.7.6.3).

Further details regarding these common blocks may be obtained from the source listings for XGPIBD and XGPIBS.

4.7.5.1 XGPIDG

1. Entry Points: XGPIDG, XGPIMW.

2. Purposes: For XGPIDG, to write all fatal and non-fatal diagnostic messages for module XGPI. For XGPIMW, to write all non-diagnostic messages for module XGPI.

3. Calling Sequences:

For XGPIDG:

```
CALL XGPIDG (NCØDE,I,J,K)
```

NCØDE - Message code number

I,J,K - Integer values determined by NCØDE.

For XGPIMW:

```
CALL XGPIMW (MSGNØ,I,J,A)
```

MSGNØ - Message code number

I,J,A - Integer values determined by MSGNØ

4.7.5.2 XGPIBS

1. Entry Point: XGPIBS.

2. Purpose: To initialize module data and the Link Specification table in name common block /XLINK/ (see section 2.4).

3. Calling Sequence:

```
CALL XGPIBS
```

4.7.5.3 XØSGEN

1. Entry Point: XØSGEN.

2. Purpose: To execute phase 1 of the compilation by translating the DMAP program into a skeleton Operation Sequence Control Array (ØSCAR).

3. Calling Sequence:

```
CALL XØSGEN
```

4.7.5.4 XLNKHD

1. Entry Point: XLNKHD.

2. Purpose: To generate the header section of an ØSCAR entry and for problem restarts, to determine whether or not to set the ØSCAR entry execute flag.

3. Calling Sequence:

```
CALL XLNKHD
```

4.7.5.5 XIPFL

1. Entry Points: XIPFL, XØPFL.

2. Purpose: For XIPFL, to generate the input data block section of an ØSCAR entry. For XØPFL, to generate the output data block section of an ØSCAR entry.

3. Calling Sequences:

```
CALL XIPFL
CALL XØPFL
```

4.7.5.6 XPARAM

1. Entry Point: XPARAM.

2. Purpose: To generate the parameter section of an ØSCAR entry.

3. Calling Sequence:

```
CALL XPARAM
```

4.7.5.7 XSCNDM

1. Entry Point: XSCNDM.

2. Purpose: To scan all DMAP instructions and return to the calling program each item in an instruction along with its identification (i.e., delimiter, BCD name,

value or end of instruction) as it is requested.

3. Calling Sequence:

CALL XSCNDM

4.7.5.8 XFLØRD

1. Entry Point: XFLØRD.

2. Purpose: To compute the LTU (Last Time Used) and NTU (Next Time Used) values for the input and output sections of ØSCAR entries, and for problem restarts, to determine which data blocks are needed from the Old Problem Tape to restart the problem.

3. Calling Sequence:

CALL XFLØRD

4.7.5.9 XFLDEF

1. Entry Point: XFLDEF.

2. Purpose: To search the Old Problem Tape restart dictionary for a requested data block name and flag name if found; and if not found, and if restart is modified and the calling routine requests it, to attempt to regenerate the data block by turning on the proper ØSCAR execute flags.

3. Calling Sequence:

CALL XFLDEF (NAM1, NAM2, NØFIND)

NAM1,NAM2 - Data block name (8 characters, 4 characters/word).

NØFIND - For input, NØFIND < 0 indicates that the calling routine wants the data block regenerated if it is not in restart dictionary. NØFIND ≥ 0 indicates no regeneration is desired. For output, NØFIND indicates to the calling routine what XFLDEF did. NØFIND < 0, the data block was regenerated. NØFIND = 0, the data block was in the restart dictionary and was flagged for use in restarting the problem. NØFIND > 0, the data block was not found and was not regenerated.

4.7.5.10 ØSCDMP

1. Entry Point: ØSCDMP.

2. Purpose: To print the ØSCAR on the system output file if requested by user, and to position the Data Pool File at the first ØSCAR entry.

3. Calling Sequence:

```
CALL ØSCDMP (FILPØS)
```

FILPØS - The number of file marks to skip over in order to be positioned at beginning of the ØSCAR.

4.7.5.11 MPLPRT

1. Entry Point: MPLPRT

2. Purpose: To print the contents of the Module Properties List (MPL) as defined by the Block Data Program XMPLBD. This printout, which occurs whenever a DIAG 31 card exists in the Executive Control Deck, is formatted for easy readability by programmers and users alike.

3. Calling Sequence:

```
CALL MPLPRT
```

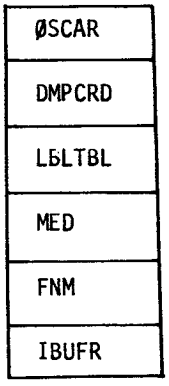
4.7.6 Design Requirements

4.7.6.1 Open Core Layout

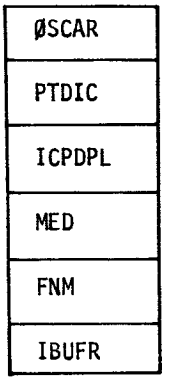
The ØSCAR array in named common block /XGPI1/ defines the first location in open core. All other arrays to be put in open core are equivalenced to ØSCAR and are offset from ØSCAR(1) by an amount determined at execution time. This dynamic allocation of arrays in open core optimizes the space available on a given machine, which means that any restrictions on data (except those noted below) are due to the machine's core size and not the program.

The diagrams below show the order in which tables reside in open core during phase 1 and phase 2 of the compilation.

Phase 1



Phase 2



In phase 1 the final sizes of the arrays ØSCAR and LBLTBL are not known until the DMAP program has been completely scanned by XØSGEN. These two arrays request space as needed until it runs out. At this time the user is informed that the DMAP should be shortened or core storage should be increased.

4.7.6.2 Data Necessary For Operation

The Problem Tape provides Executive Tables XCSA, XALTER, PVT, and for restarts, XPTDIC (see section 2.4 for details). Data in named common blocks is initialized by the BLOCK DATA routines XMPLBD, XGPIBD and XBSBD or common block data is initialized by routine XGPIBS.

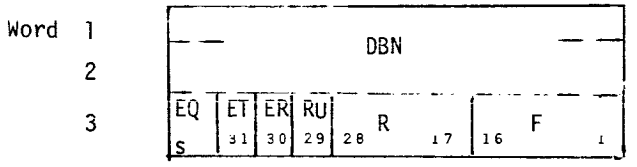
4.7.6.3 Table Formats

1. ØSCAR: Located in named common block /XGPI1/. See section 2.4.2.1 for format.

2. MED, CNM, FNM: Equivalenced to the ØSCAR table. See IS1, INM and JNM table descriptions in XCSA Module Functional Description (4.2.6.2).

3. PTDIC, ICPDPL: Equivalenced to ØSCAR array.

Sample entry:



Word	Item	Description
1,2	DBN	Data block name (BCD) of the data block from the restart dictionary. Note, a data block name appears only once in the table except for table VPS where it appears twice.
3	R,F	Reel number and file number where the data block is last located on Old Problem Tape. For XVPS there is an entry (the first in PTDIC) which indicates where the first XVPS data block is located on the Old Problem Tape. For purged or not-generated data blocks, R = 0 and F = 0.
	EQ	Equivalence flag. EQ = 0 indicates the data block is equivalenced to another data block.
	ET	End of tape flag. ET = 1 indicates that the data block is split across two reels of the Old Problem Tape.

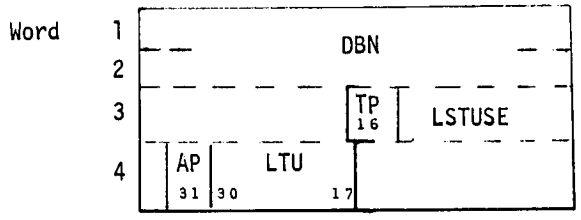
Word	Item	Description
	ER	End of logical record flag. ER = 1 indicates that the complete logical record was written out prior to changing reels when ET = 1.
	RU	Reuse flag. RU = 1 indicates that this data block is to be used to restart the problem.

Table ICPDPL contains all entries from PTDIC which had the RU flag set.

4. MPL: The MPL is located in named common block /XGPI2/. See section 2.4.2.2 for details

5. IØRDNL: Equivalenced to MPL, the IØRDNL table is used in phase 2 when the MPL is no longer needed. Data block names are entered into IØRDNL in the order that they are output from functional modules and IFP.

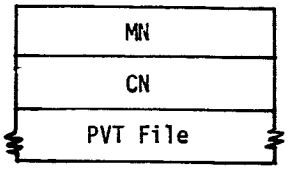
Sample entry:



Word	Item	Description
1,2	DBN	Data block name (BCD)
3	LSTUSE	Pointer to input or output section entry of a functional module ØSCAR entry where the data block was last referenced. LSTUSE is used to fill in NTU's (Next Time Used) in ØSCAR entries.
	TP	Tape flag. TP = 1 if the data block was declared TAPE in a FILE DMAP instruction.
	LTU	Last time used. Record number of ØSCAR entry beyond which the data block need not be saved for input.
	AP	Append flag. AP = 1 if the data block was declared APPEND in a FILE DMAP instruction.

6. PVT: Located in named common block /XGPI3/.

Sample entry:

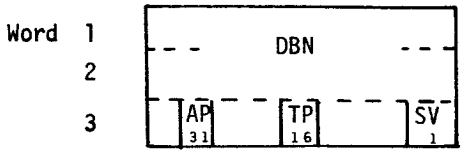


see section 2.4.2.4 for details.

MN - Maximum number of words in PVT (integer).

CN - Current number of words being used (integer).

7. IFILE: Located in named common block /XGPI7/. The purpose of IFILE is to save information from FILE DMAP instructions.



Word	Item	Description
1,2	DBN	Data block name (BCD)
3	SV	SAVE flag
	TP	TAPE flag
	AP	APPEND flag

4.7.6.4 Restrictions on Data

There are only three fixed length tables which might be overflowed by excess user data. These tables are PVT, IFILE and IØRDNL.

4.7.7 Diagnostic Messages

Every effort is made to detect syntactical and logical errors in the DMAP program, and, for restarts, to make sure that the problem is being restarted correctly. All tables are checked for overflow.

The NØGØ flag in named common block /SYSTEM/ is set according to the severity of the errors found. NØGØ = 1 indicates compilation is to be discontinued after phase 2. NØGØ = 2

indicates a serious error and causes XGPI to terminate the program immediately.

See the Diagnostic Message section of the User's Manual (section 6.2) for a detailed discussion of XGPI diagnostic messages. XGPI messages include numbers 1 thru 53.

4.8 EXECUTIVE PREFACE MODULE UMFEDIT (USER MASTER FILE EDITOR)

4.8.1 Entry Point: UMFEDT

4.8.2 Purpose

To create and manipulate User Master Files.

4.8.3 Calling Sequence

CALL UMFEDT. UMFEDT is called only by SEMINT, the Preface Driver.

4.8.4 Method

UMFEDIT functions as a post-processor to Executive Module XSØRT. Its primary task is to generate a User Master File by repeatedly transferring sorted bulk data decks generated by XSØRT from the New Problem Tape (NPTP) to the New User Master File (NUMF) based on control cards read from the System Input File. See section 2 of the User's Manual for a description of these control cards and how they control the contents of the NUMF.

In addition to creating a User Master File, UMFEDIT is used to list and/or punch Bulk Data Decks from an existing User Master File (UMF). Control cards read from the System Input File also control this process.

4.8.5 Subroutines

The UMFEDIT module has no auxiliary subroutines but uses XRCARD (see section 3.4 for a description).

4.8.6 Design Requirements

1. Open core is defined at /UMFXXX/ and is utilized as follows:

CØMMØN/UMFXXX/

GINØ Buffer for UMF
GINØ Buffer for UMF
GINØ Buffer for NPTP
: Unused core

2. The Block Data subprogram UMFZBD fills /UMFZZZ/.

3. UMFEDIT operates only in the Preface environment. The Bulk Data Deck must have been processed by XSØRT and accepted by the Input File Processor (IFP).

4.8.7 Diagnostic Messages

Bad Bulk Data Decks (indicated by ABØRT = .TRUE.) will not be accepted by UMFEDIT for inclusion on the NUMF. Subsequent Bulk Data Decks will be included, however, if acceptable.

Other errors detected in UMFEDIT will result in appropriate diagnostic messages being written on the System Output File and termination via PEXIT. These messages are: 1703 through 1716, 1718, 1719, 1721, 1722, 1723, and 1725 through 1737.

4.9 EXECUTIVE MODULE XSFA (EXECUTIVE SEGMENT FILE ALLOCATOR)

4.9.1 Entry Point: XSFA

4.9.2 Purpose

The Segment File Allocator (SFA) manages the data block to physical file relationships throughout a NASTRAN problem. Since, in general, the number of data blocks required for problem solution far exceeds the number of physical files available, allocation of files to data blocks is done dynamically as the module sequence proceeds. The SFA will allocate forward for as many modules as possible. A group of modules allocated by one operation of the SFA is termed a segment.

4.9.3 Calling Sequence

CALL XSFA (ØSCPØS)

ØSCPØS - When input to XSFA, this integer argument is the current position (record number) within the ØSCAR. Upon return from XSFA, (1) if allocation was successful, ØSCPØS is the ØSCAR position of the end of the segment as defined above; (2) if allocation was unsuccessful, the input argument is set negative.

4.9.4 Method

SFA is called by GNFIST (see section 3.3.9 for a description of GNFIST) when GNFIST fails to find the necessary data block names in the FIAT table to construct a complete FIST table for the next operating module (see section 2.4 for descriptions of the FIST and FIAT). The FIST table must contain an entry for each input, output, and scratch data block required by the module. SFA operates by processing the ØSCAR from its present position (next module to be operated) through all remaining modules. Only functional module and output processor ØSCAR entries flagged for execution are processed. The ØSCAR is read and processed by an internal subroutine named XSØSGN (Serial ØSCAR Sequence Generator) and the SØS table is formed. From this table all allocation is performed. Following XSØSGN, another internal subroutine named XCLEAN operates. XCLEAN acts to "clean up" the FIAT and DPL tables prior to the basic allocation procedure. This clean-up involves deleting data block names not needed for subsequent modules, removing equivalence flags if one member of an equivalent

pair is deleted, and closing up gaps in the FIAT caused by deletions. Following operation of XCLEAN, basic allocation begins. Allocation is accomplished during two passes through the SØS table.

Pass one first checks to see if each data block from the SØS is already in the FIAT. If so, it is considered allocated; otherwise the possibility of data block stacking is investigated. Stacking is defined as assigning two or more data blocks to the same physical file by considering their use span. The various use span attributes available are: First-Time-Used (FTU), Next-Time-Used (NTU), and Last-Time-Used (LTU). Data block A may use (be stacked on) the same file as data block B if the first use (FTU) of data block B is subsequent to the last use (LTU) of data block A. Thus many data blocks may be allocated to use the same physical file if their use spans do not overlap. INPUTS may not be stacked. Following pass one, if any data blocks within SØS remain un-allocated, pass two is begun.

Pass two first checks for files within the FIAT currently not assigned to any data block. These files are considered empty and are assigned to the un-allocated data blocks. Once the empty files are exhausted a check is made to determine if the next module to be operated has all its data blocks allocated to files. If the next module (at the least) is allocated, basic allocation is completed. If the next module has not been completely allocated, the second part of pass two will force pooling of sufficient data blocks to provide the necessary empty files for allocation of the remaining data blocks needed for the next module. Pooling is accomplished by flagging the data blocks for copying onto a separate file called the Data Pool File. The Data Pool File will therefore contain many different data blocks where all other files contain only one data block at a time. Data blocks are chosen for pooling by checking the next-time-used (NTU) attribute. The data block with the greatest NTU will be pooled first. Data blocks pooled are considered un-allocated; when they are subsequently re-allocated to their own file, they will be flagged for unpooling.

Following basic allocation, subroutine XPUNP (Pool-Unpool) is operated. All data blocks flagged for pooling are copied to the Pool File followed by all data blocks flagged for unpooling being copied from the Data Pool File. Lastly subroutine XDPH (Data Pool Housekeeper) operates to clean-up and if necessary re-copy the Data Pool File. SFA then returns control to GNFIST with the calling argument set negative if it was un-able to allocate the next module. Figure 1 illustrates the functional flow.

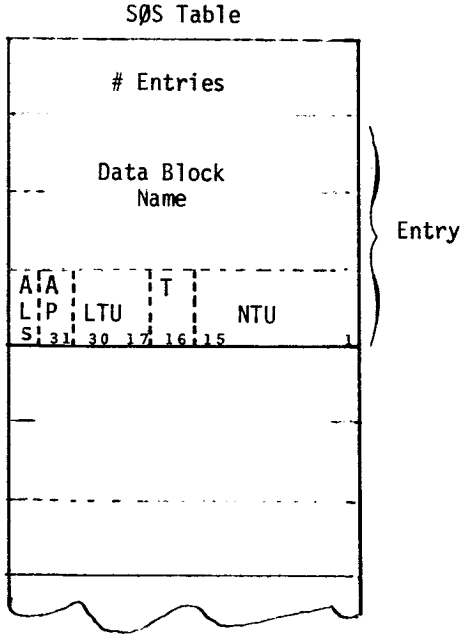
4.9.5 Subroutines

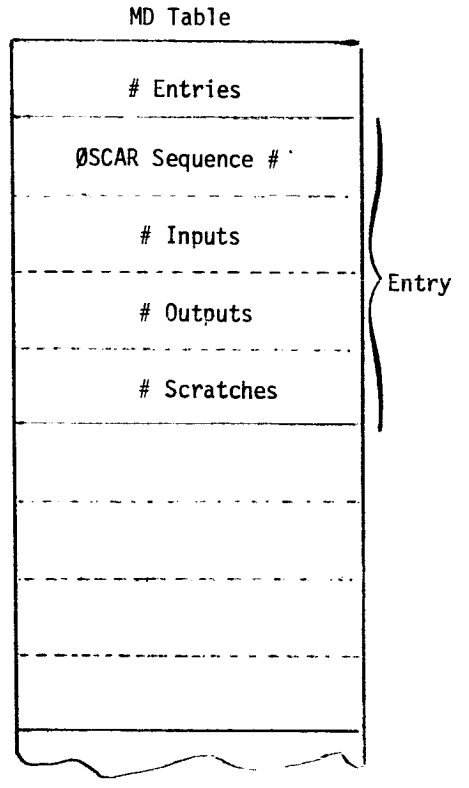
XSFA performs basic allocation and its entry point, purpose and calling sequence are given above. Below, it should be noted that XPLEQK and XFILPS are secondary entry points in XPØLCK.

4.9.5.1 Subroutine Name: XSØSGN (Serial ØSCAR Sequence Generator)

1. Entry Point: XSØSGN

2. Purpose: XSØSGN reads the ØSCAR and creates the SØS (Serial ØSCAR Sequence) and MD (Module Descriptor) tables. The SØS table contains the data block names and various attributes, while the MD table contains the ØSCAR sequence numbers and the number of input, output, and scratch data blocks required by each module.





AL = Allocation Flag, set on by SFA when data block is allocated.

AP = Append Flag, set on by module XGPI if data block is to be added to.

LTU = Last-Time-Used, created by XGPI as a data block attribute.

T = Tape Request Flag, set by XGPI to indicate a physical tape file is requested for data block.

NTU = Next-Time-Used, created by XSØSGN as a data block attribute.

= Full word integer values for items

Note: Items created or set by XGPI are passed via ØSCAR.

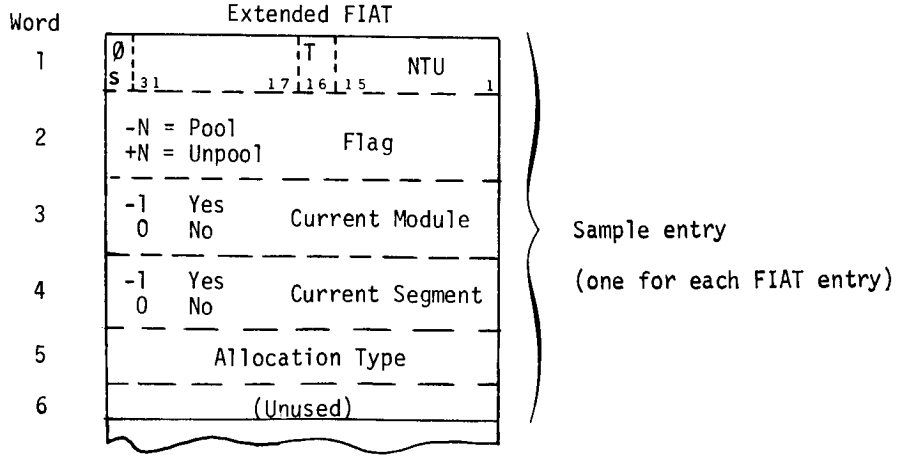
These tables are contained within the /XSFA1/ common block.

3. Calling Sequence: CALL XSØSGN

4.9.5.2 Subroutine Name: XCLEAN (FIAT and DPL Clean-up)

1. Entry Point: XCLEAN

2. Purpose: XCLEAN deletes data block names from the FIAT and DPL when they are no longer needed (their LTU has been reached). Following these deletions, equivalenced data blocks flags within FIAT are checked for continuing validity. If, for example, one member of an equivalenced pair has been deleted, the equivalence flag on the remaining member is removed. Finally, empty spaces within FIAT are removed by closing up the table. XCLEAN also regenerates and stores various parameters into the extended FIAT table. Since this table is non-resident and exists only during SFA operation, values such as NTU and the on/off switches must be restored.



Word	Item	Description
1	Ø	On/off switch, data block is turned off following stacking to prevent double stacking.
	T	Tape request flag, copied from SØS when allocated.
	NTU	Next-Time-Used; copied from SØS when allocated, regenerated by XCLEAN for data blocks remaining from previous allocation.

Word	Item	Description
2	-N	Flags XPUNP to pool data block, N = number of equivalent names for data block (Equals 1 if data block not equivalenced).
	+N	Flags XPUNP to unpool data block, N = Data Pool File number of data block.
3		Flag set yes if data block allocated for module currently being allocated - cleared between module allocations.
4		Flag set yes if data block allocated for module within current segment - i.e., all data blocks allocated during one SFA operation.
5		Allocation type - 1 = data block match, name already in FIAT 2 = data block stacking, name on file with another 3 = empty file used for data block 5 = data block using file freed by pooling another data block 7 = same as 5 except pooled data block is equivalenced
6		Unused

This table is contained within the /XSFA1/ common block.

4.9.5.3 Subroutine Name: XPUNP (Pool-Unpool)

1. Entry Point: XPUNP

2. Purpose: XPUNP checks the Pool and Unpool flags within the extended FIAT and performs the I/Ø operations necessary to copy data blocks from their separate files to the Data Pool File and vice-versa. Data block trailers are copied from the FIAT onto the Data Pool File as an additional record during pooling and are replaced from this record during unpooling. All requested pooling operations are performed prior to any unpooling operations. As data blocks are added to the Data Pool File, appropriate entries are added to the Data Pool Dictionary (DPL). The extended FIAT (4.9.5.2) is contained within the /XSFA1/ common block.

3. Calling Sequence: CALL XPUNP

4.9.5.4 Subroutine Name: XDPH (Data Pool Housekeeper)

1. Entry Point: XDPH

2. Purpose: XDPH scans the Data Pool Dictionary (DPL) to determine the number and size of the data blocks on the Data Pool File which have been flagged as no longer needed. If a sufficient quantity of data is flagged, a complete housekeeping operation is performed. This complete process involves re-copying the Data Pool File onto a scratch file while skipping those data blocks flagged for removal. Following the re-copy, the scratch file becomes the new Data Pool File and the old Data Pool File is released as a scratch file. XDPH will also perform a partial housekeeping if a (several) flagged data block(s) appears as the last data block on the Data Pool File. For this partial operation only the DPL entries are modified to release the pool space, no re-copy is necessary.

3. Calling Sequence: CALL XDPH

4.9.5.5 Subroutine Name: XPØLCK (Data Pool Dictionary Check)

1. Entry Point: XPØLCK

2. Purpose: XPØLCK scans the Data Pool Dictionary for a particular data block name. If found, the position within the dictionary and the Data Pool file number are returned to the calling program.

3. Calling Sequence: CALL XPØLCK (DBN1,DBN2,FN,L)

where:

DBN1, DBN2 - Request data block name (8 characters), 4 characters in each word, left justified and filled with blanks (if necessary).

FN - { 0, if data block not on the Data Pool File.
N, if data block on the Data Pool File; N = Data Pool File number.

L - Position of data block entry within the dictionary if data block found.

4.9.5.6 Subroutine Name: XPLEQK (Data Pool Equivalence Check)

1. Entry Point: XPLEQK

2. Purpose: XPLEQK scans the Data Pool Dictionary for any equivalence to the called data block name. If found, a copy of the equivalent names is moved from the Data Pool Dictionary to the FIAT.

3. Calling Sequence: CALL XPLEQK (PØØLX,FIATX)

where:

PØØLX - Position of data block entry within the dictionary (see argument L within XPØLCK).

FIATX - Position of same data block entry within the FIAT.

4.9.5.7 Subroutine Name: XFILPS (Data Pool File Positioner)

1. Entry Point: XFILPS

2. Purpose: XFILPS positions the Data Pool File to the beginning of a requested data block. (The Data Pool File is a multi-file file).

3. Calling Sequence: CALL XFILPS (FNEW)

where:

FNEW - The file count of the requested position. The current or old file position is stored in the /XSFA1/ common block.

4.9.6 Design Requirements

1. Open core is used only for GINØ buffers (2 maximum). The open core origin is comm*n block /ESFA/ located following all SFA subroutines.

2. SFA communicates data internal to the module subroutines via common block /XSFA1/. The SØS, MD and extended FIAT tables reside in /XSFA1/.

3. The ØSCAR must be at the entry where allocation is to begin. Following allocation, that initial ØSCAR position is restored.

4. BLOCK DATA subprogram defines the lengths of tables in /XSFA1/.

4.9.7 Diagnostic Messages

Special DMAP routing may cause the warning 3022 message to be printed by SFA.

Following output of this message, SFA flags the data block as allocated (although it will not appear in the FIAT) and continues. Since SFA cannot predict conditional DMAP routing, the data block in question may not be required and the problem will proceed satisfactorily. If the data block is required, the problem will terminate in the requesting module. Under these circumstances the DMAP routing should be studied.

All other error messages generated by SFA are fatal in nature and indicate serious I/Ø malfunctions or executive table overflow. See section 6 of User's Manual for listing and explanation of these messages. XSFA messages include numbers 1001 through 1004, 1011 through 1014, 1021, 1031 through 1035, 1041, and 1051.

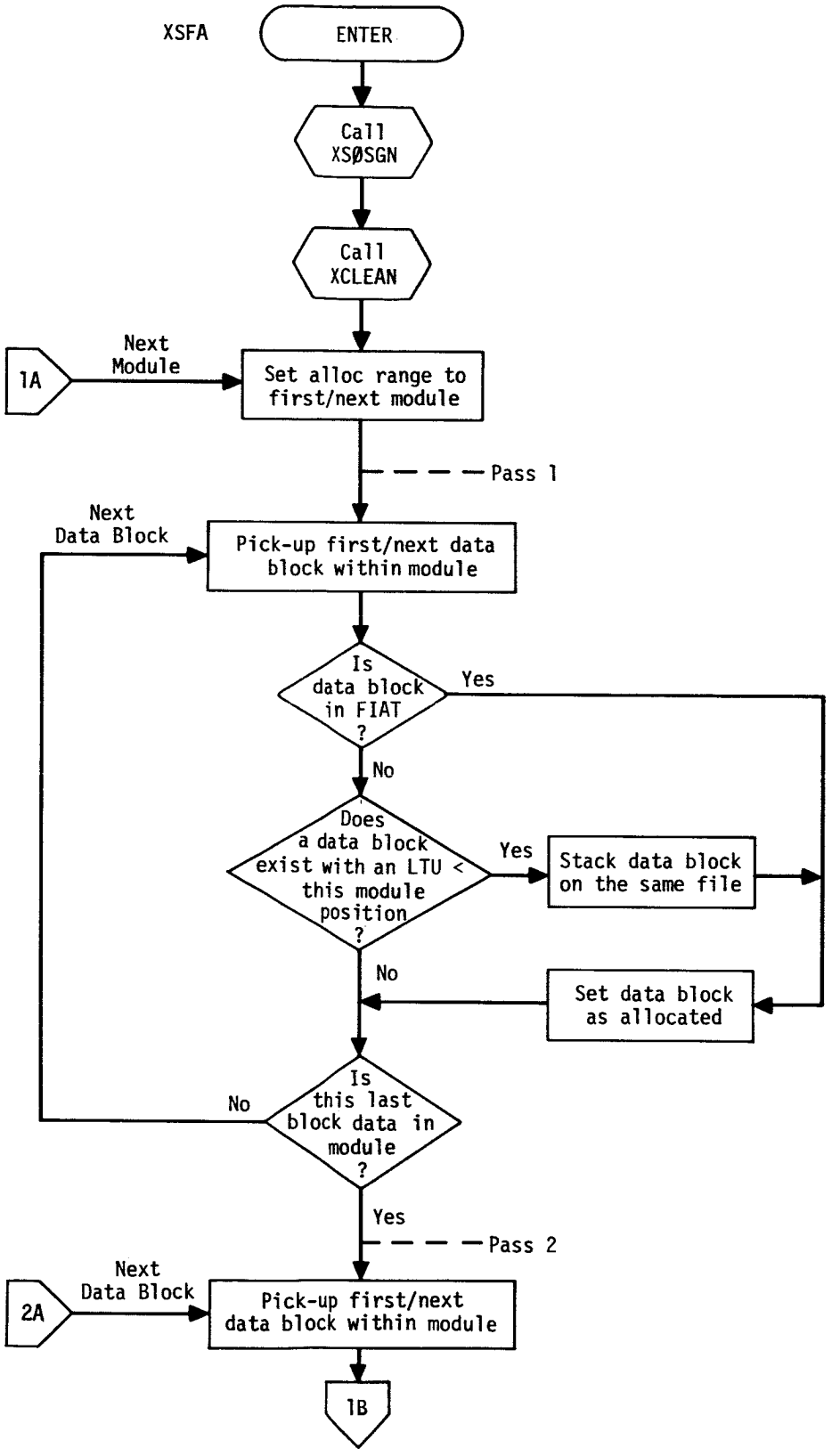


Figure 1.(a) Flowchart for module XSFA.

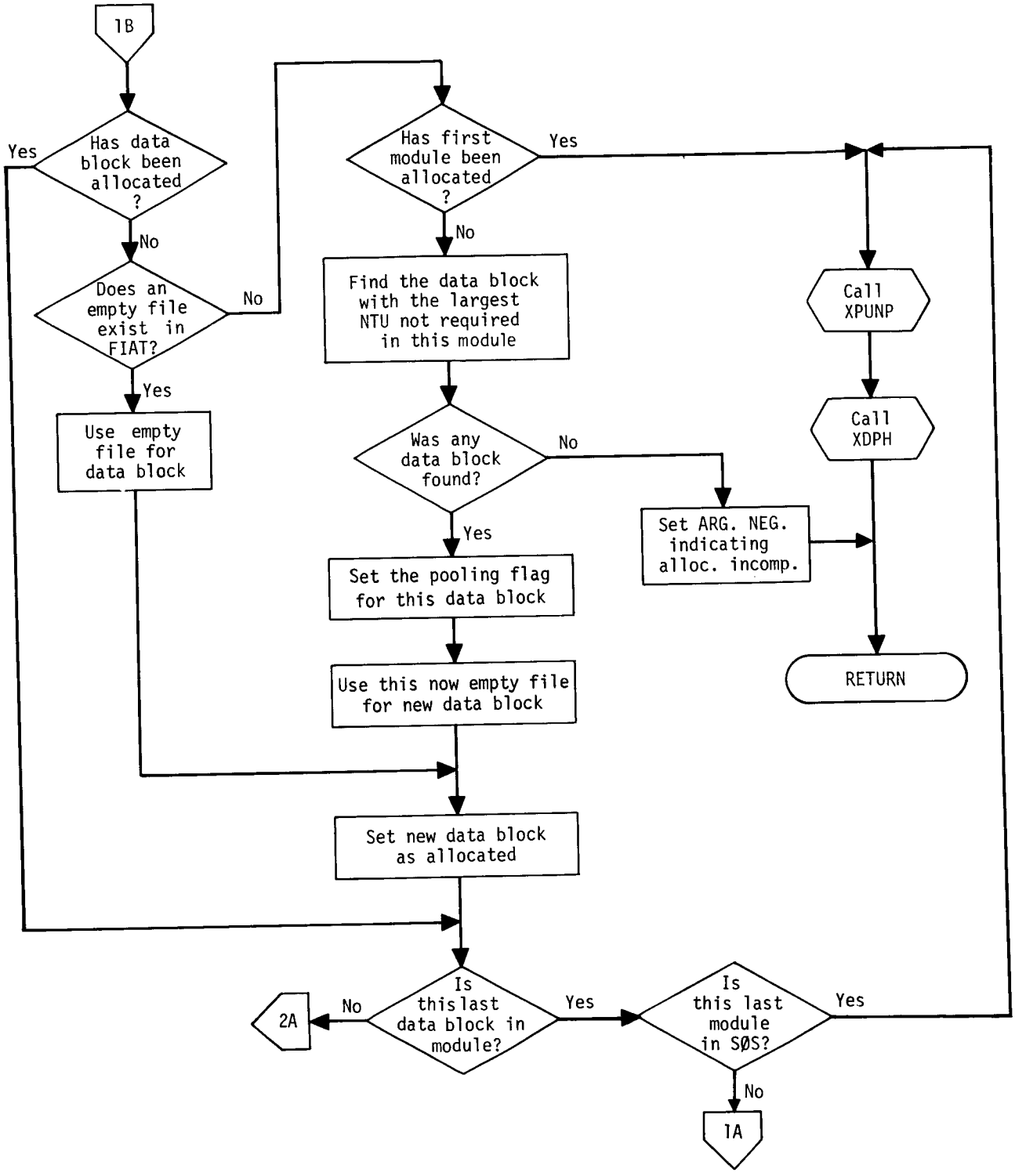


Figure 1.(b) Flowchart for module XSFA.

4.10 EXECUTIVE DMAP MODULE CHKPNT (CHECKPOINT)

4.10.1 Entry Point: XCHK

4.10.2 Purpose

To save, on the Problem Tape, specified data blocks along with other data necessary for restarting a problem.

4.10.3 DMAP Calling Sequence

CHKPNT DB1,DB2,...,DBN $

where DB1, DB2,...,DBN (N ≥ 1) are data blocks to be copied onto the Problem Tape for use in restarting a problem.

4.10.4 Method

The Problem Tape Dictionary (XPTDIC), see section 2.4.2.3, is brought into core from the Problem Tape, and the data block list in the CHKPNT ØSCAR entry is scanned. Data blocks that have been generated are entered into the local DICT table (see discussion below) along with all data blocks equivalenced to them. Data blocks that are purged, or have not yet been generated, are entered in the local PURGE table. The data blocks are assigned file numbers and are placed in the FDICT table. Data blocks are then copied onto the Problem Tape according to their file number unless the data block is equivalenced and is already in the Problem Tape Dictionary. Core resident data necessary for restart is also written on the Problem Tape as the VPS Executive Table. Entries from FDICT and PURGE are entered into the Problem Tape Dictionary, and the new checkpoint entries are punched for user submittal in the Executive Control Deck upon problem restart. The updated Problem Tape Dictionary is written back on the Problem Tape, and the Problem Tape is positioned to the beginning of the last file (i.e., XPTDIC) in preparation for the next execution of the CHKPNT module.

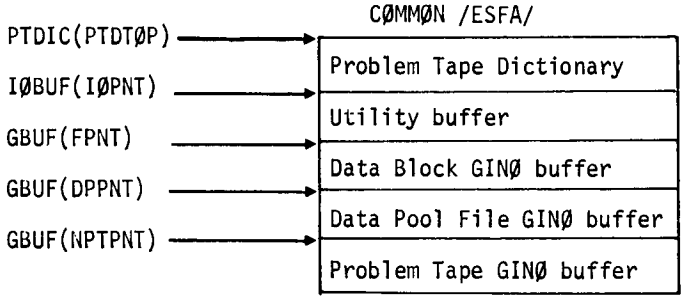
4.10.5 Subroutine

Module XCHK has no auxiliary subroutines.

4.10.6 Design Requirements

4.10.6.1 Open Core Layout

Named common block /ESFA/ defines the start of the open core area. The use of open core is optimized by origining arrays GBUF, PTDIC and IØBUF at /ESFA/ and computing their offset from the origin at execution time. The diagram below shows how the arrays are placed in open core.



4.10.6.2 Data Necessary for Operation

The data blocks, named common blocks and files needed by the CHKPNT module are listed below, along with type of access required (i.e. fetch and/or store data) and reasons for use.

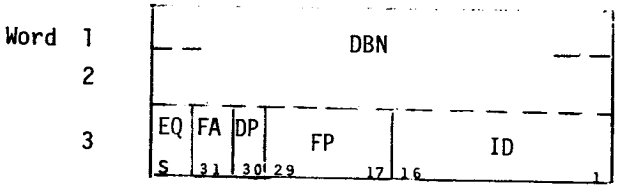
1. Data Pool File - fetch data blocks to be copied onto the Problem Tape.
2. Problem Tape - fetch and store data blocks.
3. Executive Table XPTDIC - fetch and store. Used to generate new checkpoint entries which are then added to XPTDIC.
4. Common /XFIST/ - store temporary entry in FIST for copying data blocks.
5. Common /ØSCENT/ - fetch. CHKPNT ØSCAR entry resides here.
6. Common /XCEITB/,/XVPS/ and /SYSTEM/ - fetch. Contains data to be written in VPS Executive Table.
7. Common /XFIAT/ and Common /XDPL/ - fetch. Contains data block names of data blocks to be copied.
8. Common /ØUTPUT/ - store. Prints out page heading for Checkpoint Dictionary printout.
9. Common /STAPID/ - fetch and store. Used to write Problem Tape ID file on new reel of of the Problem Tape when an end of reel is encountered.

4.10.6.3 Formats of Local Arrays

1. DICT table

The purpose of the DICT table is to hold preliminary data to be used in generating the FDICT table.

Sample DICT entry:

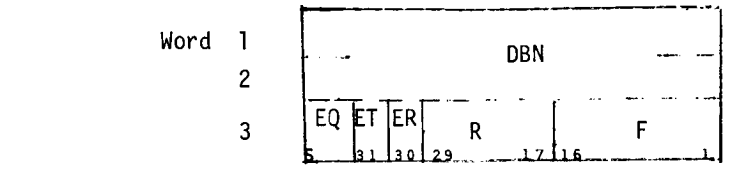


Word	Item	Description
1,2	DBN	BCD name (8 characters, 2 words) of the data block whose status is generated and is to be checkpointed.
3	EQ	Equivalence flag. EQ = 1 indicates all data blocks equivalenced to this data block also reside in DICT table.
	FA	File number assigned flag. FA = 1 indicates that an FDICT entry has been generated for this DBN and that a file number of where the data block will reside on the Problem Tape has been assigned.
	DP	Data pool flag. DP = 1 indicates that the data block is on the Data Pool File.
	FP	Varies according to DP flag. For DP = 1, FP is not used. For DP = 0, FP is a pointer to the FIAT entry containing DBN or equivalenced DBN.
	ID	Varies according to DP flag. For DP = 1, ID is the file number where the data block resides on the Data Pool File. For DP = 0, ID is the file (unit) identifier. For the IBM 7094, ID is the unit control block pointer for the file. For machines using the FØRTRAN GINØ, ID is the FØRTRAN logical unit number assigned to the file.

2. FDICT table

The purpose of the FDICT table is to hold final data to be used in generating XPTDIC entries for data blocks whose status is generated.

Sample FDICT entry:



Word	Item	Description
1,2	DBN	BCD name of data block.
	EQ	Equivalence flag. EQ = 1 indicates all data blocks equivalenced to this data block also reside in the FDICT table.
	ET	End-of-tape flag. ET = 1 indicates that the data block is split across two reels of Problem Tape.
	ER	End-of-logical-record flag. ER = 1 indicates that the complete logical record was written out prior to changing reels when ET = 1.
3	R,F	Reel number and file number where the data block will be written on the Problem Tape.

4.10.6.4 Restrictions

XPTDIC cannot be written across two reels of Problem Tape (i.e. a fatal error occurs if an end-of-tape is encountered while writing XPTDIC).

4.10.7 Diagnostic Messages

See Diagnostic Message section of User's Manual (section 6.2) for a detailed discussion of CHKPNT module diagnostic messages. XCHK messages include numbers 1101 through 1109.

4.11 EXECUTIVE DMAP INSTRUCTION REPT (REPEAT A GROUP OF DMAP INSTRUCTIONS)

4.11.1 Entry Point: XCEI

The XCEI module executes the DMAP control instructions: REPT, EXIT, CØND and JUMP.

4.11.2 Purpose

To repeat a group of DMAP instructions a specified number of times.

4.11.3 DMAP Calling Sequence

```
REPT  n,c $
```

where:

1. n is a BCD name appearing in a LABEL instruction which specifies the location of the beginning of the group of DMAP instructions to be repeated.

2. c is an integer constant which specifies the number of times to repeat the instructions.

4.11.4 Example

```
BEGIN  $
 .
 .
 .
LABEL  L1 $
MØDULE1  A/B/V,Y,P1 $
 .
 .
 .
MØDULEN B/C/V,Y,PN $
REPT  L1,3 $
 .
 .
 .
END $
```

The DMAP instructions from MØDULE1 to MØDULEN will be repeated 3 times. Note that REPT is placed at the end of the group of instructions to be repeated.

4.11.5 Method

Executive Table CEITBL in named common block /XCEITB/ (see section 2.4 for format) is searched for the REPT entry and the entry is updated after determining whether or not to repeat the loop again. If the loop is not to be repeated, a return is made to the calling routine. If a repeat of the loop is to be executed, the Problem Tape Dictionary (XPTDIC) is read into core from the Problem Tape, and dictionary entries created inside the loop are deleted. The updated XPTDIC is written back on the Problem Tape. Data blocks that are referenced only inside the loop and which have not been declared saved in a FILE DMAP instruction have their status changed to not-generated (i.e. data block trailers within FIAT are cleared and if the data block name appears in the DPL it is removed). The ØSCAR on the Data Pool Tape is positioned to the top of loop and a return is made to the calling routine.

4.11.6 Subroutine

4.11.6.1 Subroutine Name: XCEI.

1. Entry Point: XCEI

2. Purpose: To execute DMAP Control modules REPT, JUMP, CØND, and EXIT as described in the respective Executive DMAP Module Descriptions in this section and in sections 4.12, 4.13 and 4.14.

3. Calling Sequence:

```
CALL XCEI
```

4.11.7 Design Requrements

4.11.7.1 Open Core Layout

Named common block /ESFA/ defines the start of the open core area. The following diagram shows the layout.

CØMMØN/ESFA/

Data Pool File GINØ buffer area.
Problem Tape GINØ buffer area.
Problem Tape Dictionary (XPTDIC).

4.11.7.2 Data Necessary For Operation

The tables, named common blocks and files needed by the control modules are listed below, along with type of access required (i.e. fetch and/or store data) and reasons for use.

1. Data Pool File - XCEI must re-position the ØSCAR to the correct entry when a transfer is to be executed.

2. Problem Tape - fetch and store the Problem Tape Dictionary when looping.

3. Data Block XPTDIC - fetch and store. The Problem Tape Dictionary must be updated when looping.

4. CØMMØN /XVPS/ - fetch.

   /XVPS/ contains the CØND instruction parameter value.

5. CØMMØN /XCEITB/ - fetch and store.

   /XCEITB/ contains control parameters for REPT and EXIT instructions.

6. CØMMØN /ØSCENT/ - fetch.

   /ØSCENT/ contains the Control Module ØSCAR entry.

7. CØMMØN /XFIAT/ - fetch and store.

   Must be updated when looping.

8. CØMMØN /XDPL/ - fetch and store.

   Must be updated when looping.

4.12 EXECUTIVE DMAP INSTRUCTION JUMP (UNCONDITIONAL DMAP TRANSFER)

4.12.1 Entry Point: XCEI

4.12.2 Purpose

To alter the normal order of execution of DMAP modules by unconditionally transferring program control to a specified location in the DMAP program.

The normal order of execution of DMAP modules is the sequential order of occurrence of the modules as DMAP instructions in the DMAP program.

4.12.3 DMAP Calling Sequence

```
JUMP    n $
```

where n is a BCD name appearing on a LABEL instruction which specifies where control is to be transferred.

4.12.4 Method

If control is being transferred to a previous DMAP module in the ØSCAR (i.e., looping), the Problem Tape Dictionary is read into core from the Problem Tape and dictionary entries created inside the loop are deleted. The updated Problem Tape Dictionary is written back out on the Problem Tape. Data blocks that are referenced only inside the loop and which have not been declared saved in a FILE DMAP instruction have their status changed to not-generated. The ØSCAR is positioned to the specified location. Table CEITBL in named common block /XCEITB/ is searched for REPT entries and the loop count is zeroed if the jump is transferring control from inside the loop to outside the loop. A return is then made to the calling program.

If control is being transferred to a subsequent DMAP module in the ØSCAR, the ØSCAR is positioned to the specified location and a return is made to the calling program.

See description of the Executive DMAP instruction REPT (see section 4.11) for further details.

4.13 EXECUTIVE DMAP INSTRUCTION CØND (CONDITIONAL TRANSFER)

4.13.1 Entry Point: XCEI

4.13.2 Purpose

To alter the normal order of execution of DMAP modules by conditionally transferring program control to a specified location in the DMAP program.

4.13.3 DMAP Calling Sequence

CØND n,V $

where:

1. n is a BCD name appearing on a LABEL instruction which specifies where control is to be transferred.

2. V is a BCD name of a variable parameter whose value indicates whether or not to execute the transfer. If V < 0, the transfer is executed.

4.13.4 Example

```
BEGIN  $
  .
  .
  .
CØND  L1,K $
MØDULE1  A/B/V,Y,P1 $
  .
  .
  .
LABEL  L1 $
MØDULEN  X/Y/ $
  .
  .
  .
END  $
```

If K ≥ 0, MØDULE1 is executed. If K< 0 control is transferred to L1 and MØDULEN is executed.

4.13.5 Method

The parameter value for the CØND instruction is examined. If the value is greater than or equal to zero, a return is made to the calling routine. If the value is less than zero, the CØND instruction is executed exactly like the JUMP instruction. See description of the Executive DMAP instruction JUMP (section 4.12) for further details.

4.14 EXECUTIVE DMAP INSTRUCTION EXIT (TERMINATE DMAP PROGRAM)

4.14.1 Entry Point: XCEI

4.14.2 Purpose

To terminate a NASTRAN job.

4.14.3 DMAP Calling Sequence

```
EXIT  c $
```

where c is an integer constant which specifies the number of times the instruction is to be ignored before terminating the program. If c = 0 the calling sequence may be shortened to EXIT $.

4.14.4 Example

```
BEGIN $
 .
 .
 .
LABEL L1 $
MØDULE1 A/B/V,Y,P1 $
 .
 .
 .
EXIT 3 $
REPT L1,3 $
 .
 .
 .
END $
```

The EXIT instruction will be executed the third time the loop is repeated (i.e., the instructions within the loop will be executed four times).

4.14.5 Method

A determination is made whether or not to terminate the job by examining the loop count of the EXIT entry in named common block /XCEITB/. If the job is to be terminated, routine PEXIT is called; if not, the loop count in the EXIT entry is incremented, and a return is made to the calling program.

See description of the Executive DMAP instruction REPT (section 4.11) for further details.

4.15 EXECUTIVE DMAP MODULE SAVE (SAVE VARIABLE PARAMETER VALUES)

4.15.1 Entry Point: XSAVE

4.15.2 Purpose

To specify which variable parameter values are to be saved from the preceding functional module for use by subsequent modules.

4.15.3 DMAP Calling Sequence

```
SAVE    V1,V2,...,VN $
```

where V1,V2,...,VN (N ≥ 1) are the BCD names of some or all of the variable parameters which appear in the immediately preceding functional module DMAP instruction. A SAVE DMAP instruction must immediately follow the functional module instruction wherein the parameters being saved are generated.

4.15.4 Method

The specified parameter values are transferred from blank common to the VPS Executive Table located in named common block /XVPS/. See description of the ØSCAR in section 2.4.2.1 for the format of a SAVE ØSCAR entry.

4.15.5 Subroutine

The XSAVE module has no auxiliary subroutines

4.15.6 Design Requirements

SAVE must access blank common and named common blocks /XVPS/ and /ØSCENT/.

4.16 EXECUTIVE DMAP MODULE PURGE (EXPLICIT DATA BLOCK PURGE)

4.16.1 Entry Point: XPURGE

4.16.2 Purpose

To flag a data block so that it will not be allocated to a physical file and so that modules attempting to access it will be signaled.

4.16.3 DMAP Calling Sequence

PURGE DBN1A,DBN2A,D3N3A/PARMA/DBN1B,DBN2B/PARMB $

Note: The number of data block names (DBNiα) prior to each parameter (PARMα) and the number of sets of data block names and parameters in a particular calling sequence is variable.

4.16.4 Input Data Blocks

DBN1A,DBN2A, etc. - Any data block names appearing within the DMAP sequence.

4.16.5 Output Data Blocks

(None specified or permitted)

4.16.6 Parameters

PARMA, etc. - One required for each data block name or set of names.

4.16.7 Method

4.16.7.1 Summary

The data blocks (within the DMAP calling sequence) are purged if the value of the associated parameter is < 0. If the data blocks are already purged and the parameter value is ≥ 0, the purged data blocks are unpurged so that they may be subsequently reallocated. If the data blocks are not purged and if the parameter value is ≥ 0, no action is taken.

4.16.7.2 Functional Flow

PURGE operates by modifying entries within the FIAT (File Allocation Table) and DPL (Data Pool Dictionary). The FIAT contains an upper section (unique part) and a lower section (tail part). Both parts contain entries structured as described in the Executive Table description for the FIAT, section 2.4.1.2. The length of the unique part is defined by the unique files available count in the FIAT header. The tail part is defined as the remainder of the FIAT. The unique part contains one entry for each unique (separate) file available for allocation, and the file ID's within these entries are not modified through a NASTRAN run. The tail part contains entries for stacked files (see description for Executive Module XSFA, section 4.9). purged files, and members of equivalenced sets. An entry within the FIAT is purged by flagging (setting all bits on) its file ID. Therefore, if a data block within the unique part is to be purged, its name is moved to the tail. A data block entry within DPL is purged by removing its entry from the DPL. A data block which is already purged is unpurged by removing the flagged entry from the FIAT so that it may be subsequently allocated to a physical file. Figure 1 illustrates the logic flow.

4.16.8 Design Requirements

1. No open core is required by this module.

2. The ØSCAR record containing the DMAP purge request must reside in the labeled common block /ØSCENT/.

3. The validity of all data block names and controlling parameters is checked during NASTRAN initialization by module XGPI.

4.16.9 Diagnostic Messages

PURGE may produce the following System Fatal messages:

1201, FIAT ØVERFLØW

1202, DPL ØVERFLØW

Both of these messages indicate that the assembled size of the particular table has been exceeded. Although it is unlikely that either message will occur, a study of the erroneous problem's operation along with diagnostic prints of the FIAT and DPL, obtained via the DIAG Executive Control card (see User's Manual, section 2), should indicate some

corrective action. Possible corrective actions include: increasing the basic table size through re-assembly; providing more physical files to the NASTRAN system; and altering the DMAP operations.

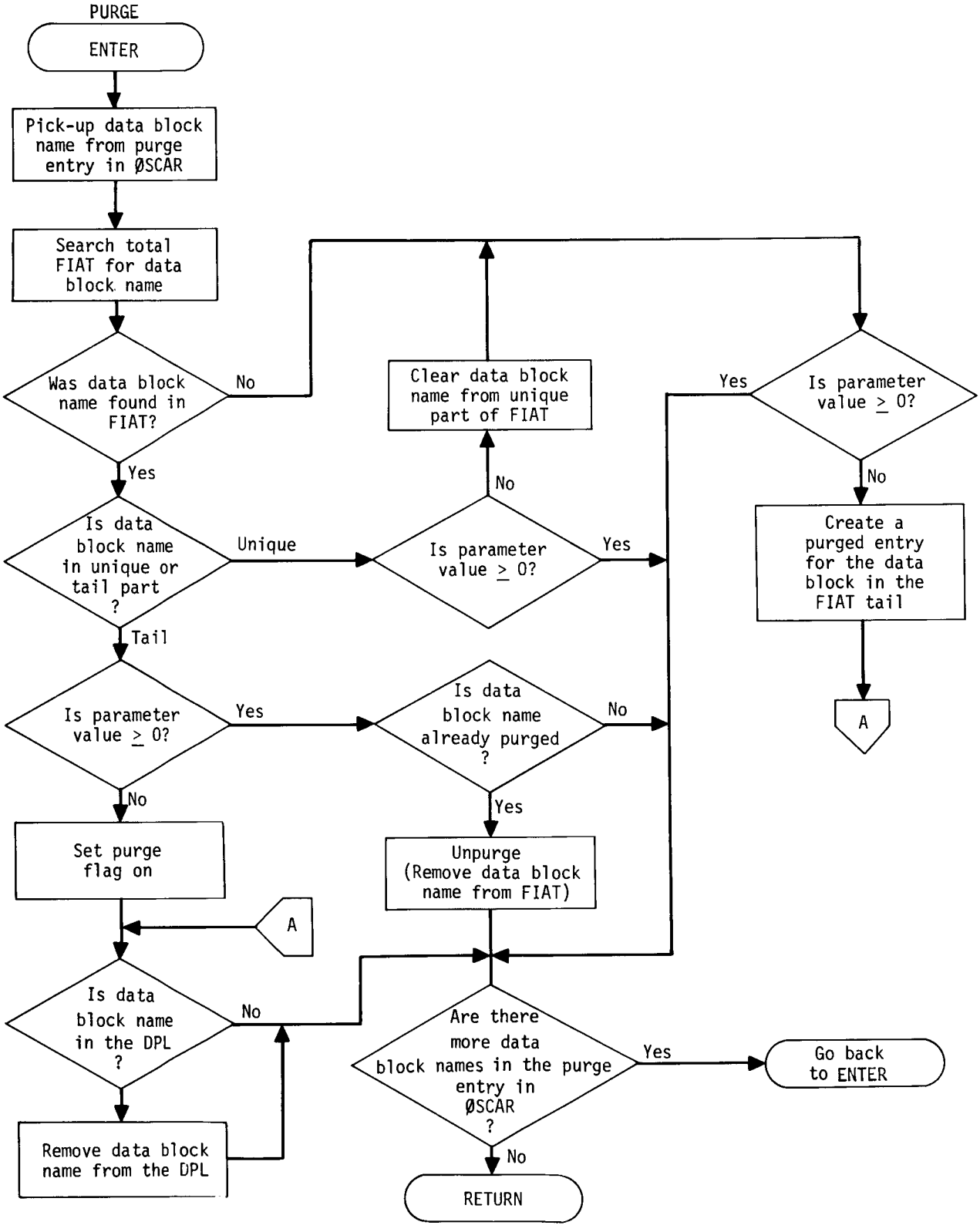


Figure 1. Flowchart for module PURGE.

4.17 EXECUTIVE DMAP MODULE EQUIV (DATA BLOCK NAME EQUIVALENCE)

4.17.1 Entry Point: XEQUIV

4.17.2 Purpose

To attach one or more equivalent (alias) data block names to an existing data block so that module accesses to data by equivalenced names will be identical.

4.17.3 DMAP Calling Sequence

```
EQUIV  DBN1A,DBN2A,DBN3A/PARMA/DBN1B,DBN2B/PARMB  $
```

Note: The number of data block names (DBNiα) prior to each parameter (PARMα) and the number of sets of data block names and parameters in a particular calling sequence are variable.

4.17.4 Input Data Blocks

DBN1A,DBN2A, etc. - Any data block names appearing within the DMAP sequence. The 1st data block name in each series (DBN1A and DBN1B) is primary and the 2nd, etc. data block names become equivalent to the primary.

4.17.5 Output Data Blocks

(None specified or permitted)

4.17.6 Parameters

PARMA, etc. - One required for each set of data block names.

4.17.7 Method

4.17.7.1 Summary

The data block names are made equivalent if the value of the associated parameter is < 0. If a set of data blocks is already equivalenced and the parameter value is ≥ 0, the equivalence is broken and the data block names again become unique. If the data blocks are not equivalenced and if the parameter value is ≥ 0, no action is taken.

4.17.7.2 Functional Flow

EQUIV operates by modifying entries within the FIAT (File Allocation Table) and DPL (Data Pool Dictionary). The FIAT contains an upper section (unique part) and a lower section (tail part). Both parts contain entries structured as described in the Executive Table description for the FIAT, section 2.4. The length of the unique part is defined by the unique files available count in the FIAT header. The tail part is defined as the remainder of the FIAT. The unique part contains one entry for each unique (separate) file available for allocation and the file ID's within these entries are not modified through a NASTRAN run. The tail part contains entries for stacked files (see description for Executive Table XSFA), purged files and members of equivalenced sets. Entries within the FIAT and DPL are made equivalent by setting their EQUIV flags (sign bit within an entry) and making their file ID's identical. Since a data block within the unique part of the FIAT must have a unique file ID, only one member of an equivalence set may reside within the unique section, all others will be placed in the FIAT tail. Thus, if two data blocks occupying unique physical files are equivalenced, one will be moved to the FIAT tail. Data blocks previously equivalenced are unequivalenced (broken) by removing the EQUIV flags and the secondary entries. When two or more data blocks are equivalenced, the first data block of the set is considered the primary data block. All others are considered secondary. The file containing the primary data block is logically attached to all data blocks in the set: primary and secondary. Data on files attached to secondary data blocks prior to equivalencing is lost upon equivalence. If the primary data block is purged, the secondary(s) will be purged. Figure 1 illustrates the logic flow.

4.17.8 Design Requirements

1. No open core is required by the module.

2. The ØSCAR record containing the DMAP EQUIV request must reside in the labeled common block /ØSCENT/.

3. The validity of all data block names and controlling parameters is checked during NASTRAN initialization by XGPI.

4. XEQUIV is an entry point in XPURGE.

4.17.9 Diagnostic Messages

EQUIV may produce the following System Fatal Messages:

1201 FIAT ØVERFLØW

1202 DPL ØVERFLØW

Both of these messages indicate that the assembled size of the particular table has been exceeded. Although it is unlikely that either message will occur, a study of the erroneous problem's operation along with diagnostic prints of the FIAT and DPL obtained, via the DIAG Executive Control card (see User's Manual, section 2), should indicate some corrective action. Possible corrective actions include: increasing the basic table size through re-assembly; providing more physical files to the NASTRAN system; and altering the DMAP operations.

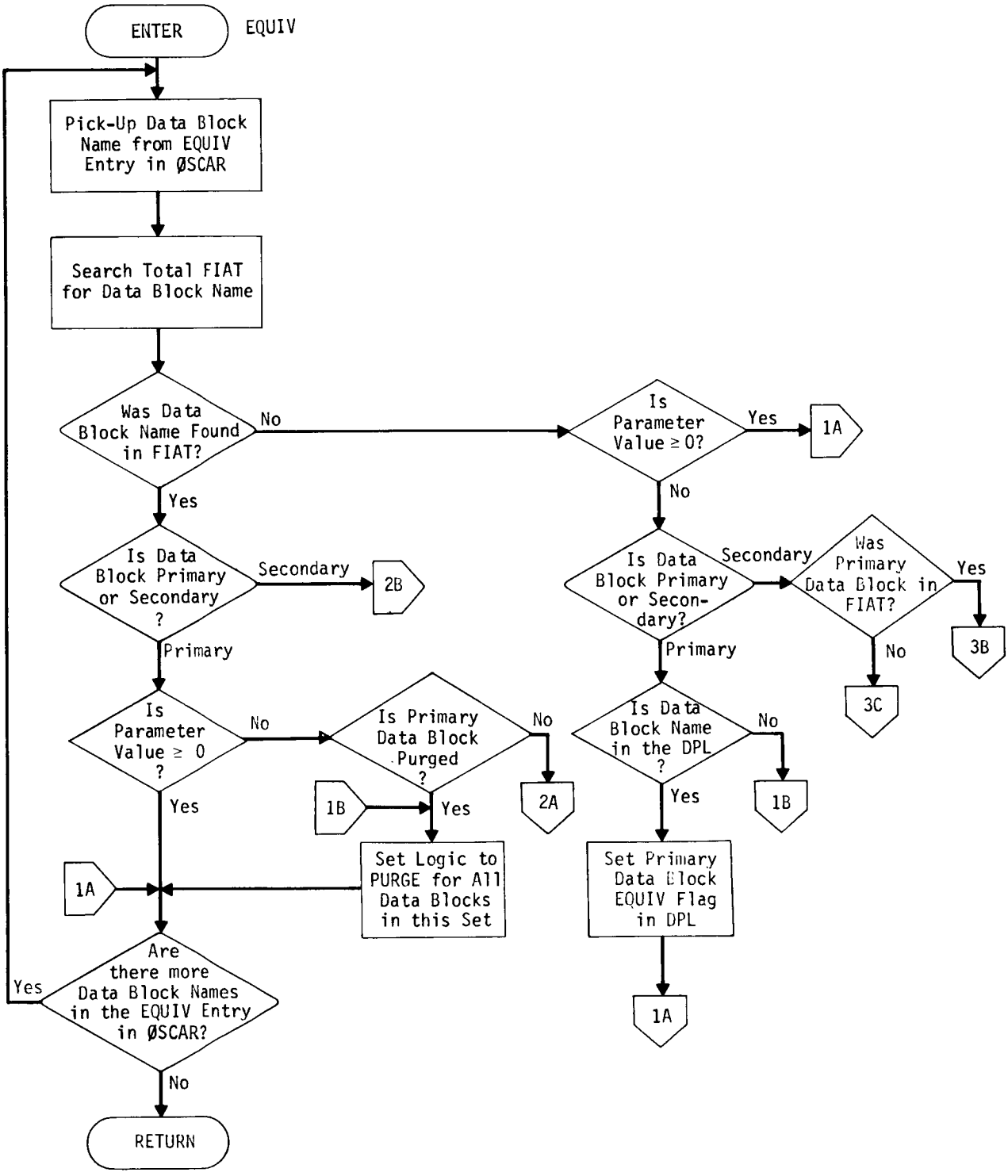


Figure 1. (a) Flowchart for EQUIV module

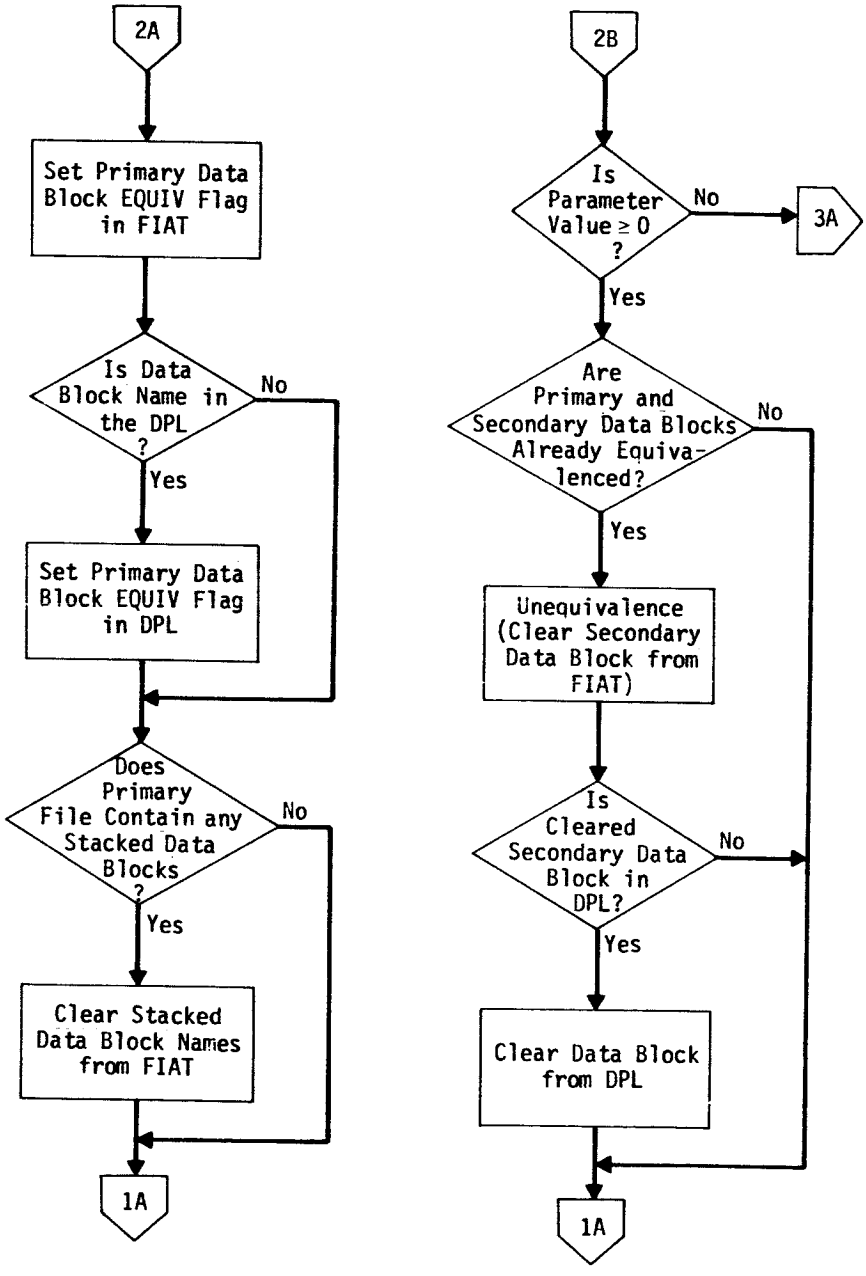


Figure 1. (b) Flowchart for EQUIV module

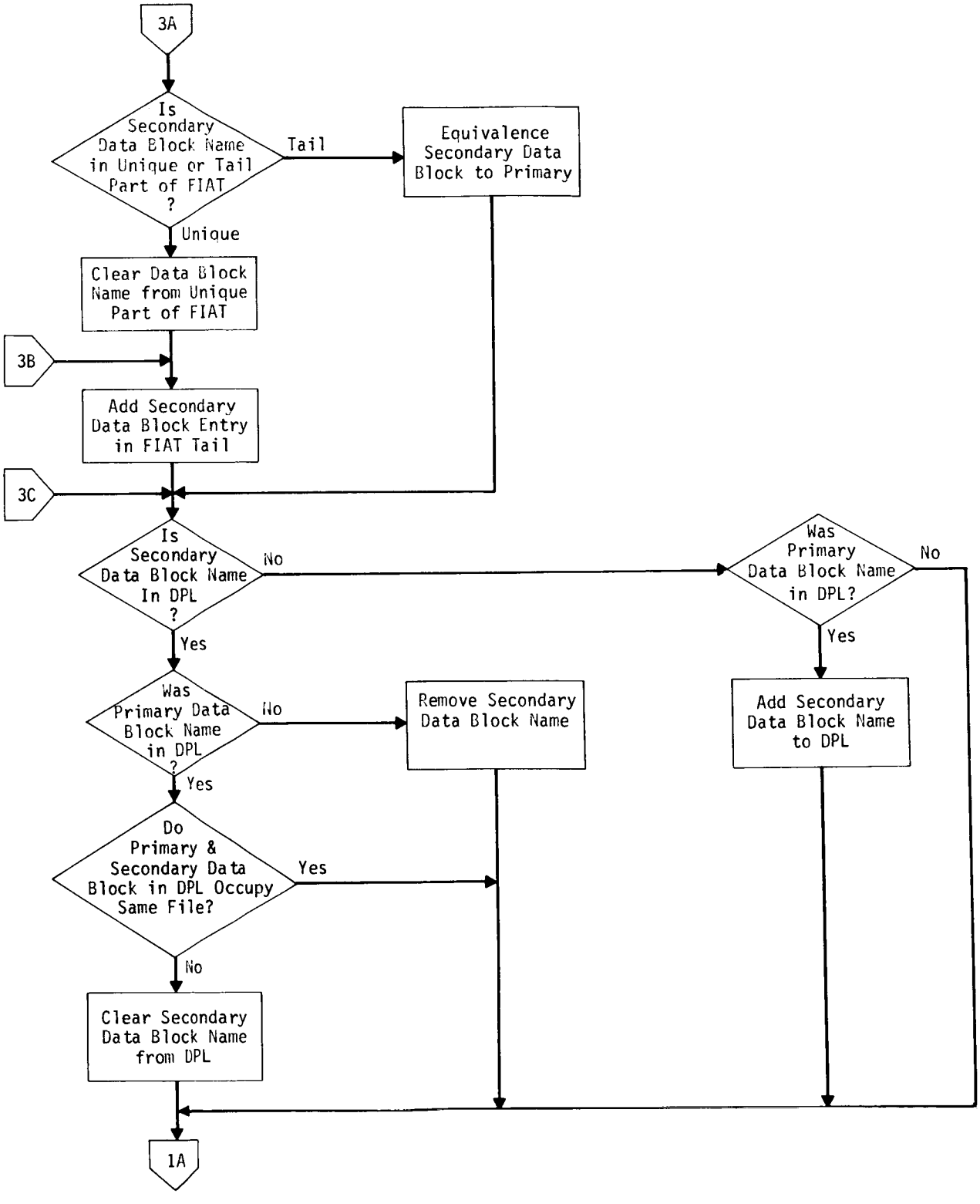


Figure 1. (c) Flowchart for EQUIV module

4.18 EXECUTIVE DMAP INSTRUCTION END (END OF DMAP PROGRAM)

4.18.1 Entry Point: XCEI

The XCEI module executes the DMAP control instructions: REPT, EXIT, CØND, and JUMP.

4.18.2 Purpose

To denote the end of a DMAP program. This DMAP instruction performs a function similar to an END statement in a FØRTRAN compilation, i.e., to signal the end of the source program.

4.18.3 DMAP Calling Sequence

```
END   $
```

Note: An END DMAP instruction is operationally equivalent to an EXIT 0 $ or EXIT $ DMAP instruction.

4.18.4 Method

The END instruction is translated during a DMAP program compilation in module XGPI into an EXIT $ instruction. (see section 4.14).

4.19 EXECUTIVE DMAP MODULE PARAM (PARAMETER PROCESSOR)

4.19.1 Entry Point: QPARAM

4.19.2 Purpose

To perform specified arithmetic and logical operations on DMAP parameters.

4.19.3 DMAP Calling Sequence

PARAM //C,N,ØP/V,N,ØUT/V,N,IN1/V,N,IN2 $

where the following operations (ØP) are available:

ØP	ØUT	IN1	IN2	
AND	-1	< 0	< 0	
	+1	< 0	≥ 0	
	+1	≥ 0	< 0	
	+1	≥ 0	≥ 0	
ØR	-1	< 0	< 0	
	-1	< 0	≥ 0	
	-1	≥ 0	< 0	
	+1	≥ 0	≥ 0	
ADD	IN1+IN2			Integer Arithmetic
SUB	IN1-IN2			
MPY	IN1*IN2			
DIV	IN1/IN2			
NØT	-IN1		*	
IMPL	-1	< 0	< 0	
	+1	< 0	≥ 0	
	-1	≥ 0	> 0	
	-1	≥ 0	≥ 0	
NØP	ØUT	*	*	

Notes:

1. *not used.

2. PARAM does its own SAVE; therefore, a DMAP SAVE instruction is not needed following the module.

3. PARAM has no input or output data blocks.

4.19.4 Examples

1. PARAM //C,N,NØP/V,N,P1=5 $ - this example sets the value of parameter P1 to 5 and saves it in the VPS.

2. PARAM //C,N,NØT/V,N,XYZ/V,N,NØXYZ $ - this example changes the sense of parameter NØXYZ which may be useful for the CØND or EQUIV instructions. Alternatively, XYZ could have been set in the following way:

```
PARAM     //C,N,MPY/V,N,XYZ/V,N,NØXYZ/C,N,-1   $
```

4.19.5 Method

QPARAM performs the indicated parameter operation and stores the result in the VPS (/XVPS/).

4.19.6 Diagnostic Messages

ØPERATIØN CØDE _____ NØT DEFINED FØR MØDULE PARAM. EXECUTIØN TERMINATED.

The listed operation code was not recognized by PARAM.

4.20 EXECUTIVE DMAP MODULE SETVAL (SET VALUES)

4.20.1 Entry Point: SETVAL

4.20.2 Purpose

To set DMAP parameters equal to other DMAP parameters or to constants.

4.20.3 DMAP Calling Sequence

```
SETVAL    //V,N,X1/V,N,Y1/V,N,X2/V,N,Y2/V,N,X3/V,N,Y3/V,N,X4/V,N,Y4/V,N,X5/V,N,Y5 $
```

4.20.4 Input Data Blocks

None.

4.20.5 Output Data Blocks

None.

4.20.6 Parameters

X1, X2, X3, X4, X5 - Output-integers-no default values.

Y1, Y2, Y3, Y4, Y5 - Input-integers-default values = -1.

4.20.7 Method

This module does nothing except set X1 = Y1, X2 = Y2, X3 = Y3, X4 = Y4, and X5 = Y5. Only two parameters need be specified in the calling sequence (X1 and Y1).

4.20.8 Subroutines

SETVAL has no auxiliary subroutines.

4.20.9 Design Requirements

SETVAL should reside in the root segment in all links.

4.20.10 Diagnostic Messages

None.

4.21 FUNCTIONAL MODULE GP1 (GEOMETRY PROCESSOR - PHASE 1)

4.21.1 Entry Point: GP1.

4.21.2 Purpose

GP1 performs basic geometry processing for the model. A list of all grid and scalar points is assembled and placed in internal order. Coordinate system transformation matrices are computed, and all grid points are transformed to the basic coordinate system.

4.21.3 DMAP Calling Sequence

```
GP1    GEØM1,GEOM2/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/V,N,NØCSTM/V,N,NØGPDT $
```

4.21.4 Input Data Blocks

GEØM1 - Grid point, coordinate system, sequence data.

GEØM2 - Element connection data.

4.21.5 Output Data Blocks

GPL - Grid Point List.

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers.

GPDT - Grid Point Definition Table.

CSTM - Coordinate System Transformation Matrices.

BGPDT - Basic Grid Point Definition Table.

SIL - Scalar Index List.

Note: No output data block may be purged.

4.21.6 Parameters

LUSET - Output, integer, no default. Total degrees of freedom in the g displacement set.

NØCSTM - Output, integer, no default. Number of coordinate systems defined in the Bulk Data Deck, -1 if no coordinate systems defined.

NØGPDT - Output, integer, no default. -1 if no grid or scalar points defined in Bulk Data Deck, +1 otherwise.

4.21.7 Method

4.21.7.1 Construction of the GPL and First Logical Record of the EQEXIN.

The SPØINT cards and the scalar element cards (CELASi, CDAMPi, CMASSi, i = 1,2,3,4) are read from GEØM2, and a list is made of all referenced scalar points. The GRID cards are read from GEØM1, and a merged list of all grid and scalar points is constructed and written on SCR1, a scratch file. The list is expanded to pairs of numbers. The first number is the identification number, ID, the second is the resequenced number which is given on the SEQGP cards or is 1000*ID if not given on SEQGP cards. The paired list is sorted by SØRT on the sequence numbers. The resulting set of first numbers is written as the first logical record in the GPL (Grid Point List). These are the point identification numbers in order of their sequence numbers. The sequenced paired list is written as the second logical record of the GPL data block. The second numbers in the sequenced paired list are replaced by the indices 1, 2, 3,..., according to position. The list is sorted again, this time using the first number of each pair (the identification number). The resulting paired list is the first logical record of the EQEXIN data block which is used to convert external numbers, given by the first number of a pair, to the internal grid point indices, given by the second number in the pair.

4.21.7.2 Formats of GPDT, BGPDT and CSTM.

The geometry data blocks are the GPDT, the BGPDT and the CSTM. Their formats, although described in section 2.3.3, are repeated here since the following terms will be referenced in the discussion below on the construction of the CSTM.

GPDT - There is one entry for each grid or scalar point. The order of the entries is by the internal (sequenced) order. Each entry contains:

1. Internal sequence number.
2. Locating coordinate system ID.
3. x,y,z for a rectangular system.
4. r,θ,z for a cylindrical system.
5. ρ,θ,ϕ for a spherical system.
6. Global coordinate local coordinate system ID.
7. Permanent single-point constraint coordinate (1 = x, 2 = y, etc.).

For scalar points, word 2 = -1 and words 3 through 7 are zero. The data is essentially a duplicate of the GRID bulk data card except that the identification number is replaced by the internal sequence number.

- BGPDT - Contains one entry for each grid or scalar point. The contents are:

  1. Local coordinate system ID for global coordinate definition.
  2. x_i } Locations of point
  3. y_i } in basic coordinate
  4. z_i } system.

CSTM - The CSTM contains one entry for each local coordinate system. The order is by coordinate system identification numbers. Each entry contains 14 words:

Word	Item
1	N - the coordinate system ID.
2	$Type_N$ - the coordinate system type (rectangular, cylindrical or spherical).
3-5	$\{R_{ON}\}$ - the location of the system origin in basic coordinates.
6-14	$[T_{ON}]$ - the three-by-three matrix defining the orientation of the coordinate system principal axes.

4.21.7.3 Construction of the GPDT.

The GPDT data block is formed in core sized groups. The grid and scalar data are read one entry at a time from SCR1. EQEXIN (in core) is searched to find the internal number, and the grid data are stored (if possible) in the internal position allocated in core. If core will not hold the GPDT, the data are written on SCR2, and SØRT is called to sort and write the data on the GPDT.

4.21.7.4 Construction of the CSTM.

Sixteen words are alloted for each local coordinate system, and five words are alloted for each referenced grid point. The CØRDij data is read from GEØM1 and stored in core. External point ID's on CØRDij cards are replaced with internal numbers. A CØRD1j card references three grid points. It may be converted to a CSTM entry if these grid points have their locations reduced to basic coordinates. A CØRD2j card references another local coordinate system. It may

be converted to a CSTM entry if that referenced system has been reduced to a CSTM entry. The basic logic is to make repeated passes over the coordinate system data, each time reducing one or more coordinate systems and, when possible, converting referenced grid points to basic system location.

A CØRD1j card image references three grid points - a, b and c. If the locations of these points in basic coordinates are the vectors $\{R_a\}$, $\{R_b\}$, $\{R_c\}$, the solution for coordinate system N is

$$\{R_{ON}\} = \{R_a\} , \tag{1}$$

$$\{V_k\} = \{R_b\} - \{R_a\}, \tag{2}$$

$$\{V_i\} = \{R_c\} - \{R_a\} , \tag{3}$$

$$\{k\} = \frac{\{V_k\}}{|\{V_i\}|} \text{ (unit "z" vector)}, \tag{4}$$

$$\{j\} = \frac{\{k\} \times \{V_i\}}{|\{k\} \times \{V_i\}|} \text{ (unit "y" vector)}, \tag{5}$$

$$\{i\} = \{j\} \times \{k\} \text{ (unit "x" vector)}. \tag{6}$$

Point a is the origin, point b lies on the z (or polar) axis, point c lies in the x-z plane ($\theta = 0$ or $\phi = 0$). The three-by-three matrix $[T_N]$ is defined as:

$$[T_N] = \begin{bmatrix} i_1 & j_1 & k_1 \\ i_2 & j_2 & k_2 \\ i_3 & j_3 & k_3 \end{bmatrix} \tag{7}$$

N, $type_N$, $\{R_{ON}\}$ and $[T_N]$ form the CSTM entry for the coordinate system.

A GRID point (j) referenced to coordinate system (N) may be reduced to basic coordinates (X_o, Y_o, Z_o) by the equations:

1. If $type_N$ = Rectangular (R), X_j, Y_j and Z_j are given by

$$\begin{Bmatrix} X_o \\ Y_o \\ Z_o \end{Bmatrix} = \{R_{ON}\} + [T_N] \begin{Bmatrix} X_j \\ Y_j \\ Z_j \end{Bmatrix}. \tag{8}$$

2. If $type_N$ = Cylindrical (C), r, θ and Z are given by

$$X_j = r \cos \theta, \tag{9}$$

$$Y_j = r \sin \theta, \tag{10}$$

$$Z_j = Z. \tag{11}$$

X_o, Y_o and Z_o are calculated as in Equation 8.

3. If $type_N$ = Spherical (S), ρ, θ and ϕ are given by

$$X_j = \rho \sin \theta \cos \phi, \tag{12}$$

$$Y_j = \rho \sin \theta \sin \phi, \tag{13}$$

$$Z_j = \rho \cos \theta. \tag{14}$$

X_o, Y_o and Z_o are calculated as above.

When the basic location of a grid point has been calculated, the entry in the list is changed such that the reference coordinate system (entry No. 2) is zero and the three values are X_o, Y_o, Z_o.

The CØRD2j card image references another coordinate system and defines three points in the referenced system: a, b and c. If system number N is defined by system number M, the solution is

1. If $type_M$ = rectangular, the numbers defining the three points are the vectors: {a}, {b}, and {c}.

2. If $type_M$ = cylindrical, the numbers are r, θ and z. The equations to convert these to rectangular vectors are

$$\begin{Bmatrix} a_1 \\ a_2 \\ a_3 \end{Bmatrix} = \begin{Bmatrix} r_a \cos \theta_a \\ r_a \sin \theta_a \\ Z_a \end{Bmatrix} = \{a\} . \tag{15}$$

The {b} and {c} vectors are calculated similarly.

3. If $type_M$ = spherical, the numbers given for the points are ρ, θ, and φ. We calculate

$$\begin{Bmatrix} a_1 \\ a_2 \\ a_3 \end{Bmatrix} = \begin{Bmatrix} a\rho \sin \theta \cos \phi \\ a\rho \sin \theta \sin \phi \\ a\rho \cos \theta \end{Bmatrix} = \{a\} \tag{16}$$

and similarly for points b and c.

4. The definition of the new system is that point a is the origin, point b lies on the z (or polar) axis and point c lies in the x-z (or θ = 0) plane. The equations for the CSTM data are

$$\{R_{ON}\} = \{R_{OM}\} + [T_{ON}] \{a\}. \tag{17}$$

In system M the vectors defining the axes of system N are

$$\{V_k\} = \{b\} - \{a\}; \tag{18}$$

$$\{k\} = \frac{\{V_k\}}{|\{V_k\}|} , \text{ ("z" unit vector)}; \tag{19}$$

$$\{V_i\} = \{c\} - \{a\}; \tag{20}$$

$$\{j\} = \frac{\{k\} \times \{V_1\}}{|\{k\} \times \{V_1\}|} \text{ , ("Y" unit vector);} \qquad (21)$$

$$\{i\} = \{j\} \times \{k\} \text{ , ("X" unit vector).} \qquad (22)$$

The orientation of the axes is defined by the matrix

$$[T_{ON}] = [T_{OM}] \begin{bmatrix} i_1 & j_1 & k_1 \\ i_2 & j_2 & k_2 \\ i_3 & j_3 & k_3 \end{bmatrix} . \qquad (23)$$

5. On each pass of the CØRDij data at least one new system must be converted. After each pass the referenced GRID data is checked and converted. The resulting CØRDij data will be the CSTM data block with each entry reduced from 16 to 14 words.

4.21.7.5 Construction of the BGPDT, the SIL and the Second Logical Record of the EQEXIN.

The BGPDT and the SIL data blocks are formed simultaneously. The SIL data block is simply a list of the first scalar index for each grid or scalar point. A grid point has six scalar indices (or degrees of freedom), and a scalar point has one scalar index. Every degree of freedom in the problem has a scalar index, but since the six degrees of freedom for a grid point are consecutive, only the first one is listed.

The GPDT data are read a point at a time. The basic location coordinates of the point are formed using Equation 8 through Equation 14 and these data are written on the BGPDT file. The SIL value for the next point is calculated by incrementing the last value by six (grid point) or by one (scalar point).

A test is made on the value of the displacement coordinate system (field 6) in the GPDT data. If this value is the integer, -1, the point is a special RINGFL, GRIDF, or GRIDS fluid point. It is given one scalar index, the displacement coordinate system is basic (0), and its location coordinates in the BGPDT data block are calculated like a normal grid point.

Finally the second logical record of EQEXIN is written. This record contains pairs of external numbers, 10*scalar index + type where type = 1 for a grid point, 2 for a scalar point.

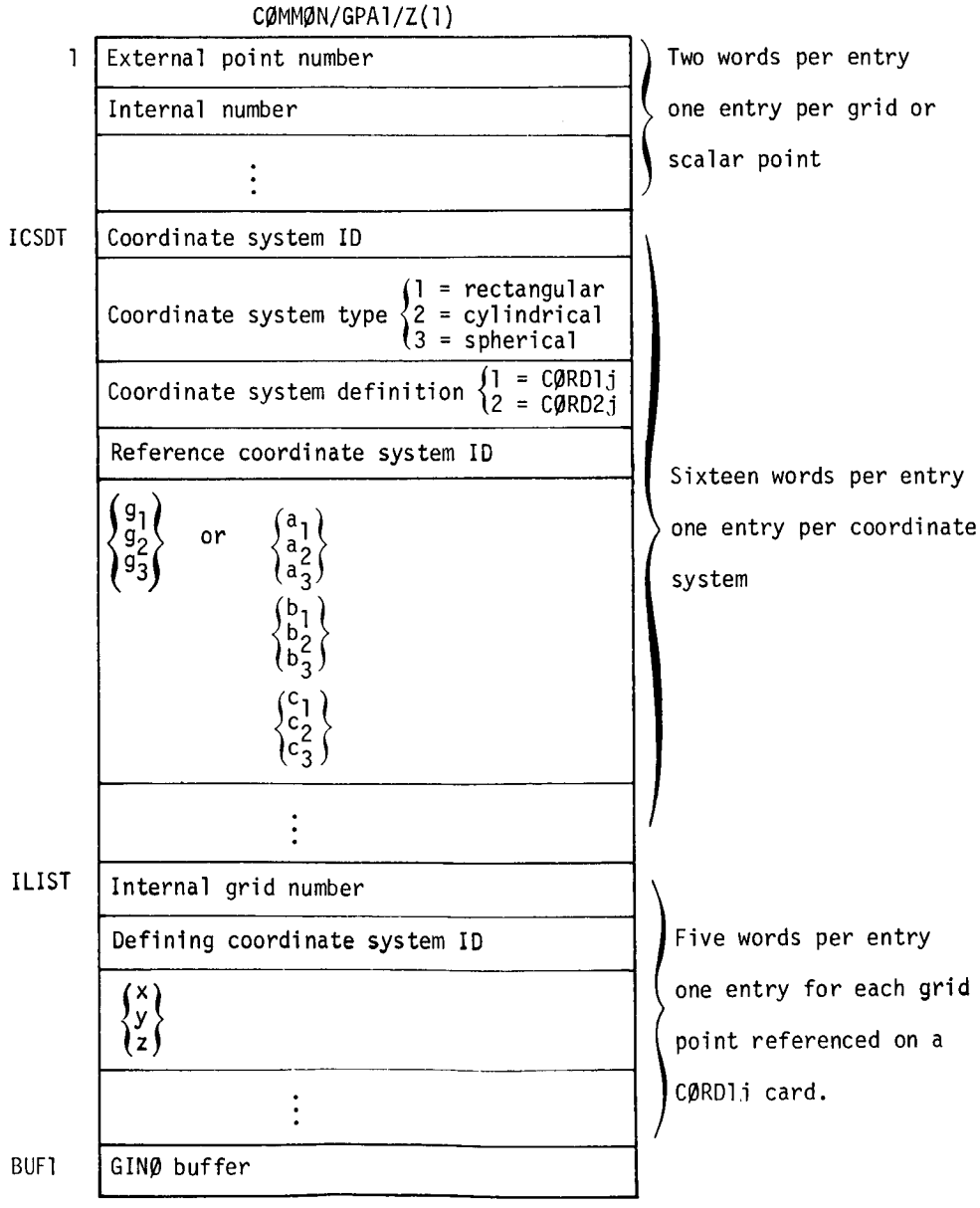
4.21.8 Subroutines

GP1 has no auxiliary subroutines.

4.21.9 Design Requirements

4.21.9.1 Allocation of Core Storage

During the assembly of the GPL, space for 2*(number of grid points plus number of scalar points) plus two GINØ buffers is required. During the assembly of the CSTM, core storage is allocated as follows:



Total storage requirements during this phase, therefore, equals 2*(number of grid + number of scalar points) + 16*(number of coordinate systems) + 5*(number of grid points referenced on CØRD1j cards) + one GINØ buffer.

4.21.9.2 Environment

Open core for GP1 is defined by /GPA1/. The table /GPTA1/ must be in core when GP1 is executed. GP1 uses two scratch files.

4.21.10 Diagnostic Messages

The following diagnostic messages may be issued by GP1:

2001, 2002, 2003, 2004, 2005, 2006, 2012

4.22 FUNCTIONAL MODULE GP2 (GEOMETRY PROCESSOR - PHASE 2)

4.22.1 Entry Point: GP2

4.22.2 Purpose

GP2 processes element connection data and converts external point numbers to internal numbers.

4.22.3 DMAP Calling Sequence

```
GP2 GEØM2,EQEXIN/ECT  $
```

4.22.4 Input Data Blocks

GEØM2 - Element connection data.

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers.

Note: EQEXIN may not be purged.

4.22.5 Output Data Blocks

ECT - Element Connection Table.

Note: ECT may not be purged.

4.22.6 Parameters

None

4.22.7 Method

The first data record of EQEXIN (containing pairs of external point identification and internal index) is read into core. GEØM2 is opened, and the header record is skipped. The ECT is opened, and the header record is written. The following process is repeated for each logical record in GEØM2.

1. The 3-word header is read. If an end-of-file is encountered, step (4) is executed. Otherwise, /GPTA1/ (see description in section 2.5) is searched for a match. If found, step (2) is executed. If not found, an internal table, CARDS, which defines additional cards processed

by GP2 (e.g. GENEL) is searched. If a match is found, step (3) is executed. Otherwise, the record is skipped, and step (1) is repeated.

2. The 3-word header from GEØM2 is written on the ECT. Parameters defining the element are fetched from /GPTA1/. If the number of words per element is less than 5, the sort flag in the GEØM2 trainer is fetched. Each element card of the current type on GEØM2 is read. Each external grid identification is converted to an internal index by performing a binary search in the EQEXIN table. If the point is not in the table, an error message is queued and the NØGØ flag is turned on. If the data is not to be sorted, the element is written directly on the ECT. Otherwise it is saved in core (or written on a scratch file if core is full). When all elements of a given type have been processed, the sort flag is again tested. If off, the ECT record is closed and return to step (1) is made. Otherwise, the data are sorted by SØRT and the ECT record is then written.

3. For GENEL, SEQBFE and QDSEP data (the latter two are Force Method only), each entry is read, all external point identifications are converted to internal indices as in (2) and the entry is written on the ECT. When the logical record on GEØM2 is exhausted, the ECT record is closed and return to step (1) is made.

4. The ECT trailer is written, and all files are closed. If the NØGØ flag was turned on, PEXIT is called. Otherwise, a normal exit is made.

4.22.8 Subroutines

The module GP2 consists of one subroutine, GP2.

4.22.9 Design Requirements

4.22.9.1 Allocation of Core Storage

GP2 requires space for 2*(number of grid points + number of scalar points) + three GINØ buffers.

4.22.9.2 Environment

Open core is defined by /GPA2/. The table /GPTA1/ must be in core when GP2 is executed. GP2 uses up to four scratch files.

4.22.10 Diagnostic Messages

The following diagnostic messages may be issued by GP2:

2007, 2059, 2060, 2061, 2138.

4.23 FUNCTIONAL MODULE PLTSET (PLOT SET DEFINITION PROCESSOR)

4.23.1 Entry Point: DPLTST

4.23.2 Purpose

To generate the structural element sets to be used by the structural plotter (functional module PLØT).

4.23.3 DMAP Calling Sequence

```
PLTSET     PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/V,N,NGP/V,N,NPSET    $
```

4.23.4 Input Data Blocks

PCDB - Plot Control Data Block for the structure plotter.

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers.

ECT - Element Connection Table.

Note: If PCDB is purged, nothing is done in this module. However, if PCDB is not purged, neither EQEXIN nor ECT may be purged.

4.23.5 Output Data Blocks

PLTSETX - User error messages related to the definition of element plot sets for the structure plotter.

PLTPAR - Plot parameters and plot control table.

GPSETS - Grid point sets related to the element plot sets.

ELSETS - Element plot set connection tables.

Note: None of these data blocks may be pre-purged unless PCDB is also purged.

4.23.6 Parameters

NGP - Output-integer-no default. Total number of grid points.

NPSET - Output-integer-default value = -1. Number of element plot sets (set to -1 if none).

4.23.7 Method

Each logical card in the plot control data block (PCDB) is read. If the first entry on a card is not "SET", the card is assumed to be a plot parameter or control card meaningful only to the PLØT module. In this case, the logical card is copied onto the PLTPAR data block.

If the first entry on a card is "SET", it is assumed to be a definition of a new element plot set. As each entry on the card is read, it is decided whether a list of elements (by type, range or explicit id's) or a list of grid points (by range or explicit id) is being included or excluded. Each element type which is specified is inserted into a table (TYP, 100 words long). If a range of elements or an explicit element id is specified, it is inserted into the beginning of open core (the EL array). And finally, if a range of grid points or an explicit grid point id is specified, it is inserted into the end of open core (the GP array). When a set has been completely specified, it is written out onto a scratch file (MSET) in the following format:

Word	1	= NEL (number of entries in the EL array).
Word 2 to NEL+1		= the entries in the EL array.
Word	1	= NTYP (number of entries in the TYP array).
Word 2 to NTYP+1		= the entries in the TYP array.
Word	1	= NPT (number of entries in the GP array).
Word 2 to NPT+1		= the entries in the GP array.

After all the SET cards have been processed, subroutine CØMECT is called to set up a shortened element connection table (ECTX). For each element type, the table is as follows:

	Word 1	= two character BCD element type symbol (left justified)
	Word 2	= number of grid points per element.
for each element of this type	Word 3	= element id.
	Word 4, etc.	= internal grid point numbers of the grid points connected by this element

This table, in conjunction with MSET, is used by subroutine CNSTRC to create the GPSETS and ELSETS data blocks. The ELSETS data block is simply a duplicate of ECTX for each plot set, except that only those elements which are in the set are included. The GPSETS data block for each plot set is simply a list of indices into the subset of grid points which pertain to this set.

4.23.8 Subroutines

Utility routines CLSTAB, FREAD, GØPEN, INTGPX, INTGPT, INTLST, RDMØDX, RDMØDE and RDWØRD are used by PLTSET. See Section 3.4 for their descriptions.

4.23.8.1 Subroutine Name: SETINP

1. Entry Point: SETINP
2. Purpose: To create the plot parameter and control data block (PLTPAR) and interpret the plot set definition cards from the Plot Control Data Block (PCDB).
3. Calling Sequence: CALL SETINP

CØMMØN/GPTA1/NTYPES,LAST,INCR,ELEM(1) (Note Section 2.5.2.1)

4.23.8.2 Subroutine Name: CØMECT

1. Entry Point: CØMECT
2. Purpose: To create a shortened form of the Element Connection Table (ECT).
3. Calling Sequence: CALL CØMECT

CØMMØN/GPTA1/NTYPES,LAST,INCR,ELEM(1) (Note Section 2.5.2.1)

4.23.8.3 Subroutine Name: CNSTRC

1. Entry Point: CNSTRC
2. Purpose: To construct the element and grid point plot set data blocks (ELSETS,GPSETS).
3. Calling Sequence: CALL CNSTRC (GP,ELE,BUF,MAX)

CØMMØN/GPTA1/NTYPES,LAST,INCR,ELEM(1) (Note Section 2.5.2.1)

Where:

GP = NGP locations used to set up the grid point index list for the grid point set data block (GPSETS).

ELE = MAX locations used to set up the element set data block (ELSETS).

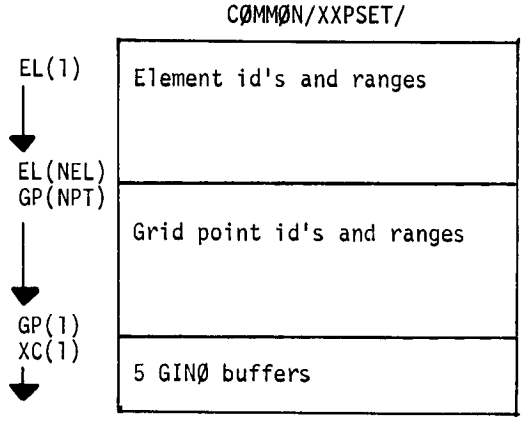
BUF = Location of 3 GINØ buffers.

MAX = Amount of core available for the ELE array (open core).

4.23.9 Design Requirements

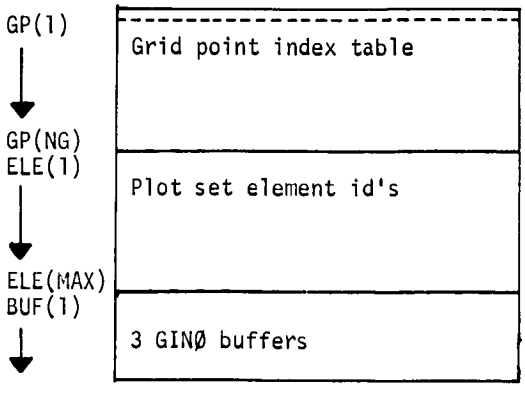
Open Core Design (Common Block XXPSET)

1. Subroutine SETINP



2. Subroutine CNSTRC

For this subroutine, open core is partitioned by the calling program as follows:



4.23.10 Diagnostic Messages

A fatal message occurs in SETINP if a set specification is so large that open core is filled (i.e., array EL meets array GP). All other diagnostics are non-fatal and are written on the PLTSETX data block for printing by the PRTMSG module.

4.24 FUNCTIONAL MODULE PLØT (STRUCTURAL PLOTTER)

4.24.1 Entry Point: DPLØT

4.24.2 Purpose

To draw structural shapes on a variety of different plotters.

4.24.3 DMAP Calling Sequence

```
PLØT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,PLTDSP1,PLTDSP2/PLØTX/V,N,NGP/
        V,N,LSIL/V,N,NPSET/V,N,PLTFLG/V,N,PLTNUM    $
```

4.24.4 Input Data Blocks

PLTPAR - Plot parameters and plot control table.

GPSETS - Grid point sets related to the element plot sets.

ELSETS - Element plot set connection tables.

CASECC - Case Control Data Table.

BGPDT - Basic Grid Point Definition Table.

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers.

SIL - Scalar Index List.

PLTDSP1 - Translational displacements (statics).

PLTDSP2 - Translational displacements (dynamics).

Notes:

1. Only SIL, PLTDSP1, and PLTDSP2 may be purged. If this is the case, only undeformed shapes may be drawn.

2. If either PLTSDP1 or PLTDSP2 is purged, that type of deformed shape will not be drawn.

3. If either PLTDSP1 or PLTDSP2 is not purged, SIL may not be purged.

4.24.5 Output Data Blocks

PLØTX - User messages.

Note: PLØTX may not be purged.

4.24.6 Parameters

NGP - Integer-input-no default value. Number of grid points.

LSIL - Integer-input-no default value. Last scalar index value.

NPSET - Integer-input-no default value. Number of element plot sets.

PLTFLG - Integer-input/output-default value = 1. Displacement plot flag.
= 1 if undeformed shapes have not yet been drawn.
= -1 if undeformed shapes have been drawn.

PLTNUM - Integer-input/output-default value = 0. Plot number.

4.24.7 Method

Subroutine PARAM reads each card in the plot parameter and control table (PLTPAR). If the first entry on a card is not 'FIND' or 'PLØT', it is assumed to be a plot parameter card to be processed within PARAM (e.g., PRØJECTIØN, PLØTTER, etc.). Within PARAM, an implied 'FIND' card is initially set up to automatically find an origin, vantage point, and scale. In addition this same implied "FIND" card is set up each time a new projection is defined as a 'PLØTTER' card is encountered. At the same time, the view angles are re-initialized to their default values, the regions pertaining to each origin are reset to full pictures, and all previously defined origins are nullified.

When a 'FIND' card is encountered, subroutine FIND is called both to interpret the card and act upon its requests. And finally, when a 'PLØT' card is encountered, subroutine PLØT is called both to interpret the card and to act upon its requests. However, in this case, if the implied 'FIND' card set up by subroutine PARAM still exists (i.e., if no origin, scale, or vantage point has been defined) the FIND subroutine is called to satisfy these needs before subroutine PLØT is called.

In subroutine FIND, after the interpretation of the 'FIND' card is completed, a coordinate system rotation matrix is calculated relative to the current view angles, and then the vantage point, scale factors, and the origin requested are calculated as needed.

In subroutine PLØT, after the interpretation of the 'PLØT' card is completed, a list of messages to the plotter operator is generated. Then all plots requested on the plot card are generated by calling subroutine DRAW for each plot request.

Subroutine DRAW generates one plot. It sets up the region of the plot, rotates the grid points based upon the current viewing angles, applies the latest scale factor to the structural coordinates, and translates these coordinates to the origin specified for this plot. It also controls the various aspects of a plot as specified on the 'PLØT' card, e.g., drawing a shape, labeling grid points, etc., for both undeformed and deformed structures (superimposition if called for).

4.24.8 Subroutines

The following utility routines are called by PLØT: CLSTAB,FREAD,GØPEN,(INTGPX,INTGPT), INTLST,(RDMØDX,RDMØDY,RDMØDE,RDWØRD). See the subroutine descriptions in section 3. The subroutines FNDSET, MINMAX, PERPEC and PROCES are support subroutines used by more than one of the following subroutines.

4.24.8.1 Subroutine Name: PARAM

1. Entry Point: PARAM

2. Purpose: To interpret the plot parameter cards and to detect the 'FIND' and 'PLØT' plot control cards. In addition, it serves as a driver for subroutine FIND and PLØT.

3. Calling Sequence: CALL PARAM (SETID,X)

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

CØMMØN/PLTDAT/ - See PLTDAT miscellaneous table description (section 2.5).

Where:

SETID = Various plot set id's created in the PLTSET module. (Record 1 of GPSETS).

X = Open core.

4. Method: All plot parameters are inserted in the XXPARM table. Any parameter which is not recognizable causes a message to be created to this effect, and the parameter is then ignored.

5. Additional Subroutines Required: FIND,PLØT

4.24.8.2 Subroutine Name: FIND

1. Entry Point: FIND

2. Purpose: To interpret a 'FIND' card and to calculate the parameters requested on the card.

3. Calling Sequence: CALL FIND (MØDE,SETID,X)

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

CØMMØN/PLTDAT/ - See PLTDAT miscellaneous table description (section 2.5).

Where:

MØDE = Current value of the XRCARD mode value as read and modified by subroutine

RDMØDX.

SETID = Various plot set id's created in the PLTSET module (record 1 of GPSETS).

X = Open core.

4. Method: After interpreting the 'FIND' card, the coordinate system rotation matrix is calculated (based upon the current view angles), the vantage point, scale factor, and desired origin are calculated.

5. Additional Subroutines Required: FNDSET,MINMAX,PRØCES,PERPEC.

4.24.8.3 Subroutine Name: PLØT

1. Entry Point: PLØT

2. Purpose: To interpret the 'PLØT' card, and produce all the plots requested on the card by acting as a driver to subroutine DRAW.

3. Calling Sequence: CALL PLØT (MØDE,SETID,X)

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

CØMMØN/PLTDAT/ - See PLTDAT miscellaneous table description (section 2.5).

Where:

MØDE = Current value of the XRCARD mode value as read and modified by subroutine RDMØDX.

SETID = Various plot set id's created in the PLTSET module (record 1 of GPSETS).

X = Open core.

4. Method: After interpreting the deformed structure plot requests (there may be many on one 'PLØT' card), the rest of the 'PLØT' card is read into memory. For each deformed structure request, the appropriate displacement data block (PLTDSP1 or PLTDSP2) is searched for a matching subcase id. If one is found, (this search does not occur if only the undeformed requests are being serviced), then the rest of the plot card is interpreted for the various plotting options. Subroutine DRAW is then called to service these options and to draw the corresponding picture for each plot element set listed on the 'PLØT' card.

5. Additional Subroutines Required: HEAD,FNDSET,GETDEF,DRAW.

4.24.8.4 Subroutine Name: GETDEF

1. Entry Point: GETDEF

2. Purpose: To read the translational components of a set of displacements (in the basic coordinate system).

3. Calling Sequence: CALL GETDEF (DFRM,GPT,D)

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

where:

DFRM = Displacement data block to be read (pre-positioned at the set of displacements to be read).

GPT = List of grid point indices defining a subset of grid points.

D = Array into which the displacement components are to be read (3 per grid point - X,Y,Z).

4. Method: The scalar index list (SIL data block) is used to determine at which grid point a particular displacement component is specified. While reading the components, a maximum absolute component (MAXDEF) is determined.

4.24.8.5 Subroutine Name: PLTØPR

1. Entry Point: PLTØPR

2. Purpose: To generate printed output to be used by the plotter operator in setting up the plotting equipment, and to generate output informing the user of the plotting parameters used to generate the plots.

3. Calling Sequence: CALL PLTØPR

CØMMØN/PLTDAT/ - See PLTDAT miscellaneous table description (section 2.5).

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

4. Method: All output is written on the PLØTX data block for subsequent processing by the PRTMSG module. The resulting output can be used by the user to alter certain plot parameters on a subsequent run, if he desires, in order to slightly alter the plots produced.

4.24.8.6 Subroutine Name: DRAW

1. Entry Point: DRAW

2. Purpose: To service the many possible plotting options and generate the corresponding picture.

3. Calling Sequence: CALL DRAW (GPLST,X,U,S,DEFØRM,STEREØ)

CØMMØN/PLTDAT/ - See PLTDAT miscellaneous table description (section 2.5).

CØMMØN/XXPARM/ - See XXPARM table description below (section 4.24.9.2).

CØMMØN/RSTXXX/ - See RSTXXX table description below (section 4.24.9.2).

CØMMØN/DRWDAT/ - See DRWDAT table description below (section 4.24.9.2).

where:

GPLST = List of indices (one for each structural grid point) into the subset of grid points which pertain to the element set appropriate to this plot.

X = Coordinates of the grid points in this element set (3 per grid point - r,s,t).

U = Deformation components for each grid point in this element set (3 per grid point - x,y,z).

S = Location into which the s and t deformed structure grid point coordinates are to be placed.

DEFØRM { = 0 if an undeformed structure plot is requested.
= 1 if a deformed structure plot is requested.

STEREØ { = 0 if the left image of a stereo plot is to be generated.
= 1 if the right image of a stereo plot is to be generated.

4. Method: Initially, the grid points are rotated based upon the current viewing angles, translated to the selected plot origin, and converted to plotter units using the current scale factor, and the deformation components are reduced to the specified maximum deformation value. Then the undeformed structural plot is generated.

Next, the deformed structural shape (if requested) is drawn. Then the deformation vectors (as requested) are drawn.

5. Additional Subroutines Required: MINMAX,PRØCES,PERPEC,INTVEC,SHAPE,GPTSYM,GPTLBL,DVECTR, ELELBL

4.24.8.7 Subroutine Name: INTVEC

1. Entry Point: INTVEC

2. Purpose: To interpret the user supplied deformation vector plot request.

3. Calling Sequence: CALL INTVEC (VECTØR)

where:

VECTØR = BCD characters specified in the deformation vector request (any combination up to four letters of the characters R, X, Y, Z, N). Input and Output. On input, VECTØR is integer (=0) or BCD. On output, VECTØR in integer (=0, if = 0 upon input).

4. Method: The result is stored into VECTØR, as follows:

$X = 2^0$

$Y = 2^1$

$Z = 2^2$

$R = 2^3$ (if VECTØR = 'R' only, it is treated as if VFCTØR = RXYZ).

N = -VECTØR (the negative of the sum of the other characters)

4.24.8.8 Subroutine Name: SHAPE

1. Entry Point: SHAPE

2. Purpose: To draw a structural shape.

3. Calling Sequence: CALL SHAPE (GPLST,X,U,PEN,DEFØRM)

where:

GPLST = List of indices into the subset of grid points pertaining to the shape to be drawn.

X = Corresponding grid point coordinates of the undeformed structure (3 per grid point - r, s, t).

U = Corresponding grid point coordinates of the deformed structure (2 per grid point - s, t).

PEN = Pen number or line density to be used to draw the shape.

DEFØRM { = 0 if the undeformed shape is to be drawn.
DEFØRM { = 1 if the deformed shape is to be drawn.

4. Method: The structural shape to be drawn is defined as a compact element connection table on the ELSETS data block (assumed open and positioned at the correct element set). As each element is read, it is drawn, taking into account whether the element is one or two dimensional.

4.24.8.9 Subroutine Name: GPTSYM

1. Entry Point: GPTSYM

2. Purpose: To type a special symbol at each of a subset of grid points.

3. Calling Sequence: CALL GPTSYM (GPLST,X,U,SYM,DEFØRM)

Where:

GPLST = List of indices defining the subset of grid points.

X = Corresponding grid point coordinates of the undeformed structure (3 per grid point - x,s,t).

U = Corresponding grid point coordinates of the deformed structure (2 per grid point - s,t).

SYM = Two indices to be used to construct the special symbol.

DEFØRM { = 0 if the undeformed grid points are to be used.
DEFØRM { = 1 if the deformed grid points are to be used.

4.24.8.10 Subroutine Name: GPTLBL

1. Entry Point: GPTLBL

2. Purpose: To type the external grid point id of each of a subset of grid points.

3. Calling Sequence: CALL GPTLBL (GPLST,X,U,DEFØRM)

CØMMØN/PLTDAT/ - See the PLTDAT miscellaneous table description (section 2.5).

Where:

GPLST = List of indices defining the subset of grid points.

X = Corresponding grid point coordinates of the undeformed structure (3 per grid point - r,s,t).

U = Corresponding grid point coordinates of the deformed structure (2 per grid point - s,t).

DEFØRM = { 0 if the undeformed grid points are to be used.
1 if the deformed grid points are to be used.

4. Method: The internal and external id of each structural grid point is read from the EQEXIN data block. If the grid point is part of the specified subset, then the external id is printed to the immediate right of the grid point.

4.24.8.11 Subroutine Name: DVECTR

1. Entry Point: DVECTR

2. Purpose: To draw deformation vectors.

3. Calling Sequence: CALL DVECTR (GPT,X,U,PEN)

Where:

GPT = List of indices defining the subset of grid points at which vectors are to be drawn.

X = Corresponding grid point coordinates of the undeformed structure (3 per grid point - x,s,t).

U = Corresponding grid point coordinates of the deformed structure (2 per grid point - s,t).

PEN = Pen number or line density to be used to draw the vectors.

4.24.8.12 Subroutine Name: FNDSET

1. Entry Point: FNDSET

2. Purpose: To find the subset of grid points pertaining to a set of elements, and to read the corresponding grid point coordinates from the BGPDT data block.

3. Calling Sequence: CALL FNDSET (SET,GPID,X)

Where:

SET = Element plot set index.

GPID = Array into which the list of indices defining the subset of grid points is to be read.

X = Array into which the corresponding coordinates are to be read (3 per grid point - x,y,z).

4. Method: If SET = 0, the grid point set index data block (GPSETS) is assumed positioned at the correct record. Otherwise, GPSETS is first positioned correctly (record SET+1). The indices are then read into GPID, and the corresponding coordinates are read from BGPDT into X.

4.24.8.13 Subroutine Name: MINMAX

1. Entry Point: MINMAX

2. Purpose: To initialize the minimum and maximum grid point coordinates to a very large and small number, respectively.

3. Calling Sequence: CALL MINMAX

CØMMØN/RSTXXX/ - See the RSTXXX table description below (section 4.24.9.2).

4.24.8.14 Subroutine Name: PERPEC

1. Entry Point: PERPEC

2. Purpose: To calculate the vantage point and/or translate the grid point coordinates to the vantage point.

3. Calling Sequence: CALL PERPEC (X,STEREØ)

CØMMØN/XXPARM/ - See XXPARM table description (section 4.24.9.2).

CØMMØN/RSTXXX/ - See the RSTXXX table description (section 4.24.9.2).

where:

X = = Set of grid point coordinates to be translated (3 per grid point - r,s,t)

STEREØ = {0 if the coordinates of the left image for stereo are to be calculated.
{1 if the coordinates of the right image for stereo are to be calculated.

4. Method: After the vantage point is calculated (if required), each grid point is translated. In the process, unless the projection is stereo, the minimum and maximum s and t coordinates are calculated. Finally, the differences between these minima and maxima, and their averages, are calculated.

4.24.8.15 Subroutine Name: PRØCES

1. Entry Point: PRØCES

2. Purpose: To exchange coordinate axes (as requested) and rotate the grid point coordinates based upon the current view angles.

3. Calling Sequence: CALL PRØCES (X)

CØMMØN/XXPARM/ - See the XXPARM table description below (section 4.24.9.2).

CØMMØN/RSTXXX/ - See the RSTXXX table description below (section 4.24.9.2).

where:

X = Grid point coordinates (3 per grid point - x,y,z).

4. Method: In addition to its primary purpose, this subroutine calculates the minimum and maximum rotated grid point coordinates, and the differences and averages of these minima and maxima.

4.24.8.16 Subroutine Name: ELELBL

1. Entry Point: ELELBL

2. Purpose: To type the element identification number of each element in a subset of elements.

3. Calling Sequence: CALL ELELBL (GPLST,X,U,DEFØRM)

CØMMØN/CHAR94/ - See the CHAR94 miscellaneous table description (section 2.5).

CØMMØN/PLTDAT/ - See the PLTDAT miscellaneous table description (section 2.5).

where:

GPLST = List of indices defining the set of grid points associated with the elements to be labeled.

X = Corresponding grid point coordinates of the undeformed structure.

U = Corresponding grid point coordinates of the deformed structure.

DEFØRM = {0 if the undeformed grid points are to be used
1 if the deformed grid points are to be used

4. Method: The compact element connection table (ELSETS) is read. As each element id is read, it is typed at the center of the element. The two character symbolic name of the element type is appended to the element ID.

4.24.8.17 Subroutine Name: WRTPRT

1. Entry Point: WRTPRT

2. Purpose: To write messages on a data block for subsequent processing by WRTMSG.

3. Calling Sequence: CALL WRTPRT (G,L,F,N)

G = GINØ file name
L = List vector of length L(1) in cells L(2)-L(L(1)+1)
F = Format vector
N = Length of format vector

4.24.9 Design Requirements

4.24.9.1 Open Core Design (Common Block XXPLØT)

Define NPSET = Number of element plot sets.

NGP = Total number of grid points.

NGPSET = Number of grid points in an element.

1. Subroutine DPLØT partitions open core for subroutine PARAM as follows:

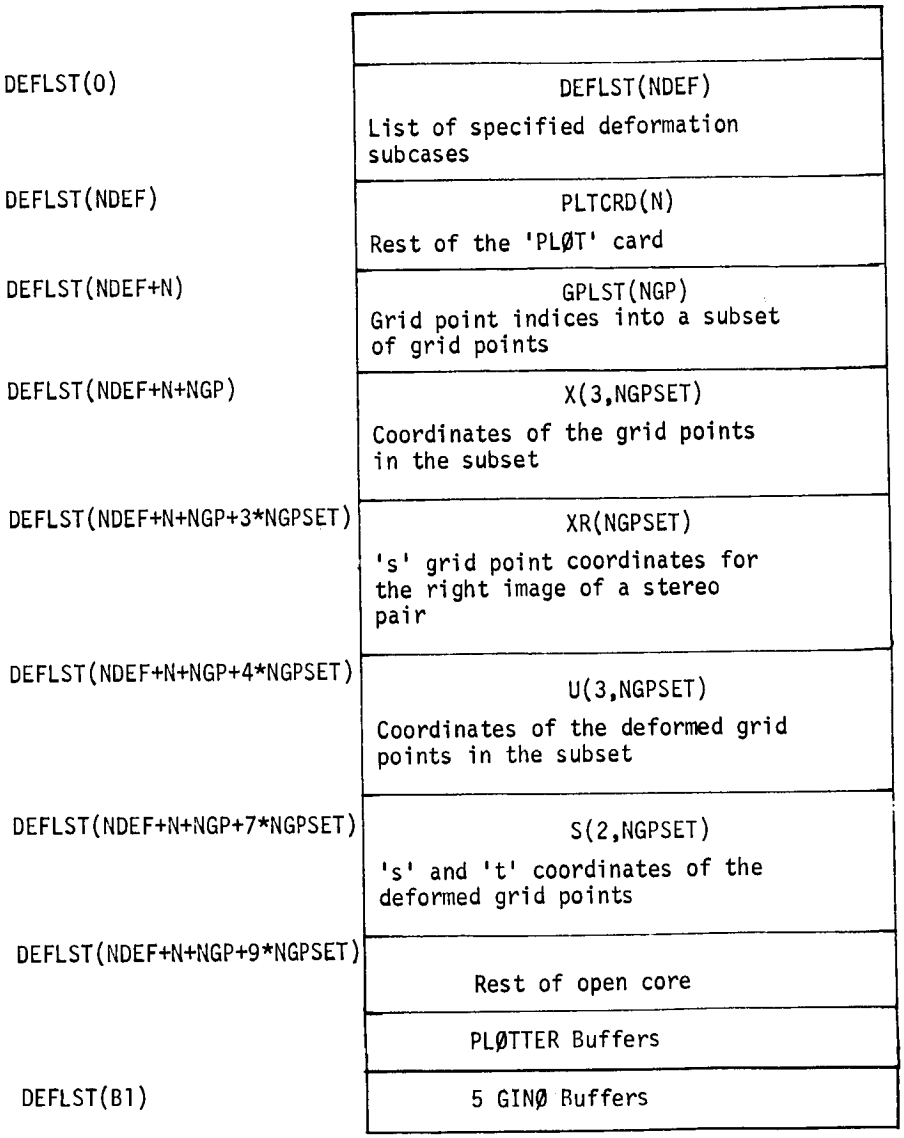
CØMMØN/XXPLØT/

X(0)	Element plot set id's
X(NPSET)	Open Core
X(BUF)	3 GINØ buffers

2. Subroutine FIND partitions open core for subroutines FNDSET, PERPEC, and PRØCES as follows:

X(0)	GPLST(NGP) Grid point indices into a subset of grid points
X(NGP)	X(3,NGPSET) Coordinates of the grid points in the subset
X(NGP+3*NGPSET)	XR(NGPSET) 's' grid point coordinates for the right image of a stereo pair.
X(NGP+4*NGPSET)	Rest of open core

3. Subroutine PLØT partitions open core for subroutines FNDSET, GETDEF, and DRAW as follows:



4.24.9.2 Block Data Interface

1. CØMMØN/DRWDAT/ SET,LABEL,ØRIGIN,PEN,SHAPE,SYMBØL(2),SYM(6),VECTØR

SET - Element plot set index.
LABEL - Grid point label option.
ØRIGIN - Origin index.
PEN - Pen number or density value.
SHAPE - Structural shape drawing option.
SYMBØL - Grid point symbol indices.
SYM - Symmetry options.
VECTØR - Deformation vector options.

} Integer

2. CØMMØN/RSTXXX/ CSTM(3,3),MIN(3),MAX(3),D(3),AVER(3)

CSTM - 3x3 coordinate system rotation matrix.
MIN - Minimum rotated grid point coordinates.
MAX - Maximum rotated grid point coordinates.
D - Differences between the minima and maxima.
AVER - Averages of the minima and maxima.

} Real

3. CØMMØN/XXPARM/ PBUFSZ,CAMERA,BFRAMS,PLTMDL(2),TAPDEN,
NPENS,PAPSIZ(2),PAPTYP(2),PENSIZ(8),PENCLR(8,2),"SKIP(1)",
SCALE,ØBJMØD,FSCALE,MAXDEF,DEFMAX,
AXIS(3),DAXIS(3),VANGLE(3),BETAØS,BETAP,"SKIP(4)",
FVP,RO,SOL,SOR,TO,DO,DO2,DO3,PRJECT,SOS
FØRG,ØRG,NØRG,ØRIGIN(11),EDGE(11,4),XY(11,3)

In the following descriptions, the value(s) in parentheses to the right of the variable name, the default value, and the letter in parentheses to the right of the explanation pertain to the type of the variable (I implies integer and R implies real).

PBUFSZ(0) = Plot tape buffer size (I)

Plotter Data

CAMERA(2)	= Plotter camera number (I).
BFRAMS(1)	= Number of blank frames between plots (I).
PLTMDL(4020,0)	= Plotter model (BCD or I or R).
TAPDEN(0)	= Plot tape density (I).

Pen and Paper Data

NPENS(8)	= Maximum number of pens (I).
PAPSIZ(8.5,11.)	= Paper size in inches (R).
PAPTYP(VELLUMbb)	= Paper type (BCD).
$PENSIZ_i$(1)	= Pen sizes (I).
$PENCLR_{i,1}$(BLAC) & $PENCLR_{i,2}$(Kbbb)	= Pen colors (BCD).

Scaling Data

SCALE	= Object-to-plotter or model-to-plotter (stereo only) scale factor (R).
ØBJMØD(1.)	= Object-to-model scale factor (R-stereo only).
FSCALE(1)	= Find scale factors option (I).
MAXDEF(0.)	= Forced value of the largest deformation component (R).
DEFMAX	= Actual largest deformation component (R).

Viewing Data

AXIS (1,2,3)	= Undeformed structure axis orientation (I).
DAXIS(1,2,3)	= Deformed structure axis orientation (I).
VANGLE(0.,-1.10^{10}, 34.27)	= View angles (R-alpha,beta,gamma).
BETAØS(23.17)	= Orthographic and stereo default value for the "beta" view angle (R).
BETAP(0.)	= Perspective default value for the "beta" view angle (R).

Projection Data

FVP(1)	=	Find vantage point option (I).
RO	=	"r" component of the vantage point (R).
SOL	=	"s" component of the perspective vantage point (R).
SOL,SOR	=	"s" components of the stereo vantage point (R).
TO	=	"t" component of the vantage point (R).
DO	=	Projection plane separation value (R).
DO2(1.)	=	Perspective default projection plane separation value (R).
DO3(2.)	=	Stereo default projection plane separation value (R).
PRJECT(1)	=	Projection type (I, 1=orthographic, 2 = perspective, 3 = stereo).
SOS(2.756)	=	Ocular separation value (R).

Origin Data

FØRG(1)	=	Find origin point option (I).
ØRG(0)	=	Number of active origins (I).
NØRG(10)	=	Maximum number of active origins (I).
ØRIGIN	=	Active origin id's (I).
$EDGE_{i,1}$(0.) & $EDGE_{i,2}$(0.)	=	Lower left corner of the region specified for the ith origin (R).
$EDGE_{i,3}$(1.) & $EDGE_{i,4}$(1.)	=	Upper right corner of the region specified for the ith origin (R).
$XY_{i,1}$	=	x component of the i^{th} origin (R).
$XY_{i,3}$	=	y component of the i^{th} origin (R).
$XY_{i,1}$ & $XY_{i,2}$	=	left and right x components of the i^{th} origin for stereo projection (R).

4.24.9.3 Common Storage Requirements

1. /XXPLØT/ - Open core.
2. /PLTDAT/ - Plotter data (see miscellaneous table description - section 2.5).
3. /XXPARM/ - Plotting parameters.
4. /RSTXXX/ - Plot co-ordinate system calculations.
5. /DRWDAT/ - Drawing data.

4.24.10 Diagnostic Messages

A non-fatal message, number 3008, CALL MESAGE (8,x,x), will be generated by subroutine PLØT if not enough core is available for the grid point data needed for a specific element plot set. If this occurs, this set will not be used to generate a plot.

All other diagnostics are non-fatal and are written onto the PLØTX message data block for printing by the PRTMSG module. These messages are all quite self-explanatory and straightforward, and do not have any external message numbers.

4.25 FUNCTIONAL MODULE GP3 (GEOMETRY PROCESSOR - PHASE 3)

4.25.1 Entry Point: GP3

4.25.2 Purpose

GP3 processes static loads and temperature data. Static load data are collected by load set, and external numbers are converted to internal numbers. Similarly, temperature data are collected by temperature set and external numbers are converted to internal numbers.

4.25.3 DMAP Calling Sequence

```
GP3     GEØM3,EQEXIN,GEØM2/SLT,GPTT/V,N,NØLØAD/V,N,NØGRAV/V,N,NØTEMP  $
```

4.25.4 Input Data Blocks

GEØM3 - Static loads and temperature data.

EQEXIN - Equivalence between external grid and scalar numbers and internal numbers.

GEØM2 - Element connection data.

Note: EQEXIN may not be purged.

4.25.5 Output Data Blocks

SLT - Static Loads Table.

GPTT - Grid Point Temperature Table.

4.25.6 Parameters

NØLØAD - Output-integer-no default. -1 if no static loads (i.e. SLT is not created), +1 otherwise.

NØGRAV - Output-integer-no default. -1 if no GRAV cards in the Bulk Data Deck, +1 otherwise.

NØTEMP - Output-integer-no default. -1 if no TEMP or TEMPD cards in Bulk Data Deck (or if GPTT is purged), +1 otherwise.

4.25.7 Method

Subroutine GP3 is the control program for the module. It executes each of the major subroutines of GP3 (GP3C, GP3A, GP3B) depending on the status of the data blocks. A flow chart for GP3 is included in Figure 1.

4.25.8 Subroutines

4.25.8.1 Subroutine Name: GP3

1. Entry Point: GP3

2. Purpose: Module control program.

3. Calling Sequence: CALL GP3

4.25.8.2 Subroutine: GP3C

1. Entry Point: GP3C

2. Purpose: To convert PLØAD2 data to PLØAD format, merge PLØAD2 data with PLØAD data (if present) and write the resulting data on SCR2, a scratch file.

3. Calling Sequence: CALL GP3C

4. Method: PLØAD2 cards are read into core from GEØM3. Six words are used for each entry. The first word (set identification) is set negative and the sixth word of each entry is set to zero. GEØM2 is opened and the header record is skipped. The following steps occur for each record on GEØM2.

1. The 3-word header is read. /GPTA1/ (see section 2.5) is searched for a match. If no match is found, the record is skipped and the process is repeated. If an end-of-file is encountered, step (3) is executed. If a match is found, a test on element type is made. If a one-dimensional element, the record is skipped and the process repeated. Otherwise, step (2) is executed.

2. An entry of the current element type is read. A linear search through the PLØAD2 data in core is made to find a match on element identification (3rd word of each PLØAD2 entry). If no match is found, the next entry is read. For each match which is found, the grid identification numbers which connect the element are stored

in the corresponding PLØAD2 entry and the first word of the PLØAD2 entry is set positive. When all data for the current element type has been read, a return to step (1) is made.

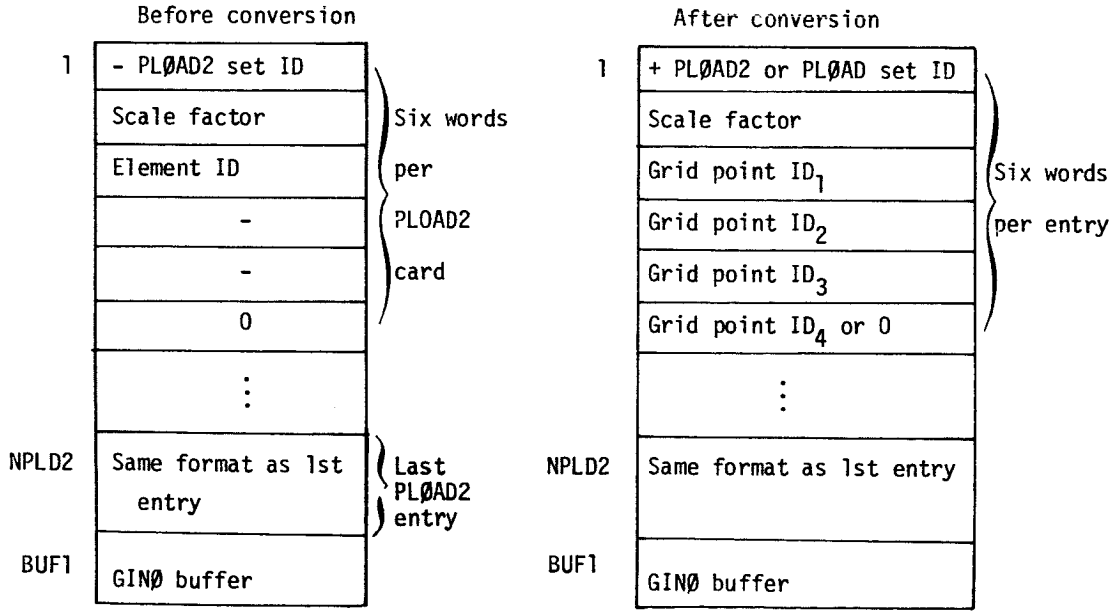
3. A pass through each entry in the PLØAD2 data is made. For each entry for which the first word is negative, an error message is queued and the NØGØ flag turned on. Upon completion of the pass, PEXIT is called if the NØGØ flag was turned on. Otherwise step (4) is executed.

4. LØCATE is called to position GEØM2 to PLØAD data. If none exists, step (5) is executed. Otherwise, the PLØAD data is read into core following the PLØAD2 data. The combined list is sorted by SØRT on set identification number.

5. The data in core is written as one logical record on SCR2. A return to GP3 is given.

Allocation of core storage in GP3C is as follows:

CØMMØN/GP3CØR/Z(1)



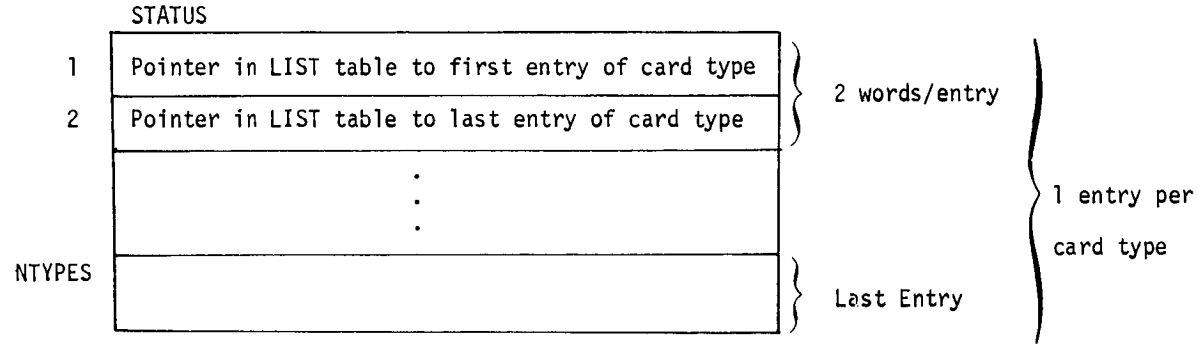
4.25.8.3 Subroutine: GP3A

1. Entry Point: GP3A

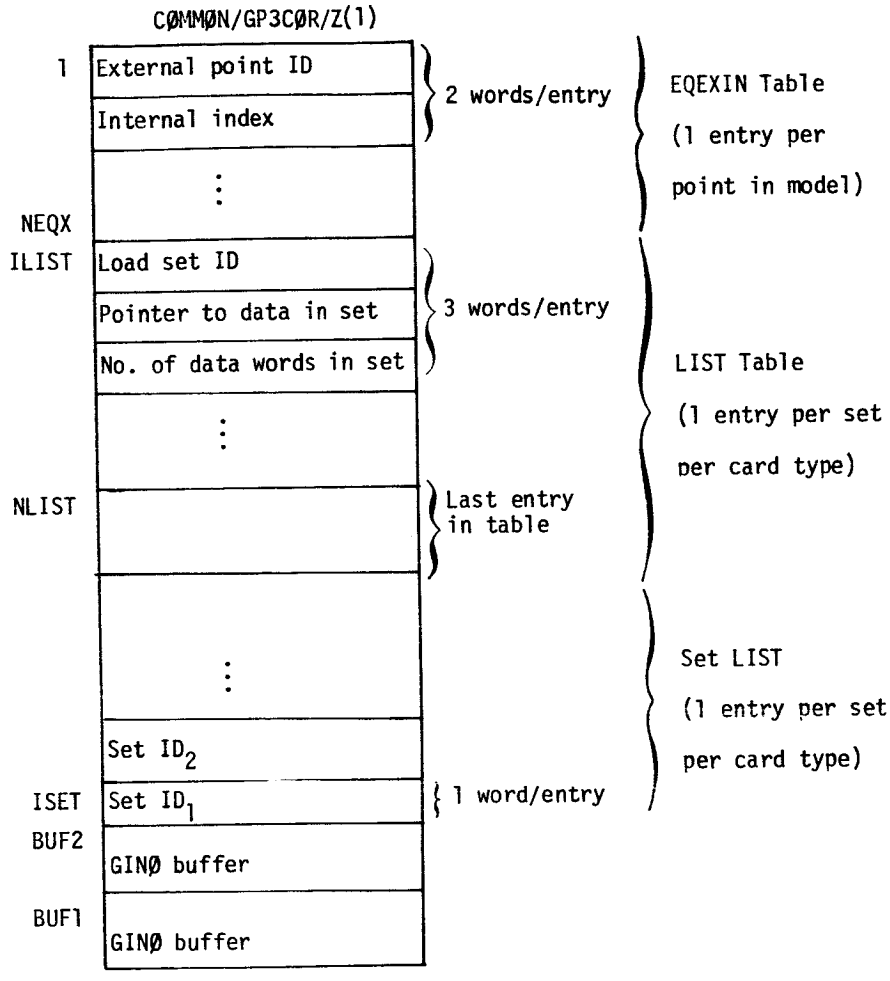
2. Purpose: To assemble to Static Loads Table (SLT).

3. Calling Sequence: CALL GP3A

4. Method: GP3A assembles the SLT by making two passes on the load cards (FØRCEi, MØMENTi, etc). On the first pass each of the cards is read from GEØM3, (or SCR2 for PLØAD data), unique set identifications are extracted and saved in core, all external point identifcations are converted to internal indices by performing a binary search in the EQEXIN table, the data are written on SCR1, and pointer tables are accumulated. These tables are as follows:



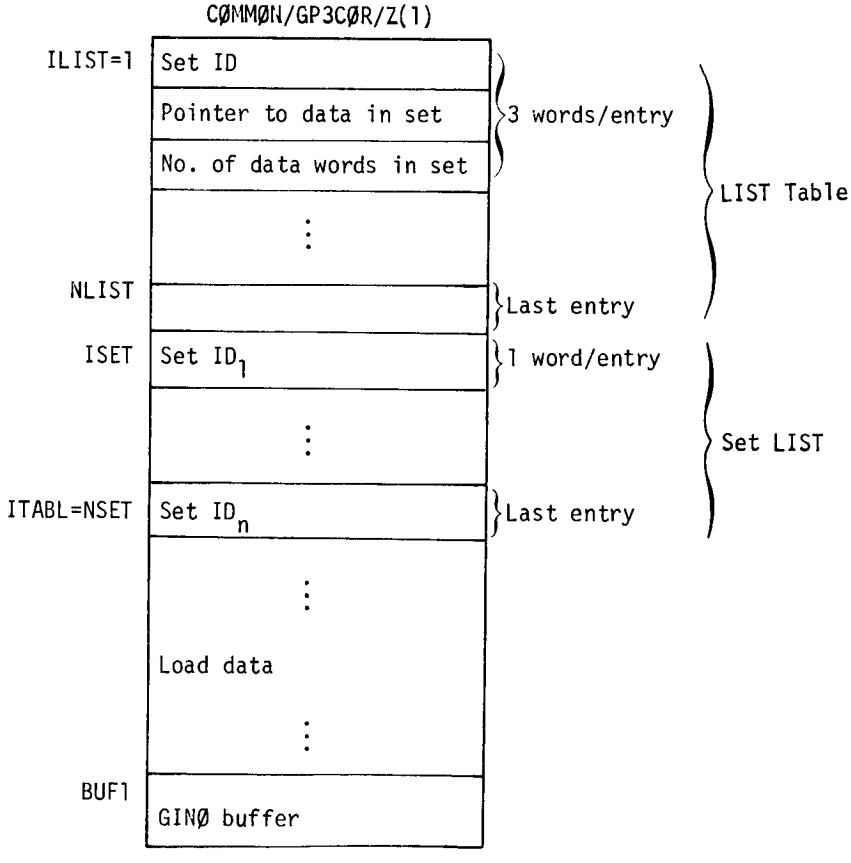
Note: entry = (-1, -1) if card type not present



Note:

Set IDs are stored backward in core. ISET points to first entry, ISET-1 to record entry, etc.

At the end of the first pass, the LIST table is moved to the beginning of open core. The set list is sorted, and duplicate set identifications are discarded. The resulting list is stored immediately following the LIST table. If all data for the load cards will fit in the remaining core, this data is read from SCR1. Core storage is as follows:



The SET list is written in the header record on the SLT. For each set ID in the SET list, the LIST table is searched for a match. When found, the pointer to the data is fetched. The data are sorted on the applied point (except GRAV and PLØAD data) and the data written on the SLT. As a result, each logical record of the SLT contains all data for one set. Finally, if combination load cards are present, they are copied from GEØM3 to the last record of the SLT.

If core will not hold the entire load data, the logic is similar to above except that SCR1 is passed once for each set and only data belonging to a single card type within a set are read into core.

4.25.8.4 Subroutine Name: GP3B

1. Entry Point: GP3B
2. Purpose: To assemble the grid point related temperature data and store on the SCRATCH1 file.
3. Calling Sequence: CALL GP3B
4. Method: EQEXIN is read into core. A list of default temperatures (TEMPD cards if present) is read from GEØM3. The temperature data (TEMP cards) are read to determine the number of temperature sets, the set identifications and the number of entries in each temperature set. For each temperature set, a three-word entry is written in the header record of the SCRATCH1:

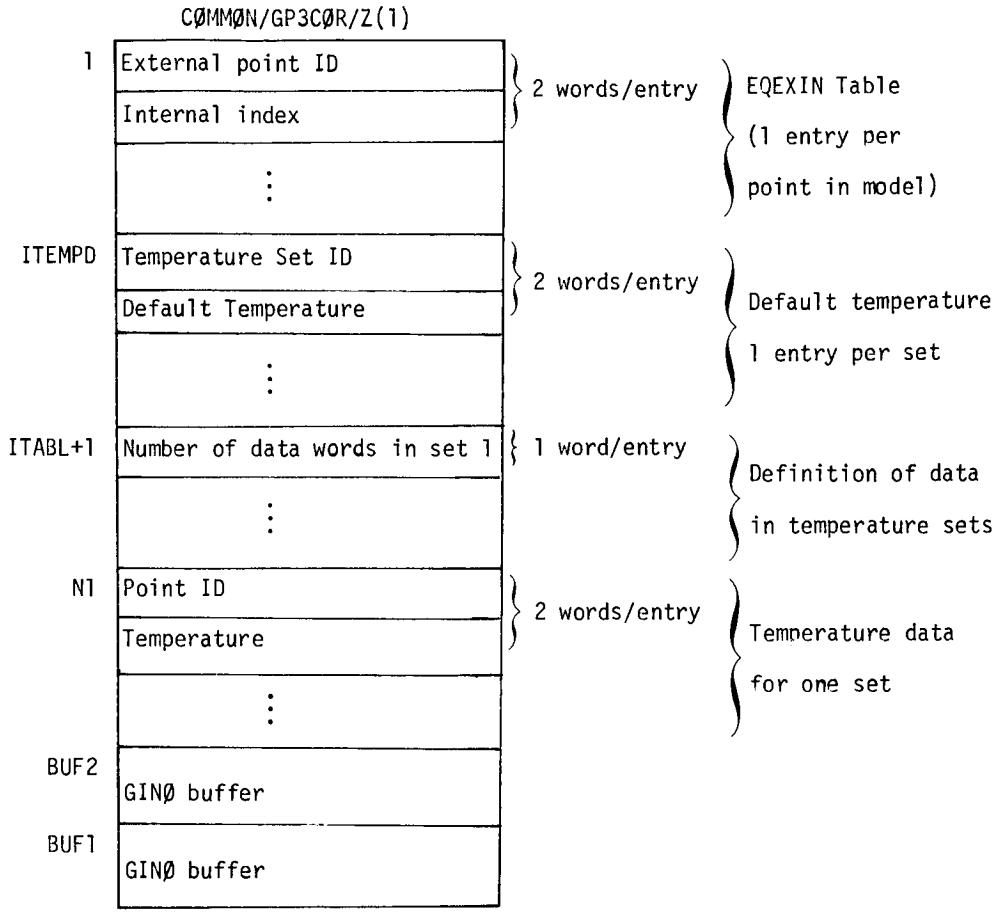
   Word 1 = Set ID

   Word 2 = default temperature (real) or -1 (integer)

   Word 3 = record number in SCRATCH1 of temperature data for the set or zero if only default temperature is defined.

   GEØM3 is backspaced one logical record. The temperature data are re-read. When all temperature data for a set have been read into core, the data are sorted on point identification and written as one logical record on SCRATCH1. This process is repeated for each temperature set.

   Allocation of core storage for GP3C is as follows:


CØMMØN/GP3CØR/Z(1)
1
External point ID
Internal index
2 words/entry
EQEXIN Table
(1 entry per
point in model)
ITEMPD
Temperature Set ID
Default Temperature
2 words/entry
Default temperature
1 entry per set
ITABL+1
Number of data words in set 1
1 word/entry
Definition of data
in temperature sets
N1
Point ID
Temperature
2 words/entry
Temperature data
for one set
BUF2
GINØ buffer
BUF1
GINØ buffer

4.25.8.5 Subroutine Name: GP3D

1. Entry Point: GP3D

2. Purpose: To process TEMPP1, TEMPP2, TEMPP3, and TEMPRB data and assemble the element temperature table referred to as the GPTT.

3. Calling Sequence: CALL GP3D

4. Method: TEMPP1, TEMPP2, TEMPP3, and TEMPRB card data are read from GEØM3, converted for GP3D's use and written on SCRATCH2. The grid point temperature data header is then read from SCRATCH1 (as created in GP3B). A similar header record is then constructed from the union of the grid point temperature set data and the element temperature set data. This is written on GPTT. For each temperature set, for which there is other than a default temperature available, a record is then written on the GPTT containing specific element temperature data by element type and element identification. Allocation of core storage for GP3D is as follows:

Element temperature set list data (2 words/entry)	Z(1) Z(NLIST)
Grid point temperature set list data (3 words/entry)	Z(IGPTT) Z(NGPTT)
Grid point data for current temperature set (2 words/entry)	Z(IGPT) Z(NGPT)
TEMPP1, TEMPP2, TEMPP3 data for current temperature set (7/words/entry)	Z(IET1) Z(NET1)
TEMPRB data for current set ID (15 words/entry)	Z(IET2) Z(NET2)
⋮ unused	
GINØ buffer	Z(BUF2)
GINØ buffer	Z(BUF1)

4.25.9 Design Requirements

4.25.9.1 Allocation of Core Storage

The core storage maps presented in the method sections of GP3A, GP3B and GP3C provide detailed storage requirements. A summary is presented here.

GP3C: Maximum requirement = 6* (number of PLØAD2 + number of PLØAD cards) + one GINØ buffer.

GP3A: Let NPTS = number of grid + number of scalar points and NSETS = (number of load sets) * (number of card types per load set) and SYSBUF = one GINØ buffer.

Then maximum storage requirement equals MAX ((2*NPTS+4*NSETS+2*SYSBUF), (4*NSETS + MAX (number of words for one set of one card type) + SYSBUF)).

GP3B: See storage map.

4.25.9.2 Environment

1. Block Data

The block data program GP3BD initializes /GP3CØM/ with GINØ file names, data defining the load cards and other miscellaneous data. It must be resident in core when GP3 is executed.

2. General

/GPTA1/ is used by GP3C and must be core resident when GP3 is executed. Open core is defined by /GP3CØR/. The normal overlay is to include GP3BD, GP3, GP3C, GP3A, GP3B in one segment. GP3 uses two scratch files.

4.25.10 Diagnostic Messages

The following messages may be issued by GP3:

2008, 2009, 2015, 3008, 4010, 4011, 4012. See Section 6 of the User's Manual for details.

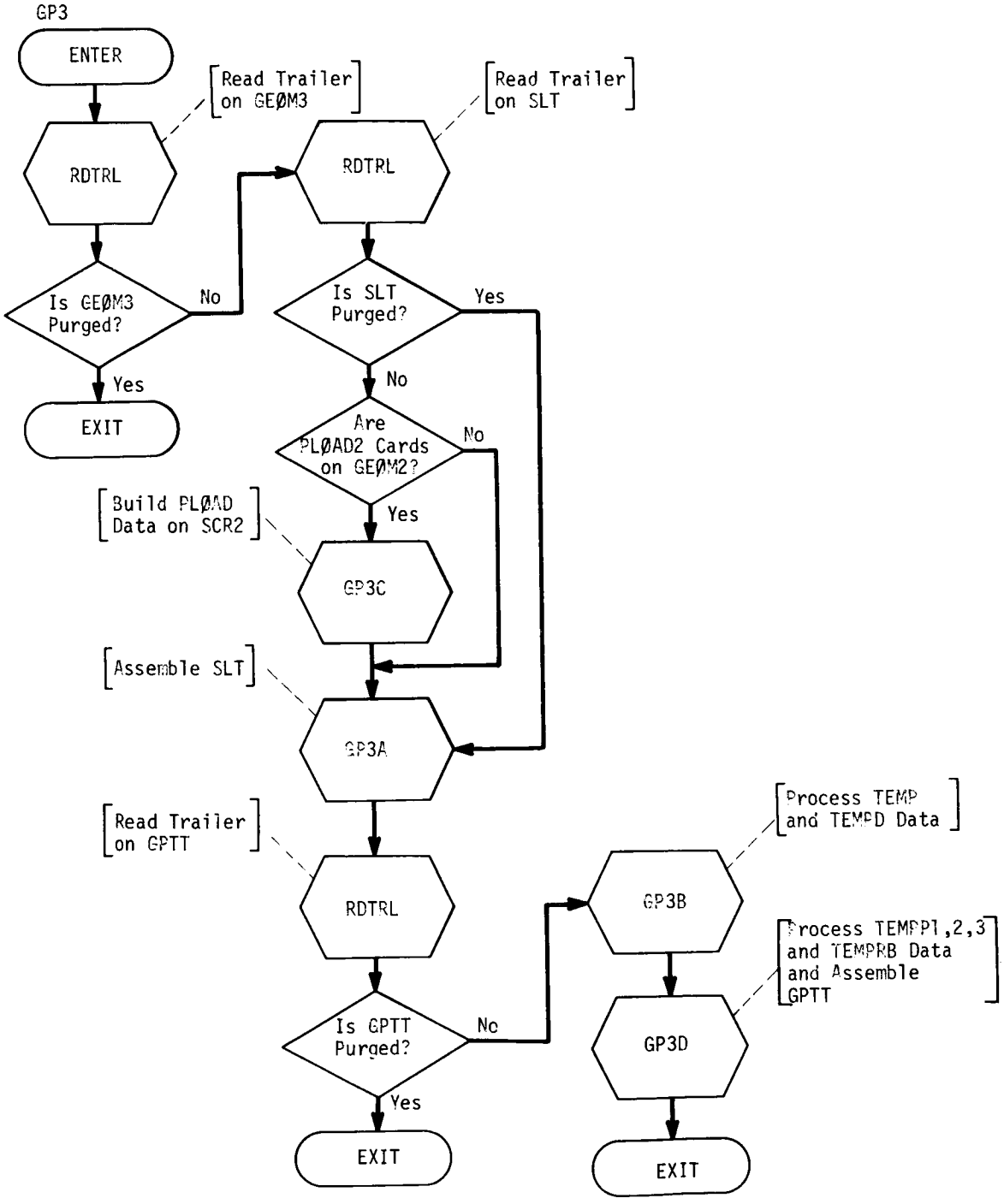


Figure 1. Flowchart for module GP3

4.26 FUNCTIONAL MODULE TA1 (TABLE ASSEMBLER)

4.26.1 Entry Point: TA1

4.26.2 Purpose

TA1 processes element connection data, element property data and geometry. These data are merged in two different sorts for efficiency in later processing. The Element Summary Table contains, for each element, connection, property and geometry data. The Element Connection and Properties Table contains, for each grid or scalar point in the model, connection, property and geometry data for all elements connected to the point. Element temperature data are also included for both data blocks where applicable. Additionally, general elements are processed and the GEI (General Element Input) data block is assembled.

4.26.3 DMAP Calling Sequence

```
TA1,    ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,ECPT,GPCT/V,N,LUSET/V,N,NSIL/V,N,NØSIMP
        /C,N,0/V,N,NØGENL/V,N,GENEL  $
```

4.26.4 Input Data Blocks

ECT - Element Connection Table.

EPT - Element Properties Table.

BGPDT - Basic Grid Point Definition Table.

SIL - Scalar Index List.

GPTT - Grid Point Temperature Table.

CSTM - Coordinate System Transformation Matrices.

Note: The ECT, BGPDT and SIL data blocks may not be purged.

4.26.5 Output Data Blocks

EST - Element Summary Table.

GEI - General Element Input.

ECPT - Element Connection and Properties Table.

GPCT - Grid Point Connection Table.

Note: No output data block may be purged.

4.26.6 Parameters

LUSET - Input-integer-no default. Degrees of freedom in the g-displacement set.

NSIL - Output-integer-no default. Number of grid points plus number of scalar points in the model.

NØSIMP - Output-integer-no default. Number of elements in the model (exclusive of general elements) or -1 if no elements.

NØGENL - Output-integer-no default. Number of general elements in the model or -1 if no general elements.

GENEL - Output-integer-no default. GENEL = -NØGENL.

4.26.7 Method

4.26.7.1 General Comments

The purpose of the Table Assembler Module is to combine all of the element data in a convenient form for the generation of the structural matrices (ECPT) and for the calculation of the element stresses and forces (EST). The complete description of an element requires: (1) the locations of the connected grid points, (2) necessary orientation data and end conditions, (3) element properties, (4) a material reference, (5) transformations from the basic system to the global coordinate system and (6) element temperature. Scalar elements require no geometric or material data. General elements may require geometric data.

Four data blocks are formed in this module. The ECPT data block is used in structural matrix generation. It contains all element data for each grid point or scalar point in the order of the sequenced grid point numbers (internal grid point indices). The EST data block contains element data in groups of element type and with sequential element I.D. numbers within each group. It is used to calculate element stresses and forces in a convenient order for output. The GEI data block contains the general element flexibility and support matrices. The GPCT data block is used to allocate storage in the structural matrix assemblers.

The reason for assembling the ECPT and EST tables rather than generating functions such as element stiffness matrices and stress functions is the expected size of the problems. The computing time used to recalculate certain data is expected to be compensated for by the time savings that result from sorting and merging smaller tables.

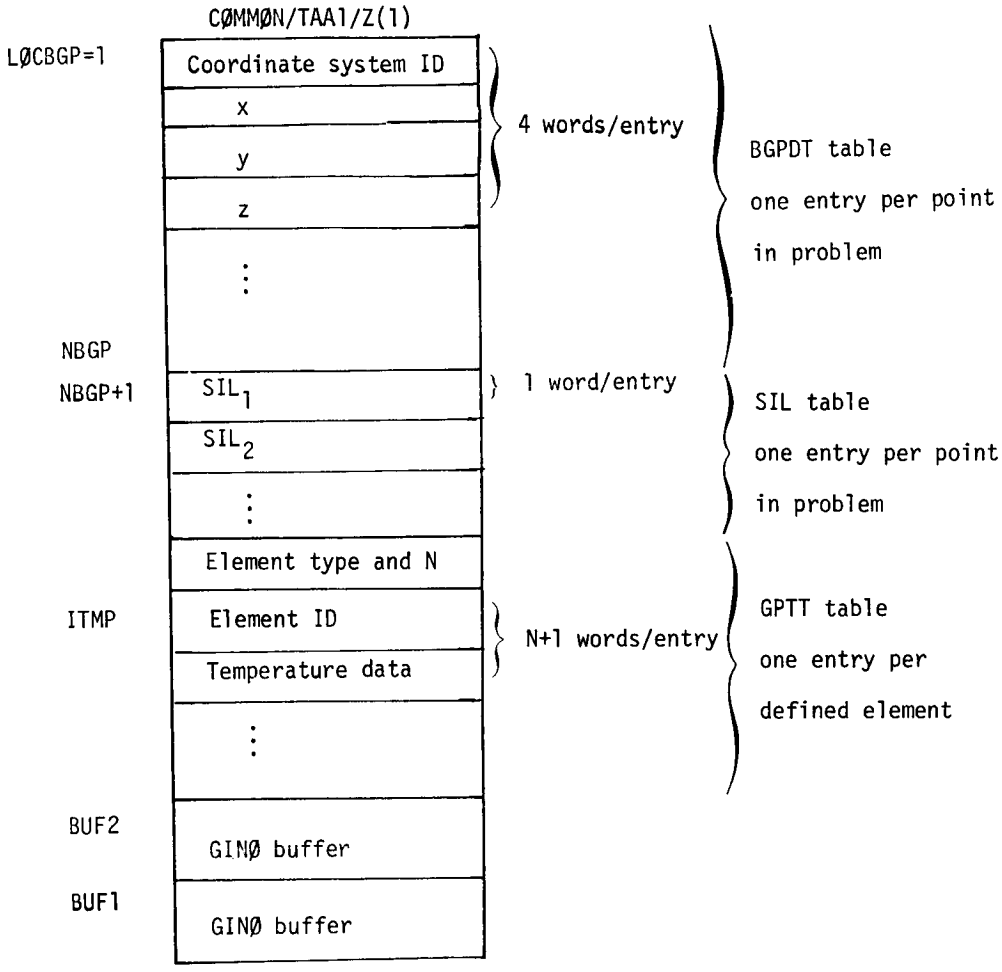
Subroutine TA1 is the main control program for the module. It executes each of the major routines of the Table Assembler (TA1A to assemble the EST, TA1B to assemble the ECPT and GPCT, and TA1C to assemble the GEI) depending on the status of the data blocks and data for the problem. A flow chart of TA1 is included as Figure 1.

4.26.7.2 TA1A

Assembly of the Element Summary Table is performed in two steps. For the first step, the EPT is read into core one property type at a time. The ECT is read one element at a time. For each element the referenced property data are found by performing a binary search in the EPT in core. The ECT and EPT data are written on SCR1, a scratch file, one element at a time. one logical record per element type.

To initiate the second step, the BGPDT and SIL data blocks are read into core. If a temperature set is selected, the appropriate temperature data from the GPTT are read into core. Data from SCR1 are read one element at a time. Internal indices for the grid points are used as pointers into the BGPDT and SIL tables. The temperature of the element is extracted from the GPTT data block. Each temperature is found by performing a binary search in the GPTT with the element identification number. If the entry is not found in the GPTT, the default temperature for the set is substituted. The internal indices are now replaced with corresponding scalar index values. A line comprising ECT, EPT, BGPDT and GPTT data for the element is written on the EST. Each logical record of the EST comprises all data of one element type.

Allocation of core storage during the second step is as follows:



4.26.7.3 TA1B

The ECPT data block is assembled in TA1B. Each logical record in the ECPT corresponds to a grid or scalar point in the model. For each point, the data for each element connected to the point are listed. The data for each element are identical to the EST data. Each set of element data will be listed in the ECPT "n" times, where "n" is the number of grid points connected by the element. A sample of the ECPT is given in Table 1. The logical phases of the operation are as follows:

A list is formed in core giving the relative locations of the elements in the ECT data in the order which they will be placed in the ECPT data block. Storage is allocated by

forming the GPC (Grid Point Counter) and then replacing the GPC by a running sum of elements connected to points. A sample is:

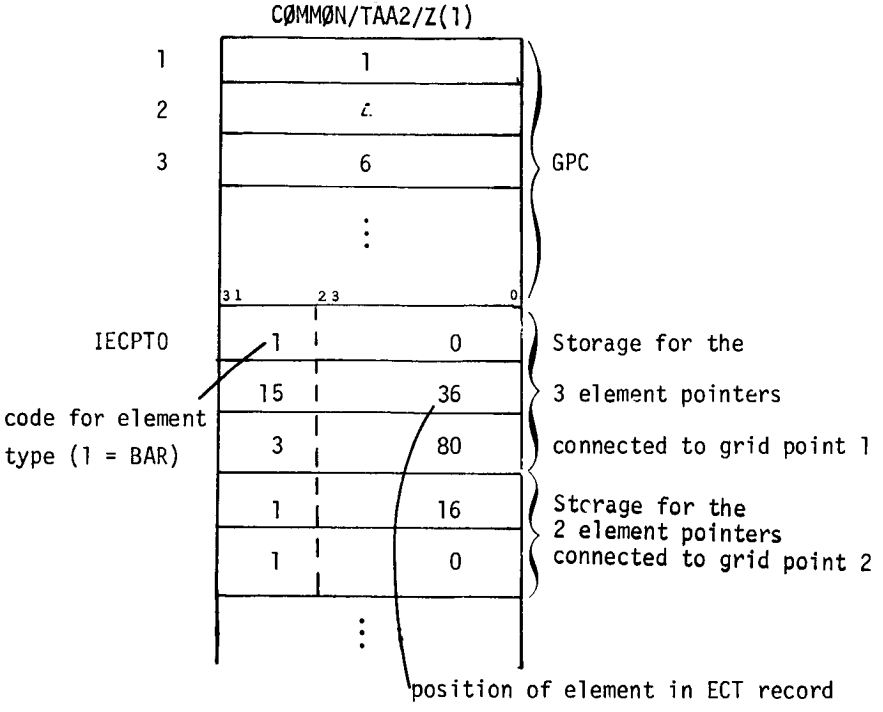
Implied Grid Point internal index	GPC Number of Connected Elements	GPCS Sum of Previous Elements
(1)	5	0
(2)	3	5
(3)	1	8
(4)	2	9
(5)	6	11
.	.	17
.	.	.
.	.	.
.	.	.

The GPC is formed as follows. An area of core equal to the number of grid and scalar points of the model is set to zero. The ECT is read one element at a time. The storage location corresponding to the internal index of each referenced grid point is incremented by one. When each element in the ECT has been processed, a running sum of the core table is formed.

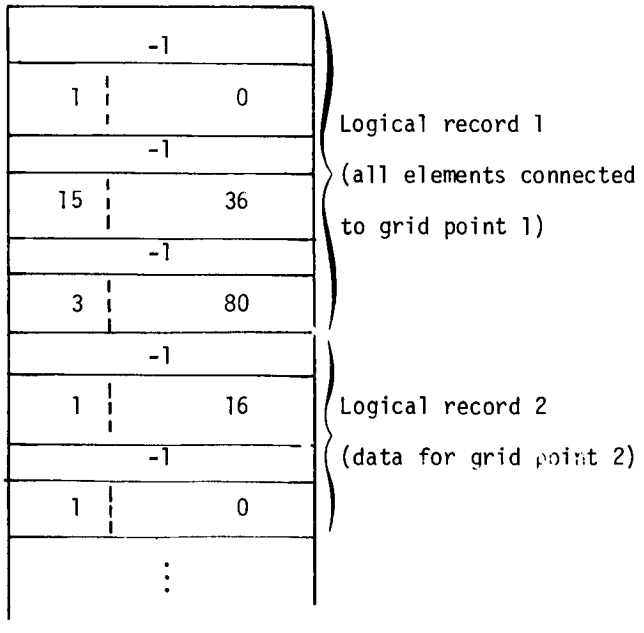
The contents of each word in the GPC now provide a pointer to the first storage location where a second pointer to the element data will be stored. Since the total number of connected elements may exceed available core storage, spill logic is provided. A band of entries in the GPC is determined. The ECT is read one element at a time. The position of each element of a given element type is determined by summing the number of words for each entry for the element (i.e. if m = number of words per ECT entry, then the position of the element in the ECT record = (i-1)*m where i = entry number in the ECT record). For each point referenced by the element (which is in the band currently being processed), the contents of the associated position in the GPC is fetched. The element position and its type are stored at the indicated locations.

The location in the GPC is incremented by one. When a pass of the ECT is complete, the skeleton ECPT is written, one logical record per point in the band of the current pass. Each

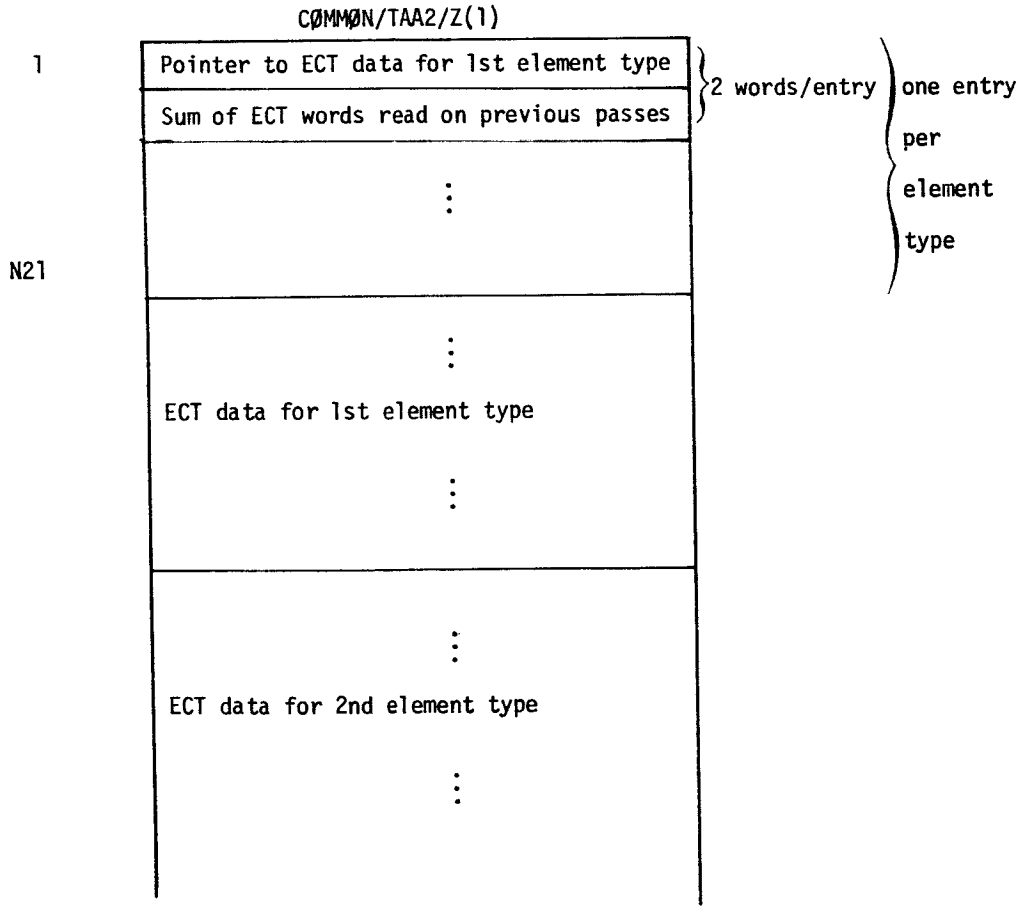
logical record consists of pairs of (-1, element pointer). The number of pairs equals the number of elements connected to the point. Example:



Skeleton ECPT data is written on a scratch file:



When all entries of the GPC have been processed, the skeleton ECPT is complete. An area of core equal to two words per element type is set to zero. The ECT is read into core following the above table until either the ECT is exhausted or core is filled. A pointer to the beginning of data for each element type is stored in the table. The skeleton ECPT is now read one pair of words at a time. If the data to which the element pointer points are currently in core, they are written out on a second scratch file. The first word of the entry contains the number of words in the ECT data. If the data are not in core, the pair (-1, element pointer) is written on the second scratch file. This process is repeated until the skeleton has been exhausted. If all the ECT is in core, the new skeleton ECPT is complete. Otherwise, the files for old and new skeleton ECPT are switched, and the process continues by reading more of the ECT data into core. Storage allocation at this point follows:



The remainder of the ECPT assembly is very similar to the EST construction. The principal difference is that the entire EPT is held in core. A pointer table similar to the ECT table is formed (two entries per element type). The EPT is read into core, and the first position of each EPT type is stored in the table along with the number of EPT entries of that type. If the BGPDT, SIL and GPTT can be held in core with the EPT, the ECPT is assembled in one pass. Otherwise, two passes are made. The skeleton ECPT is read one entry at a time. For each element, the property data are attached by performing a binary search in the associated property table in core. If one pass, the BGPDT, SIL and GPTT data are attached as in TA1A. Otherise the ECT and EPT data are written on a scratch file, and a second pass is made to attach the BGPDT, SIL and GPTT data. Table 1 contains sample ECPT contents.

During the final pass of the ECPT assembly, the GPCT is constructed. The GPCT is comprised of one logical record per point (same as ECPT). Each logical record consists of the pivot point and all other points connected to the pivot by means of element connections.

Table 1. Sample ECPT Data Contents.

Reference Grid Point First Scalar Index (Pivot Point)	235
1st Element Type	9 (Triangular membrane)
Connected Grid Point First Scalar Indices (From ECT and SIL)	625 235 535
Anisotropic Angle (From ECT)	0.0
Material Number (From EPT)	2
1st Element Properties (From EPT)	0.5 0.0 1.0
Location and Orientation Data for Grid Points (From BGPDT)	5, 10.0, 100.0, 0.0 5, 11.0, 100.0, 0.0 0, 235.0, 50.0, 25.0
Element Temperature (From GPTT)	15.5
2nd Element Type	34 (Bar)
. . etc. . .	
Last Element Type (for point 235)	1 (Rod)
. . etc. . .	
End of Logical Record (new grid point)	******
Reference Grid Point First Scalar Index (Pivot Point)	241
. . etc. .	

4.26.7.3 TA1C

The General Element flexibility and support matrices are assembled in TA1C. The data, given in the ECT data block, consist of the following sections for each General Element:

1. A list of the independent degrees of freedom, u_i, in terms of grid points and components and/or scalar points.
2. A list of supporting degrees of freedom, u_d, given by grid and scalar points (May be null).
3. A flexibility matrix [Z] with rows and columns corresponding to the list of given u_i points.
4. A support matrix [S] with rows corresponding to the u_i points and columns corresponding to the u_d points. (May be null).

The tasks of TA1C are to (1) convert the lists of u_i and u_d to scalar indices and sort them by increasing scalar index, (2) rearrange the matrices to correspond to the sorted lists of u_i and u_d degrees of freedom, and (3) on user option calculate the support matrix from grid point geometry.

These tasks are accomplished as follows:

1. For each set of coordinates (u_i and u_d) of length n, a 4xn table is formed where the four entries corresponding to each degree of freedom are:
   a) The position as given (1, 2, 3 ...n)
   b) The internal position (zero initially)
   c) The grid or scalar point I.D. (Internal index)
   d) The grid point component (1 = x, 2 = y, etc)
2. The list is sorted on the third and fourth position. If a point I.D. in the third position is duplicated, the duplicates are sorted on the components in the fourth position. The list now corresponds to the desired order of increasing scalar indices.
3. The SIL data block is read, and each of the points in the list is converted to its SIL value. (The position of a SIL number is its internal point index.) The SIL value and the component c_i determine the scalar index, N_i, of a degree of freedom by:

$$N_i = SIL + (c_i - 1) \quad (1)$$

for grid points and

$$N_i = SIL \quad (2)$$

for scalar points.

The list of scalar indices is written on the GEI data block file.

4. In order to rearrange the matrices to correspond to the proper sequence of degrees of freedom the above list is modified as follows:

   a) The internal position number is placed in the second position of each entry in the list. The first entry uses 1, the second, 2, etc.

   b) The list is sorted again to return the original order as given on the input card images. The first position of each entry supplies this order. The internal position of a term in a matrix is now given by the second numbers in each entry.

5. Steps (1) through (4) are repeated for both the u_i and u_d sets.

6. The [Z] and [S] matrices are rearranged according to the sorted lists of degrees of freedom. The row and column numbers are converted by the algorithm:

   a) For a term of Z_{ij}, where i and j are the row and column as given by the matrix order, the position i of the u_i irternal number list gives ℓ, the new column number.

   b) For a term of S_{ij}, where i and j are the external row and column numbers, the row number i is converted using the u_i list. The column number j uses the u_d list.

   If a matrix is small enough to fit in core, the new row and column numbers are used to place the term in its correct position in core. If the matrix will be larger than core, the new row and column indices and the term itself are written on a scratch file. When all terms are processed, the file is sorted to form a sequenced matrix. The terms of the matrix are written on the GEI file in full matrix form.

4.26.7.4 TAlCA

The [S] matrix must be generated if the user inputs a list of six u_d points and does not supply an [S] matrix. This is accomplished in subroutine TAlCA as follows:

The BGPDT and CSTM data are read into core. (SIL is already in core).

A six by six matrix $[D_o]$ is formed, where each row corresponds to a u_d scalar index (j). $[D_o]$ is a six by six matrix which transforms the three translations and three rotations in the basic coordinate system to the six rigid body u_d degrees of freedom:

$$\{u_d\} = [D_0] \begin{Bmatrix} x_o \\ y_o \\ z_o \\ \theta_{xo} \\ \theta_{yo} \\ \theta_{zo} \end{Bmatrix}_{\text{basic}} \tag{3}$$

The steps for generation of each row of [D] are as follows:

1. X_j, Y_j, Z_j the BGPDT location vector for the grid point containing scalar point j is found.
2. $[T_j]$ the 3x3 global-to-basic transformation matrix for the grid point containing j is fetched using subroutine MAT.
3. If scalar j is a translation, define:

$$[E_j] = \begin{bmatrix} 1 & 0 & 0 & 0 & Z_j & -Y_j \\ 0 & 1 & 0 & -Z_j & 0 & X_j \\ 0 & 0 & 1 & Y_j & -X_j & 0 \end{bmatrix} \tag{4}$$

The column of $[T_j]$ corresponding to the degree of freedom j is defined as the row vector $\{V_j\}^T$. The row vector of $[D_o]$ corresponding to point j is:

$$\{D_{oj}\}^T = \{V_j\}^T [E_j]. \tag{5}$$

4. If scalar j is a rotation, the column of $[T_j]$ corresponding to the degree of freedom j is defined as the row vector $\{V_j\}^T$. The row vector of $[D_o]$ corresponding to point j is:

$$\{D_{oj}\}^T = \{0\ 0\ 0:\ V_j^T\}. \tag{6}$$

When all 6 rows $[D_o]$ have been generated, the matrix is inverted:

$$[H_{do}] = [D_o]^{-1}. \tag{7}$$

$[H_{do}]$ transforms the u_d displacements to rigid body motions about the basic coordinate system, i.e.:

$$\left\{\begin{array}{c} X_o \\ Y_o \\ Z_o \\ \theta_{xo} \\ \theta_{yo} \\ \theta_{zo} \end{array}\right\}_{\text{basic}} = [H_{do}]\{u_d\} \tag{8}$$

If the matrix is ill-conditioned, a fatal error exists.

The [S] matrix may now be calculated a row at a time. The list of u_i points, (s_i), is read one at a time, and the [S] matrix is formed a row at a time. Call each row $\{S_i\}^T$.

The steps for generation of each row are as follows:

1. Using the basic coordinates X_i, Y_i, Z_i for the grid point corresponding to scalar s_i, the global-to-basic transformation matrix $[T_i]$ is fetched.

2. The column of $[T_i]$ corresponding to the scalar coordinate of u_i is defined as the row vector $\{V_i\}^T$.

3. If u_i is a translation, we form

$$[E] = \begin{bmatrix} 1 & 0 & 0 & 0 & Z_i & -Y_i \\ 0 & 1 & 0 & -Z_i & 0 & X_i \\ 0 & 0 & 1 & Y_i & -X_i & 0 \end{bmatrix} , \quad (9)$$

and

$$\{S_i\}^T = \{V_i\}^T [E] [H_{od}] . \quad (10)$$

4. If u_i is a rotation:

$$\{S_i\}^T = \{0\ 0\ 0 : V_i^T\} [H_{od}] . \quad (11)$$

4.26.8 Subroutines

4.26.8.1 Subroutine Name: TA1

1. Entry Point: TA1
2. Purpose: Module driver.
3. Calling Sequence: CALL TA1

4.26.8.2 Subroutine Name: TA1A

1. Entry Point: TA1A
2. Purpose: To assemble the EST.
3. Calling Sequence: CALL TA1A

4.26.8.3 Subroutine Name: TA1B

1. Entry Point: TA1B
2. Purpose: To assemble the ECPT and GPCT.
3. Calling Sequence: CALL TA1B

4.26.8.4 Subroutine Name: TA1C

1. Entry Point: TA1C

2. Purpose: To assemble the GEI.

3. Calling Sequence: CALL TA1C

4.26.8.5 Subroutine Name: TA1CA

1. Entry Point: TA1CA

2. Purpose: To calculate the general element support matrix [S].

3. Calling Sequence: CALL TA1CA

4.26.9 Design Requirements

2.26.9.1 Allocation of Core Storage

TA1A. Step (1): Maximum core storage equals all property data for one element type plus three GINØ buffers.

Step (2): Maximum core storage equals 5* (number of grid and scalar points in model) plus 2* (number of grid point temperatures in selected set) plus two GINØ buffers.

TA1B. The initial steps of TA1B are open ended. The final assembly of the ECPT requires that all EPT data be held in core at one time. At another time the same storage requirement as TA1A exists plus additional storage to hold a list of the maximum number of points connected to any one point by means of element connections.

TA1C. The maximum storage requirement equals 5* (number of grid and scalar points in the model) plus the CSTM table plus 4* (number of u_i + number of u_d points) plus three GINØ buffers.

4.26.9.2 Environment

TA1 is designed to allow each of the major phases of the module to be in a separate overlay segment. Open core for each is defined as follows:

TA1A: /TAA1/

TA1B: /TAA2/

TA1C: /TAC1/

GINØ file names and DMAP parameters are communicated through blank CØMMØN. No block data program is used. Communication between TA1C and TA1CA occurs through /TA1CAX/ and /TAC1/.

4.26.10 Diagnostic Messages

The following messages may be issued by TA1:

2010, 2011, 2013, 2014, 2015, 2044, 2045, 2063, 2082

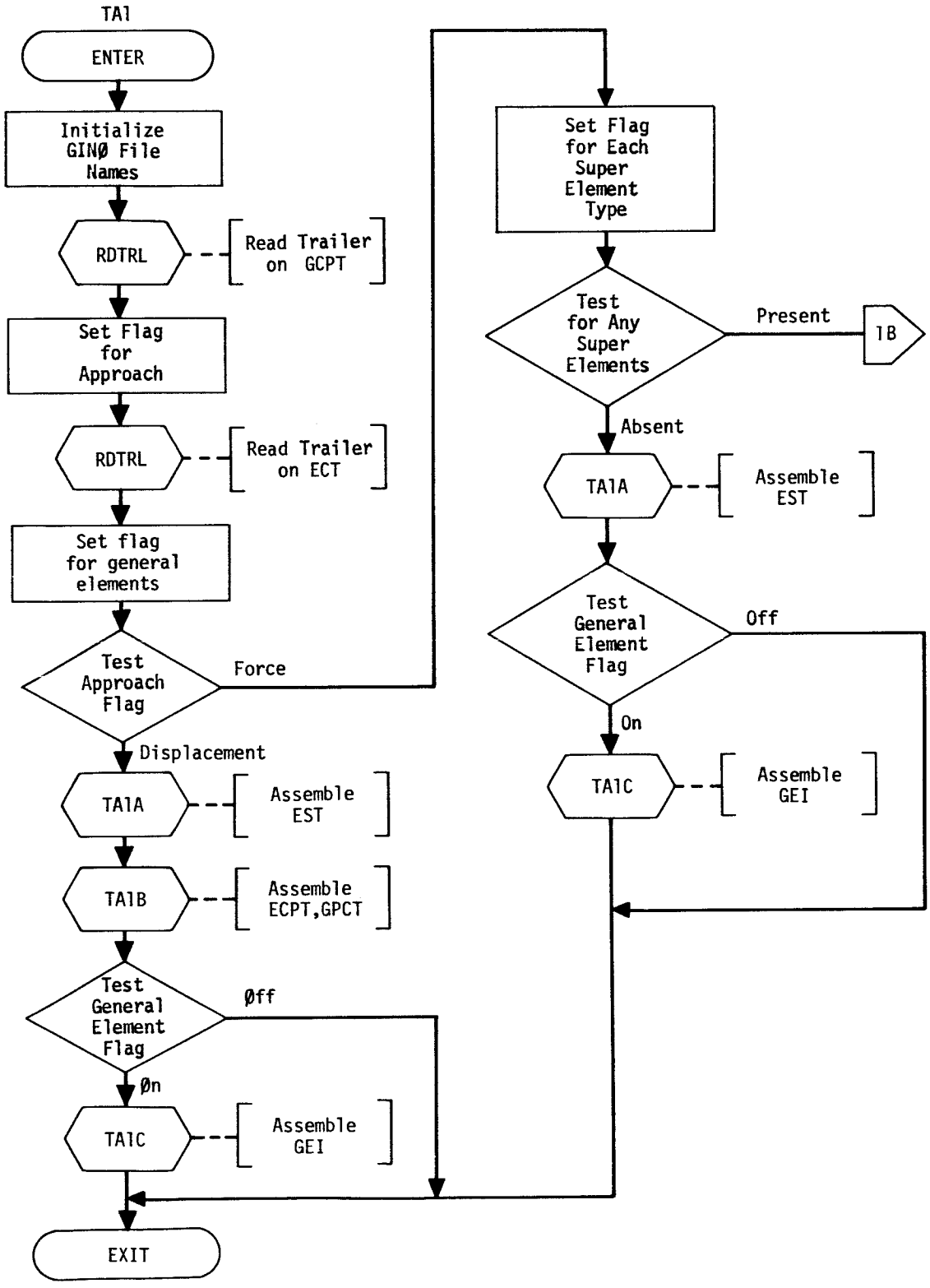


Figure 1(a). Flowchart for module TA1

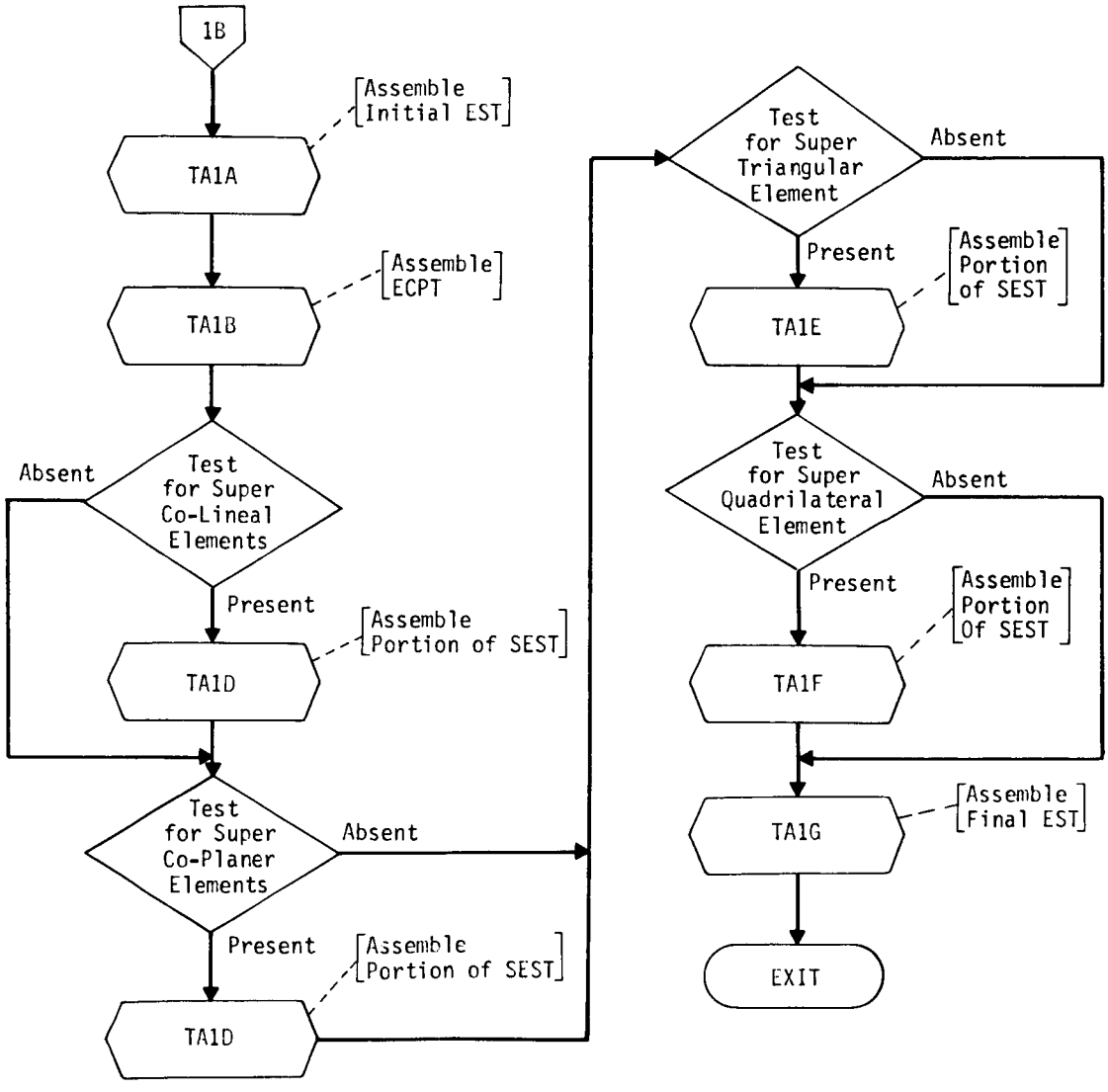


Figure 1(b). Flowchart for module TA1

4.27 FUNCTIONAL MODULE SMA1 (STRUCTURAL MATRIX ASSEMBLER - PHASE 1)

4.27.1 Entry Point: SMA1

4.27.2 Purpose

To generate the stiffness matrix exclusive of general elements, $[K^{x}_{gg}]$, the structural damping matrix, $[K^{4}_{gg}]$, and the Grid Point Singularity Table, GPST.

4.27.3 DMAP Calling Sequence

```
SMA1    CSTM,MPT,ECPT,GPCT,DIT/KGGX,K4GG,GPST/V,N,NØGENEL/V,N,NØK4GG    $
```

4.27.4 Input Data Blocks

CSTM	-	Coordinate System Transformation Matrices.
MPT	-	Material Properties Table.
ECPT	-	Element Connection and Properties Table.
GPCT	-	Grid Point Connection Table.
DIT	-	Direct Input Tables.

Notes:
1. The CSTM may be purged.
2. The ECPT and the GPCT cannot be purged, or else a fatal error will occur.
3. If some element references a material property, the MPT cannot be purged.
4. If some material property is temperature dependent, DIT cannot be purged.

4.27.5 Output Data Blocks

KGGX	-	Partition of stiffness matrix exclusive of general elements - g set.
K4GG	-	Partition of structural damping matrix - g set.
GPST	-	Grid Point Singularity Table.

Notes:
1. Neither KGGX or GPST may be pre-purged.
2. If K4GG is pre-purged, K4GG will not be generated.
3. If NØGENL > 0 (see below) the GPST will not be generated.

4.27.6 Parameters

NØGENL - Input-integer-no default value. NØGENL is the number of general

elements in the model. If NØGENL > 0 then GPST will not be generated.

NØK4GG - Output-integer-no default value. If K4GG has been pre-purged or is the zero matrix, NØK4GG is set equal to -1. Otherwise NØK4GG is set = +1.

4.27.7 Method

Matrix generation modules such as SMA1, SMA2, DSMG1 and PLA4 all use the ECPT (or a variation thereof in the case of PLA4) and its companion data block, the GPCT, as the basic data blocks for generation of stiffness and structural damping matrices (SMA1), mass and viscous damping matrices (SMA2), the differential stiffness matrix (DSMG1), and the non-linear stiffness matrix (PLA4). The central role of the ECPT data block in these modules is discussed in section 1.8.

Subroutine SMA1 is the module driver. Its tasks are: to set up GINØ buffers and matrix control blocks for the output matrices; to determine if the CSTM data block exists, and, if it does, to read it into open core and call the initialization routine PRETRD; to call the material properties initialization routine PREMAT, where material property cards and tables are read into open core; to open and position all files so that input data blocks are ready to be read and output data blocks are ready to be written; to call subroutine SMA1A, the module "workhorse", which will create the output data blocks. Upon return from SMA1A, files are closed and trailers are written. Subroutine descriptions for PRETRD and PREMAT can be found in section 3.4.37 and 3.4.36 respectively.

Subroutine SMA1A consists entirely of a loop in which, during each pass of the loop, a record of the GPCT and a record of the ECPT are processed in a complementary manner. Each pass through this principal loop creates either one or six rows (or columns since $[K^x_{gg}]$ and $[K^4_{gg}]$ are symmetric of the stiffness matrix, KGGX, (and the structural damping matrix, K4GG, if called for in the DMAP calling sequence). One row will be generated if the pivot point, the first word of both the GPCT record and the ECPT record, is a scalar point; six rows will be generated if the pivot point is a grid point. The latter case holds in the majority of cases. The loop is terminated when an end-of-file is sensed on the file containing the GPCT.

The loop begins by attempting to read the first two words of the current GPCT record. If the second non-standard return from subroutine READ occurs, it implies the current pivot point has no elements connected to it so that one or six null rows must be output for the

matrices. This non-standard return, it should be noted, does not occur in the majority of cases. A normal return from READ implies a normal path through the principal loop. The remainder of the GPCT record is read into core, and a pointer table is constructed. This pointer table relates the scalar index numbers of the GPCT record, which are the column indices of the (possible) non-zero terms of the generated matrices, to locations in core in which the corresponding submatrices will reside. The pointer table is defined recursively as follows:

$$p_1 = 1 \tag{1}$$

$$p_i = p_{i-1} + q, \; i > 1 \tag{2}$$

where q is 6 if the point (i-1) is a grid point and q is 1 if the point (i-1) is a scalar point.

It is then determined if all the submatrices corresponding to the current pivot point can be held in open core. If they can, there is no problem. If they cannot, spill logic is provided only if the structural damping matrix is not called for. Rather than compute all submatrices, store them on a scratch file, retrieve them when computations have been completed and sort them, the following approach was adopted. It is determined what the maximum number of rows that can be held in core is: 3, 2 or 1. The element submatrices are computed in their respective routines (i.e. KRØD, KBAR) and passed to the "insertion" subroutine, SMA1B, which "inserts" into the correct open core positions only those rows which can be contained.

When the ECPT record is exhausted, the link vector, LINK, (see discussion below of the LINK variable in /SMA1CL/) is searched to determine if any structural element entries in the ECPT were skipped because the corresponding element subroutine did not reside in the link (element subroutine overlay segment) currently in core. If there did exist such an element, the ECPT file is backspaced and the ECPT record is reprocessed such that all element submatrices not computed on the previous pass(es) of the ECPT record will be computed. If (or when) the LINK array is identically zero, signifying that all element submatrices corresponding to the current pass of the ECPT record have been computed, the DETCK subroutine is called if the input parameter NØGENL ≤ 0. DETCK generates the GPST by examining the "translational" and "rotational" diagonal 3 X 3 submatrices of the 6 rows of the KGGX matrix currently in core. If the total number of rows to be computed (6 or 1) for the current ECPT record is not in core due to spill problems, DETCK stores those elements of the 3 X 3 sub-

matrices currently in core in local variables and then processes the entire 3x3 submatrices on the last pass of the ECPT record (see definitions of the variables LRØWIC and NRØWSC in /SMA1CL/ below).

After DETCK returns, the number of rows in core are packed onto the KGGX (and, if called for, the K4GG) data block(s) using the standard matrix packing routines BLDPK, ZBLPKI and BLDPKN. If the last row in core is not equal to the total number of rows to be computed, the ECPT file is backspaced and the record is processed again, this time the next set of 3, 2 or 1 rows being output. If the last row in core is equal to the total number of rows to be computed, the processing of the ECPT record is complete and a transfer is made to the top of the "GPCT and ECPT processing" loop to process the next record of the GPCT and ECPT. The loop terminates when an end-of-file is encountered while attempting to read the GPCT. Upon loop termination, SMA1A returns to SMA1.

It should be noted that the most difficult logic of the routine involves the LINK vector and the spill logic. The programmer is advised that the LINK vector logic will not be used on any of the current hardware/software configurations because 1) the routine residing in segment (link) 2, KCØNE, cannot be used in conjunction with any other structural element routine and 2) the axisymmetrical element routines KTRIRG, KTRAPR and KTØRDR cannot (from a mathematical modeling point of view) be used in conjunction with any other structural element routines. The spill logic is very seldom entered since for the majority of cases the geometry of the mathematical model is such that the number of words in any GPCT record - and hence the number of (potentially) non-zero columns in any six rows of the matrix - is generally quite small. A high upper limit for the number of words in any GPCT record would be 40.

4.27.7.1 Determining Grid Point Singularities in Subroutine DETCK

Let the pivot point be a grid point with scalar index p in the following discussion. Let [Q] be the "translational" or "rotational" 3x3 symmetric submatrix along the diagonal of the stiffness matrix, $[K^{x}_{gg}]$, i.e., the rows and columns of the "translational" [Q] matrix would correspond to scalar index numbers p, p+1, and p+2; and the rows and columns of the "rotational" [Q] matrix would correspond to scalar index numbers p+3, p+4, and p+5.

The following steps comprise the algorithm for determining the presence or absence of grid point singularities. The discussion assumes [Q] is the "translational" 3x3 matrix but the same algorithm holds for the "rotational" [Q].

1. The matrix [Q] is scaled by the magnitude of the largest term, Q_{max}:

$$[B] = \frac{[Q]}{Q_{max}}. \tag{3}$$

If the largest term is non-positive, the singularity is of order 3, and the scalar index numbers p, p+1 and p+2 are written on the GPST.

2. The vector magnitudes of 3x1 columns (rows) are calculated:

$$b_1 = \sqrt{B_{11}^2 + B_{12}^2 + B_{13}^2}, \tag{4}$$

$$b_2 = \sqrt{B_{21}^2 + B_{22}^2 + B_{23}^2}, \tag{5}$$

$$b_3 = \sqrt{B_{31}^2 + B_{32}^2 + B_{33}^2}. \tag{6}$$

3. For each $b_i = 0$, the singularity order counter IØRDER is increased by one.

4. If two b_i are zero, the order of the singularity is two, and the scalar index numbers j and k corresponding to these two rows of [B] are written on the GPST.

5. If one b_i is zero, and i is the row such that $b_i = 0$, define j and k as the other rows of [B] and calculate:

$$m = \det \begin{bmatrix} B_{jj} & B_{jk} \\ B_{kj} & B_{kk} \end{bmatrix} , \tag{7}$$

$$R = \sqrt{\left(B_{jj}^2 + B_{kj}^2\right)\left(B_{jk}^2 + B_{kk}^2\right)} . \tag{8}$$

If $\frac{m}{R} < 10^{-2}$, the order of the singularity is 2 and the GPST contains the paired scalar index values for i, j, k in the order (1) (i,j) if $B_{kk} > 0$ or (2) (i,k) if $B_{jj} > 0$. If $\frac{m}{R} \geq 10^{-2}$, the order of the singularity is one and only the SIL value for i is written on the GPST.

6. If all $b_i > 0$, we calculate

$$D = \det [B] \tag{9}$$

If $D > .5 \times 10^{-2} \times (b_1 b_2 b_3)$, there are no singularities, and DETCK returns if [Q] is the "rotational" matrix. If [Q] is the "translational" matrix, the "rotational" [Q] is input to the algorithm.

7. If $D < .5 \times 10^{-2} \times (b_1 b_2 b_3)$, one or more singularities exist. The following terms are calculated:

$$m_1 = \det \begin{bmatrix} B_{22} & B_{23} \\ B_{32} & B_{33} \end{bmatrix} , \tag{10}$$

$$m_2 = \det \begin{bmatrix} B_{11} & B_{13} \\ B_{31} & B_{33} \end{bmatrix} , \tag{11}$$

$$m_3 = \det \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} , \tag{12}$$

$$R_1 = \sqrt{(B_{22}^2 + B_{23}^2)(B_{32}^2 + B_{33}^2)}\ , \tag{13}$$

$$R_2 = \sqrt{(B_{11}^2 + B_{13}^2)(B_{31}^2 + B_{33}^2)}\ , \tag{14}$$

$$R_3 = \sqrt{(B_{11}^2 + B_{12}^2)(B_{21}^2 + B_{22}^2)}\ . \tag{15}$$

8. Determine i, j, k such that:

$$\frac{m_i}{R_i} > \frac{m_j}{R_j} > \frac{m_k}{R_k}\ . \tag{16}$$

9. If $\frac{m_i}{R_i} < 10^{-2}$, the singularity is of order 2. Redefine i, j, k such that $B_{ii} < B_{jj} < B_{kk}$. The SIL values for the paired indexes (j,k), (i,k) and (i,j) are written on GPST only if the corresponding B is greater than zero. For instance if B_{kk} is zero, the SIL pair (i,j) is not written on the GPST.

10. If $\frac{m_i}{R_i} \geq 10^{-2}$, (see step 8) the singularity is of order 1. The SIL values are written on the GPST in the order

$$i \text{ since } \frac{m_i}{R_i} > 10^{-2}\ , \tag{17}$$

$$j \text{ if } \frac{m_j}{R_j} > 10^{-2}\ , \tag{18}$$

$$k \text{ if } \frac{m_k}{R_k} > 10^{-2}\ . \tag{19}$$

4.27.8 Subroutines

The utility routines PRETRD and PREMAT (or HMAT) are called in SMA1 for initialization purposes so that the structural element subroutines can call the entry points TRANSD of PRETRD and MAT of PREMAT (or HMAT) to fetch Coordinate System Transformation Matrices (CSTM) data and material properties data respectively. GMMATD is used by element routines as a general matrix multiply routine, and INVERD is used for inversion of small in-core (order usually $\leq$ 12) matrices. It should be noted that all matrices referenced in the structural element subroutines are stored by rows and are double precision. See the subroutine descriptions for these routines in Section 3.

The principal means of communicating an element entry of the ECPT to an element stiffness matrix generation routine is through /SMA1ET/. This fact is not explicitly stated in each of the descriptions of the element routines (e.g. KRØD) given below. Since much of the mathematics needed for generating: (1) element stiffness matrices (module SMA1); (2) element mass and damping matrices (module SMA2); (3) element contributions to load vectors (module SSG1); (4) element stress (and force) data recovery (module SDR2); (5) element differential stiffness matrices (module DSMG1); (6) element stress (and force) data recovery for non-linear elements in a Piecewise Linear Analysis Rigid Format problem (module PLA3); and (7) element stiffness matrices for non-linear elements in a Piecewise Linear Analysis problem (module PLA4), is similar or even identical, detailed mathematical algorithms are grouped by element in Section 4.87.

It should be noted that routines DKI,DKK,DKM,DKINT,DKJ,DKEF,DK89,DK100,KFAC,DKJAB,DK219, DK211,RØMBDK,D4K,D5K,D6K and DMATRX are used only (directly or indirectly) by the axisymmetric shell element routines KTRIRG, KTRAPR and KTØRDR.

4.27.8.1 Subroutine Name: SMA1

1. Entry Point: SMA1
2. Purpose: See discussion above.
3. Calling Sequence: CALL SMA1

4.27.8.2 Subroutine Name: SMA1A

1. Entry Point: SMA1A

2. Purpose: See discussion above.

3. Calling Sequence: CALL SMA1A

4.27.8.3 Subroutine Name: SMA1B

1. Entry Point: SMA1B

2. Purpose: This routine, called by the module's element stiffness matrix generation routines such as KRØD, KBAR, etc., adds a double precision 6 x 6 or 1 x 1 matrix, $[K^e]$, to the "submatrix" of $[K^x_{gg}]$ or $[K^4_{gg}]$ corresponding to the current pivot point.

3. Calling Sequence: CALL SMA1B (KE,J,II,IFILE,DAMPC)

KE - Row-stored double precision 6 x 6 or 1 x 1 matrix to be added to the submatrix in core - double precision - input.

J - The column index of the $[K^x_{gg}]$ or $[K^4_{gg}]$ matrix which corresponds to the first column of the $[K^e]$ matrix - integer - input.

II - If II is 0, the $[K^e]$ matrix is 6 x 6. If II is greater than zero, it is the row index of the $[K^x_{gg}]$ or $[K^4_{gg}]$ matrix corresponding to the 1 x 1 matrix $[K^e]$ to be added - integer - input.

IFILE - GINØ file number of the matrix in core being added to - KGGX or K4GG - integer - input.

DAMPC - If $[K^e]$ is 6 x 6 and the $[K^4_{gg}]$ matrix is called for, the input matrix $[K^e]$ is multiplied by DAMPC before being added to the submatrix of $[K^4_{gg}]$ in core.

4.27.8.4 Block Data Program Name: SMA1BD

1. Entry Point: SMA1BD

2. Purpose: Block data program which sets GINØ file numbers, I/Ø parameters, and SMA1 overlay parameters.

3. Calling Sequence: None

4.27.8.5 Subroutine Name: DETCK

1. Entry Point: DETCK

2. Purpose: This routine generates the Grid Point Singularity Table by examining the 3x3 "translational" and "rotational" diagonal submatrices of the KGGX matrix. This routine is called after the submatrix for each pivot point has been completed.

3. Calling Sequence: CALL DETCK (JARG)

JARG - { If JARG = 0, the pivot point has elements connected to it.
If JARG = -1, the pivot point is a scalar point and no elements are connected to it.
If JARG = 1, the pivot point is a grid point and no elements are connected to it.

4.27.8.6 Subroutine Name: KRØD

1. Entry Point: KRØD

2. Purpose: To generate the element stiffness matrix for a RØD element.

3. Calling Sequence: CALL KRØD

4.27.8.7 Subroutine Name: KBAR

1. Entry Point: KBAR

2. Purpose: To generate the element stiffness matrix for a BAR element.

3. Calling Sequence: CALL KBAR

4.27.8.8 Subroutine Name: KTUBE

1. Entry Point: KTUBE

2. Purpose: To generate the element stiffness matrix for a TUBE element.

3. Calling Sequence: CALL KTUBE

4.27.8.9 Subroutine Name: KPANEL

1. Entry Point: KPANEL

2. Purpose: To generate the element stiffness matrix for a SHEAR or TWIST panel element.

3. Calling Sequence: CALL KPANEL (IARG)

IARG - { IARG = 4 calls for generation of the matrix for a shear panel;
IARG = 5 implies a twist panel.

4.27.8.10 Subroutine Name: KTRMEM

1. Entry Point: KTRMEM

2. Purpose: To generate the element stiffness matrix for a TRMEM element.

3. Calling Sequence: CALL KTRMEM (I)

I = { 0 - Do complete triangular membrane.
1 - Return 3 transformed 3 x 3 matrices only for pivot point. If I = 1, KTRMEM is called by KQDMEM.

4.27.8.11 Subroutine Name: KQDMEM

1. Entry Point: KQDMEM

2. Purpose: To generate the element stiffness matrix for a QDMEM element.

3. Calling Sequence: CALL KQDMEM

4.27.8.12 Subroutine Name: KTRBSC

1. Entry Point: KTRBSC

2. Purpose: To generate the element stiffness matrix for a basic bending triangle element.

3. Calling Sequence: CALL KTRBSC (I)

I = { 0 - Do complete element computation for basic bending triangle
1 - Form only the $[K^U]$ 9x9 matrix.
2 - Form only the $[K^U]$ 9x9 matrix but save the $[H]^{-1}$ and [S] matrices.

4.27.8.13 Subroutine Name: KTRPLT

1. Entry Point: KTRPLT

2. Purpose: To generate the element stiffness matrix for a triangular plate element.

3. Calling Sequence: CALL KTRPLT

4.27.8.14 Subroutine Name: KQDPLT

1. Entry Point: KQDPLT

2. Purpose: To generate the element stiffness matrix for a quadrilateral plate element.

3. Calling Sequence: CALL KQDPLT

4.27.8.15 Subroutine Name: KTRIQD

1. Entry Point: KTRIQD

2. Purpose: To generate the element stiffness matrix for any of the following elements: TRIA1,TRIA2,QUAD1,QUAD2.

3. Calling Sequence: CALL KTRIQD (IARG)

IARG = { 1 - TRIA1 element.
2 - TRIA2 element.
3 - QUAD1 element.
4 - QUAD2 element.

4.27.8.16 Subroutine Name: KELAS

1. Entry Point: KELAS

2. Purpose: To generate stiffness matrix contributions from the ELAS1,ELAS2,ELAS3 and ELAS4 elements and structural damping matrix contributions from the ELAS1,ELAS2 and ELAS3 elements.

3. Calling Sequence: CALL KELAS (IARG)

IARG - Indicates the type of element being processed. It can take on the values 1,2,3 and 4 denoting the ELAS1,ELAS2,ELAS3 and ELAS4 elements respectively. Integer-input.

4.27.8.17 Subroutine Name: KBEAM

1. Entry Point: KBEAM

2. Purpose: To generate the element stiffness matrix for a BEAM element.

3. Calling Sequence: CALL KBEAM

4.27.8.18 Subroutine Names: KCØNE, KCØNEX

1. Entry Point: KCØNE, KCØNEX

2. Purpose: To generate the element stiffness matrix for a conical shell problem.

3. Calling Sequence: CALL KCØNE and CALL KCØNEX

4.27.8.19 Subroutine Name: KTRIRG

1. Entry Point: KTRIRG

2. Purpose: To calculate an element stiffness matrix for a triangular cross-section ring, TRIARG, element.

3. Calling Sequence: CALL KTRIRG

4.27.8.20 Subroutine Name: KTRAPR

1. Entry Point: KTRAPR

2. Purpose: To calculate an element stiffness matrix for a trapezodial cross-section ring, TRAPRG, element.

3. Calling Sequence: CALL KTRAPR

4.27.8.21 Subroutine Name: KTØRDR

1. Entry Point: KTØRDR

2. Purpose: To calculate an element stiffness matrix for a toroidal thin shell ring, TØRDRG, element.

3. Calling Sequence: CALL KTØRDR

4.27.8.22 Function Name: DKI

1. Entry Point: DKI

2. Purpose: To evaluate integrals in double precision for the triangular and trapezoidal cross-section rings in subroutines KTRIRG and KTRAPR.

3. Calling Sequence: DP = DKI (I,J,K,L,M,N,IP,IQ,R,Z)

I, J - The subscripts of R defining two lines on the limit of integration, integer-input.

K, L - The subscripts of R, Z defining another line on the limit of integration, integer-input.

M, N - The subscripts of R, Z defining the fourth line on the limit of integration, integer-input.

IP,IQ - Integers that define the power of the r and z variables respectively, - input.

R,Z - Vectors of the r and z coordinates of all points used to describe the area of integration, double precision - input.

4.27.8.23 Function Name: DKK

1. Entry Point: DKK
2. Purpose: To calculate the slope of a line given two points in function DKI.
3. Calling Sequence: DP = DKK (I,J,R,Z)

   I, J - The subscripts of R, Z defining the two points.

   R, Z - Vectors of the r and z coordinates.

4.27.8.24 Function Name: DKM

1. Entry Point: DKM
2. Purpose: To calculate the y-intercept of a line given two points in function DKI.
3. Calling Sequence: DP = DKM (I,J,R,Z)

   I, J - The subscripts of R, Z defining the two points.

   R, Z - Vectors of the r and z coordinates.

4.27.8.25 Function Name: DKINT

1. Entry Point: DKINT
2. Purpose: To evaluate the following function in the FØRTRAN function routine DKI:

$$f_1(A,B) = \frac{1}{w} \sum_{t=0}^{w} CØEF \cdot A^t \cdot B^{w-t} \cdot AJ \qquad (20)$$

where

$$CØEF = \begin{cases} \prod_{s=1}^{t} \frac{w-s+1}{s} & \text{for } t \neq 0 \\ 1 & \text{for } t = 0 \end{cases} \qquad (21)$$

and

$$AJ = \begin{cases} \frac{R(J)^{(w+v-t+1)} - R(I)^{(w+v-t+1)}}{w+v-t+1} & \text{for } (w+v-t+1) \neq 0 \\ \ln[\frac{R(J)}{R(I)}] & \text{for } (w+v-t+1) = 0 . \end{cases} \qquad (22)$$

3. Calling Sequence: DP = DKINT (I,J,A,B,V,W,R,Z)

   I, J - The subscripts of R, Z.

   A, B - The arguments of the function f in Equation 20.

   V, W - Integer parameters of the function.

   R, Z - Vectors of the r and z coordinates.

4.27.8.26 Function Name: DKJ

1. Entry Point: DKJ

2. Purpose: To evaluate the following function in function DKINT.

$$DKJ = \begin{cases} \frac{R(J)^{(s+1)} - R(I)^{(s+1)}}{s+1} & \text{for } s+1 \neq 0 \\ \ln[\frac{R(J)}{R(I)}] & \text{for } s+1 = 0 . \end{cases} \qquad (23)$$

3. Calling Sequence: DP = DKJ (I,J,R,S)

   I, J - The subscripts of R

R - Vector of the r coordinates.

S - Integer parameters of the function.

4.27.8.27 Function Name: DKEF

1. Entry Point: DKEF

2. Purpose: To evaluate the following function in function DKINT.

$$DKEF = \begin{cases} \prod_{s=1}^{t} \frac{w-s+1}{s} & \text{for } t \neq 0 \\ 1 & \text{for } t = 0. \end{cases} \tag{24}$$

3. Calling Sequence: DP = DKEF (T,W)

T, W - Integer parameters of the function.

4.27.8.28 Function Name: DK89

1. Entry Point: DK89

2. Purpose: To evaluate the following function in function DKI.

$$DK89(I,A,B) = \frac{1}{B^{M+1}} \sum_{s=0}^{M} M! \, (-A)^s \cdot d \ , \tag{25}$$

where

$$d = \begin{cases} \frac{(A+B\cdot R(I))^{(M+1-N-S)}}{(M-S)!\ S!(M+1-N-S)} & \text{for } (M+1-N-S) \neq 0 \\ \frac{\ln(|A + B\cdot R(I)|)}{(M+1-N)!\ (N-1)!} & \text{for } (M+1-N-S) = 0 \ . \end{cases} \tag{26}$$

3. Calling Sequence: DP = DK89 (I,A,B,M,N,R)

I - The subscript of R.

A, B - The arguments of the function.

M, N - Integer parameters of the function.

R - Vector of the r coordinates

4.27.8.29 Function Name: DK100

1. Entry Point: DK100

2. Purpose: To evaluate the following function in subroutine DKI.

$$DK100(I,A,B) = \frac{-1}{A^{(M+N-1)}} \sum_{s=0}^{M+N-2} (M+N-2)! \cdot d \quad , \tag{27}$$

where

$$d = \begin{cases} \dfrac{(A+B\cdot R(I))^{(M-1-S)} \cdot (-B)^{S}}{(M+N-2-S)!\ S!\ (M-1-S)\cdot R(I)^{(M-1-S)}} & \text{for } (M-1-S) \neq 0 \\ \dfrac{(-B)^{M-1} \cdot \ln\left(\left|\dfrac{A+B\ R(I)}{R(I)}\right|\right)}{(M-1)!(N-1)!} & \text{for } (M-1-S) = 0 \ . \end{cases} \tag{28}$$

3. Calling Sequence: DP= DK100 (I,A,B,M,N,R)

I - The subscript of R.

A, B - The arguments of the function.

M, N - Integer parameters of the function.

R - Vector of the r coordinates.

4.27.8.30 Function Name: KFAC

1. Entry Point: KFAC

2. Purpose: To evaluate the factorial function in functions DK89 and DK100.

3. Calling Sequence: K = KFAC (N)

N - The integer argument of the function.

If N < 2, the functional value is set to 1.

4.27.8.31 Function Name: DKJAB

1. Entry Point: DKJAB

2. Purpose: To evaluate the following function in FØRTRAN function DKI using the function evaluated in FØRTRAN function DK89.

$$DKJAB(I,A,B) = \frac{R(I)^{M} \ln(|A+B\cdot R(I)|)}{M} - \frac{B}{M} \cdot DK89(I,A,B) \ . \tag{29}$$

3. Calling Sequence: DP= DKJAB (I,A,B,M,N,R)

I - The subscript of R.

A, B - The arguments of the function.

M, N - Integer parameters of the function.

R - Vector of the r coordinates.

4.27.8.32 Function Name: DK219

1. Entry Point: DK219

2. Purpose: To evaluate the following function in FØRTRAN function DKI using the function evaluated in FØRTRAN function DK100.

$$DK219\ (I,A,B) = -\frac{\ln(|A+B\cdot R(I)|)}{M\cdot R(I)^M} + \frac{B}{M}\cdot DK100\ (I,A,B) \tag{30}$$

3. Calling Sequence: DP= DK219 (I,A,B,M,N,R)

I - The subscript of R.

A, B - The arguments of the function.

M, N - Integer parameters of the function.

R - Vector of the r coordinates.

4.27.8.33 Function Name: DK211

1. Entry Point: DK211

2. Purpose: To evaluate the following function in FØRTRAN function DKI.

$$DK211(I,A,B) = \begin{cases} 0 & \text{for } B\cdot R(I) = A \\ \frac{1}{2}[\ln(|2\cdot B\cdot R(I)|)]^2 & \text{for } B\cdot R(I)\neq A,\ [B\cdot R(I)]^2=A^2 \\ [\ln|A|]\cdot[\ln|R(I)|] - \sum_{t=1}^{\infty} \frac{1}{t^2}\left[\frac{-B\cdot R(I)}{A}\right]^t & \text{for } [B\cdot R(I)]^2 < A^2 \\ \frac{1}{2}[\ln(|B\cdot R(I)|)]^2 + \sum_{t=1}^{\infty} \frac{1}{t^2}\left[\frac{-A}{B\cdot R(I)}\right]^t & \text{for } [B\cdot R(I)]^2 > A^2 \end{cases} \tag{31}$$

3. Calling Sequence: DP = DK211 (I,A,B,R)

I - The subscript of R.

A, B - The arguments of the function.

R - Vector of the r coordinates.

4.27.8.34 Subroutine Name: RØMBDK

1. Entry Point: RØMBDK

2. Purpose: To evaluate integrals in double precision for the toroidal thin shell ring in subroutine KTØRDR.

3. Calling Sequence: CALL RØMBDK (A,B,NØSIG,PRECIS,NUM,ITDØNE,FINTG,KØDE,FUNCT,X)

A, B - Lower and upper limit of integration respectively.

NØSIG - Number of correct significant digits desired.

PRECIS - Actual number of significant digits attained.

NUM - Maximum number of halvings of the interval [A,B] to be made.

ITDØNE - Actual number of halvings of the interval [A,B].

FINTG - Resultant value of integral.

KØDE - Print control (not used).

FUNCT - Function subprogram used to evaluate the integral.

X - Vector of parameters used by function subprogram.

4.27.8.35 Function Name: D4K

1. Entry Point: D4K

2. Purpose: To evaluate the following function to be integrated by subroutine RØMBDK.

$$D4K = \frac{\phi^J \cdot \sin^2\phi}{R_1 - R_p \cdot \sin\alpha_1 + R_p \cdot \sin\alpha_1 \cdot \cos\phi + R_p \cdot \cos\alpha_1 \cdot \sin\phi} \quad (32)$$

3. Calling Sequence: DP = D4K (X)

X - Vector of function parameters.

X(1) - ϕ

X(2) - R_p

X(3) - R_1

X(4) - $\cos \alpha_1$

X(5) - $\sin \alpha_1$

X(6) - J + 1

4.27.8.36 Function Name: D5K

1. Entry Point: D5K

2. Purpose: To evaluate the following function to be integrated by subroutine RØMBDK.

$$D5K = \frac{\phi^J \cdot 2 \cdot \sin\phi \cdot \cos\phi}{R_1 - R_p \cdot \sin\alpha_1 + R_p \cdot \sin\alpha_1 \cos\phi + R_p \cdot \cos\alpha_1 \cdot \sin\phi} . \quad (33)$$

3. Calling Sequence: DP= D5K (X)

X - Vector of function parameters.

X(1) - ϕ

X(2) - R_p

X(3) - R_1

X(4) - $\cos \alpha_1$

X(5) - $\sin \alpha_1$

X(6) - J + 1

4.27.8.37 Function Name: D6K

1. Entry Point: D6K

2. Purpose: To evaluate the following function to be integrated by subroutine RØMBDK.

$$D6K = \frac{\phi^J \cos^2\phi}{R_1 - R_p \cdot \sin\alpha_1 + R_p \cdot \sin\alpha_1 \cdot \cos\phi + R_p \cdot \cos\alpha_1 \cdot \sin\phi} . \quad (34)$$

3. Calling Sequence: DP = D6K (X)

X - Vector of function parameters.

X(1) - ϕ

X(2) - R_p

X(3) - R_1

X(4) - $\cos \alpha_1$

X(5) - $\sin \alpha_1$

X(6) - J + 1

4.27.8.38 Subroutine Name: DMATRX

1. Entry Point: DMATRX

2. Purpose: To form the element stiffness matrix in field coordinates for the toroidal thin shell ring in subroutine KTØRDR.

3. Calling Sequence: CALL DMATRX (D,V,C,CA,CA2,VA,DM,DB,YI)

D - Resultant stiffness matrix.

V,C,CA, CA2,VA, DM,DB - Terms used in the evaluation of the stiffness matrix.

YI - Array of integral values.

4.27.8.39 Subroutine Name: KFLUD2

1. Entry Point: KFLUD2

2. Purpose: To form the element psuedo stiffness matrix for the FLUID2 and AXIF2 elements.

3. Calling Sequence: CALL KFLUD2

4.27.8.40 Subroutine Name: KFLUD3

1. Entry Point: KFLUD3

2. Purpose: To form the element psuedo stiffness matrix for the FLUID3 and AXIF3 elements.

3. Calling Sequence: CALL KFLUD3

4.27.8.41 Subroutine Name: KFLUD4

1. Entry Point: KFLUD4

2. Purpose: To form the element psuedo stiffness matrix for the FLUID4 and AXIF4 elements.

3. Calling Sequence: CALL KFLUD4

4.27.8.42 Subroutine Name: KSLØT

1. Entry Point: KSLØT
2. Purpose: To form the element psuedo stiffness matrix for the SLØT3 and SLØT4 elements.
3. Calling Sequence: CALL KSLØT(IARG)

IARG = 0 = SLØT3 elements; 1 = SLØT4 elements

4.27.8.43 Subroutine Name: KTETRA

1. Entry Point: KTETRA
2. Purpose: To calculate and insert element stiffness matrices for the TETRA (solid tetrahedron) element. It is also used for the subelements of the WEDGE, HEXA1, and HEXA2 elements.
3. Calling sequence: CALL KTETRA (IØPT), where:

   If IØPT = 0, the stiffness is divided by 2.

   If IØPT = 1, the stiffness is unmodified.

   If IØPT $\geq$ 100, the element is tested for geometric consistency.

4.27.8.44 Subroutine Name: KSØLID

1. Entry Point: KSØLID
2. Purpose: To perform, on the WEDGE, HEXA1, and HEXA2 elements, the following tasks:
   a) Check geometric consistency.
   b) Rearrange the ECPT data into the TETRA format for each subelement and call the KTETRA subroutine.
3. Calling sequence: CALL KSØLID (ITYPE), where

   ITYPE = 1 implies a WEDGE element (three tetrahedra).

   ITYPE = 2 implies a HEXA1 element (five tetrahedra).

   ITYPE = 3 implies a HEXA2 element (ten tetrahedra).

4.27.8.45 Subroutine Name: HHBDY

1. Entry Point: HHBDY

2. Purpose: To calculate thermal convection matrix terms for the boundary heat transfer elements (HBDY).

3. Calling sequence: CALL HHBDY.

4.27.8.46 Subroutine Name: HRING

1. Entry Point: HRING

2. Purpose: To calculate thermal conductivity matrix terms for the TRIARG and TRAPRG elements.

3. Calling Sequence: CALL HRING(ITYPE), where

ITYPE = 3 implies a TRIARG element.
ITYPE = 4 implies a TRAPRG element.

4.27.8.47 Subroutine Name: KPLTST

1. Entry Point: KPLTST

2. Purpose: To examine the planarity of quadrilateral elements.

3. Calling Sequence: CALL KPLTST (G1,G2,G3,G4) where

Gi = Grid Point coordinate vectors

4.27.9 Design Requirements

4.27.9.1 Open Core Design

The open core common block for module SMA1 is defined by the following FØRTRAN statements:

1. DØUBLE PRECISIØN DZ(1)
2. INTEGER IZ(1)
3. CØMMØN /SMA1X/ Z(2)
4. EQUIVALENCE (Z(1),IZ(1),DZ(1)).

The open core layout is given in Figure 1.

1. DØUBLE PRECISIØN DZ(1)
2. INTEGER IZ(1)
3. CØMMØN /SMA1X/ Z(1)
4. EQUIVALENCE (Z(1),IZ(1),DZ(1)).

The open core layout is given in Figure 1.

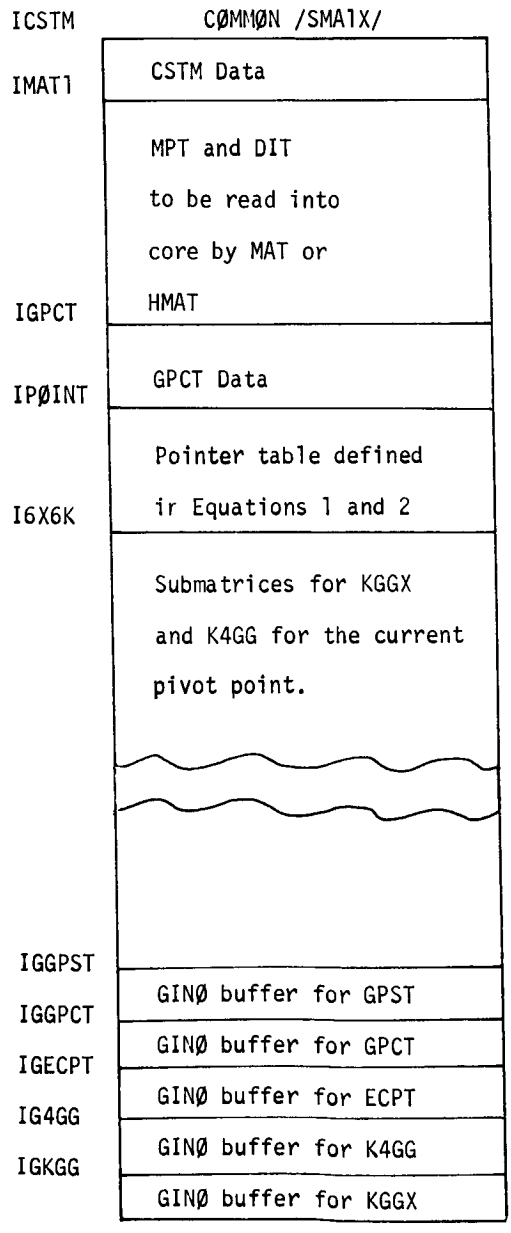


Figure 1. Open core layout for module SMA1.

The definition of the variables is as follows:

ICSTM - The zero pointer to the CSTM portion of open core; defined to be zero.

IMAT1 - The zero pointer to the MPT and DIT data read into core by subroutine PREMAT; defined to be ICSTM + NCSTM, where NCSTM is the length of the CSTM portion of open core.

IGPCT - The zero pointer to the GPCT portion of open core; defined to be IMAT1 + MATCR, MATCR being the length of open core used by subroutine PREMAT.

IPØINT - The zero pointer to the pointer table in open core. The pointer table is used as a dictionary to relate the GPCT to the submatrices in core; defined to be IGPCT + NGPCT, NGPCT being the length of the GPCT.

I6X6K - The zero pointer to the submatrices of KGGX; I6X6K = (IPØINT + NPØINT -1)/ 2+2 where NPØINT = NGPCT is the length of the pointer table. The extra arithmetic to define I6X6K is necessary because the submatrices are double precision numbers. While the above indices are single precision indices, I6X6K is a double precision index.

I6X64 - The zero pointer to be submatrices of K4GG; I6X64 = I6X6K + N6X6K, where N6X6K is the number of double precision numbers in the submatrices of KGGX. I6X64 is a double precision index.

The pointers for the GINØ buffers, IGGPST, IGGPCT, IGECPT, IG4GG and IGKGG are, unlike the above, 'one' pointers. It should be noted that the lengths NCSTM and MATCR are constant throughout the module operation, while the length of the GPCT data will vary from pivot point to pivot point as the ECPT and GPCT data blocks are processed serially. (Hence it is probable that for a pivot point with a relatively small number of elements connected to it the entire submatrix may be held in core, while spill logic will be entered only when a pivot point has a great many elements connected to it.)

4.27.9.2 Block Data Subprogram

The block data program SMA1BD sets GINØ file numbers, I/Ø parameters and SMA1 overlay parameters in common blocks /SMA1IØ/ and /SMA1CL/.

4.27.9.3 Common Storage Requirements

Blank common is used only for DMAP parameters. The following common blocks are used throughout the module: /SMA1IØ/, /SMA1BK/, /SMA1CL/, /SMA1ET/ and /SMA1DP/. They are given in detail here since other matrix assembler modules such as SMA2 and DSMG1 are designed similarly. All common block variables are integer except (1) DØDET in /SMA1CL/ which is a logical variable; (2) the array in /SMA1ET/ which is a mixed (integer and real) array; and (3) the double precision array in /SMA1DP/.

1. The SMA1IØ common block is 36 words in length and is used for SMA1 input/output parameters.

Word Number	Variable	Definition
1	IFCSTM	GINØ file number for the CSTM data block.
2	IFMPT	GINØ file number for the MPT data block.
3	IFDIT	GINØ file number for the DIT data block.
4	IDUM1	Undefined.
5	IFECPT	GINØ file number for the ECPT data block.
6	IGECPT	GINØ buffer pointer for the ECPT.
7	IFGPCT	GINØ file number for the GPCT data block.
8	IGGPCT	GINØ buffer pointer for the GPCT.
9-10	IFGEI,IGGEI	Undefined.
11	IFKGG	GINØ file number for the KGGX data block.
12	IGKGG	GINØ buffer pointer for KGGX.
13	IF4GG	GINØ file number for the K4GG data block.
14	IG4GG	GINØ buffer pointer for K4GG.
15	IFGPST	GINØ file number for the GPST data block.
16	IGGPST	GINØ buffer pointer for the GPST.
17	INRW	Input with rewind option for subroutine ØPEN.
18	ØUTRW	Output with rewind option for subroutine ØPEN.
19	CLSNRW	Close without rewind option for subroutine CLØSE.
20	CLSRW	Close with rewind option for subroutine CLØSE.
21	NEØR	No end-of-record indicator for subroutine READ.
22	EØR	End-of-record indicator for subroutine READ.
23-29	MCBKGG	Matrix control block for the KGGX matrix.
30-36	MCB4GG	Matrix control block for the K4GG matrix.

2. The SMA1BK common block is 10 words in length and is used for SMA1 open core bookkeeping parameters. It contains zero pointers and lengths for the various sub-arrays in open core.

Word Number	Variable	Definition
1	ICSTM	Zero pointer to the CSTM sub-array in open core. For example the first location of this sub-array is referenced as IZ (ICSTM + 1).
2	NCSTM	Length of the CSTM sub-array in open core.
3	IGPCT	Zero pointer to the GPCT sub-array in open core.
4	NGPCT	Length of the GPCT sub-array.
5	IPØINT	Zero pointer to the PØINT sub-array in open core.
6	NPØINT	Length of the PØINT sub-array.
7	I6X6K	Zero pointer to the 6x6 submatrices of KGGX.
8	N6X6K	Number of words allocated to the 6x6 submatrices of KGGX.
9	I6X64	Zero pointer to the 6x6 submatrices of K4GG.
10	N6X64	Undefined.

3. The SMA1CL common block is 133 words in length and is used for module control parameters.

Word Number	Variable	Definition
1	IØPT4	Indicator used by element routines denoting whether or not the K4GG matrix will be generated. IØPT4 = 0, implies no generation; IØPT4 = 1 implies generation.
2	K4GGSW	Indicator set to -1 initially. If IØPT4 = 1, then element routines will set K4GGSW = 1, when a non-zero element structural damping matrix is generated.
3	NPVT	The scalar index which is the pivot point. This is the first word of every record of the ECPT data block.
4	LEFT	The number of words of open core remaining after all sub-arrays in open core have been allocated.
5	FRØWIC	The first row of the submatrices in core. If all six rows of the matrices to be generated cannot be held in core, spill logic is initiated, and 3, 2 or 1 rows of the submatrices are generated during each pass of the ECPT record for the pivot point which causes the spill. FRØWIC can take on the values 1,2,3,4,5 or 6.
6	LRØWIC	The last row of the submatrices in core. LRØWIC is defined as FRØWIC + NRØWSC -1, where NRØWSC is the number of rows in core. If there are no spill problems, then LRØWIC = 6 if the pivot point is a grid point, and LRØWIC = 1 if the pivot point is a grid point.
7	NRØWSC	The number of rows of the submatrices currently in core.
8	TNRØWS	Total number of rows of the submatrices to be generated. TNRØWS = 6 if the pivot point is a grid point and TNRØWS = 1 if the pivot point is a scalar point. This definition holds whether or not the K4GG matrix is to be generated. (In actuality, if the K4GG is generated the total number of rows

Word Number	Variable	Definition
		generated for any ECPT record is 12 or 2).
9	JMAX	The number of columns of KGGX (and K4GG) to be generated with the current ECPT record.
10	NLINKS	The number of machine links (overlay segments) necessary to contain the module's element routines. Currently NLINKS is defined to be 3. This variable is used in conjunction with the LINK array defined below. For machines with large memories, it is desirable to have all element routines in one link, for when in any ECPT record there are elements which reside in different links, overlay overhead can be very costly (particularly on second generation computing systems).
11-20	LINK	Before the current ECPT record is read for the first time, the LINK array is set to -1 for LINK(I), I = 1, ...NLINKS. When the first element is read from the ECPT, the proper element routine is called, thereby loading the link in which that element routine resides. The variable LINCØR, the link in core, is defined as LINCØR = IØVRLY(ITYPE), where ITYPE is the element's internal number, e.g., RØD = 1, BEAM = 2, etc. For the next element read from the ECPT, it is determined in what link it resides. If it resides in the link which is in core, the element routine is called. If the routine does not reside in the link currently in core, it is determined whether (a) the link has already been processed or (b) the link has not been processed in which case a "to-be-processed-later" flag is set. For case (a) LINK (ITEMP) is 1; for case (b) LINK(ITEMP) is set = 0, where ITEMP = IØVRLY(ITYPE). When an end-of-record is sensed for the ECPT, LINK(LINCØR) is set to 1 and LINK array is searched for zeros. If there are no zeros, the processing of the ECPT record is complete. If there are zeros, that is, links to be processed, the file corresponding to the ECPT is backspaced and processing of the record is repeated.
21	NØGØ	Flag used to indicate if a user fatal error message occurred in the processing of any element. NØGØ = 1 indicates an error. Execution is termination upon completion of the processing of the GPCT. NØGØ = 0 indicates no error. Continue execution.
22	IDETCK	Used as a first pass indicator in the DETCK subroutine. There will be multiple passes through the DETCK routine, for each ECPT record, only if there are spill problems, i.e., the total number of rows to be generated for the ECPT record will not fit in core.

23	DØDET	Logical variable which if true implies the DETCK routine will be called and if false will not be called. If the input parameter, NØGENL, is greater than zero, implying general elements exist, then DØDET is set false. Otherwise DØDET is true.

4. The common block SMA1ET is 100 words in length and is used as the means of communicating the element data from the ECPT data block to the element subroutines.

5. The common block SMA1DP defines an array of 300 double precision words. This block is used as "scratch" storage by element routines. Those variables which in most FØRTRAN programs would be local subroutine variables are defined in /SMA1DP/ by the module's element routines in order to preserve core storage and hence increase open core.

4.27.9.4 Arithmetic Considerations

All floating point arithmetic operations are carried out in double precision. Both $[K^{x}_{gg}]$ and $[K^{4}_{gg}]$ are double precision matrices.

4.27.10 Diagnostic Messages

The module has a variety of "fail-safe" error checks. If any of these checks fails, it implies an obscure program design error or a computer operating system/hardware failure. Diagnostic messages 2022, 2023, 2034 are of this type.

User fatal error messages 2025, 2026, 2031, 2032, 2033, 2035, 2036, 2037, 2038, 2039, 2040, 5001, 5002, 5003, and 5004 occur when one of the structural element routines encounters some user data which makes generation of an element matrix impossible. Examples would include a user defining a RØD or BAR element of zero length; a user defining the four points of a SHEAR panel element not in the proper cyclical order; a user defining TRPLT data so that a matrix in a algorithm is singular; etc. It should be noted the first time this type of user data is encountered a fatal error occurs, that is the module does not continue to process data for uncovering any more errors.

Detailed descriptions of these error messages can be found in Section 6 of the User's Manual.

4.28 FUNCTIONAL MODULE SMA2 (STRUCTURAL MATRIX ASSEMBLER - PHASE 2)

4.28.1 Entry Point: SMA2

4.28.2 Purpose

To generate the mass matrix $[M_{gg}]$ and the damping matrix $[B_{gg}]$.

4.28.3 DMAP Calling Sequence

```
SMA2    CSTM,MPT,ECPT,GPCT,DIT/MGG,BGG/V,Y,WTMASS=1.0/V,N,NØMGG/V,N,NØBGG/V,Y,
        CØUPMASS/V,Y,CPBAR/V,Y,CPRØD/V,Y,CPQUAD1/V,Y,CPQUAD2/V,Y,CPTRIA1/V,Y,CPTRIA2/
        V,Y,CPTUBE/V,Y,CPQDPLT/V,Y,CPTRPLT/V,Y,CPTRBSC/  $
```

4.28.4 Input Data Blocks

CSTM - Coordinate System Transformation Matrices.

MPT - Material Properties Table.

ECPT - Element Connection and Properties Table.

GPCT - Grid Point Connection Table.

DIT - Direct Input Tables.

Notes:

1. The CSTM may be purged.
2. If some element references a material property, the MPT cannot be purged.
3. Neither the ECPT nor the GPCT may be purged.
4. If some material property is temperature dependent, DIT cannot be purged.

4.28.5 Output Data Blocks

MGG - Partition of mass matrix - g set.

BGG - Partition of damping matrix - g set.

Notes:

1. MGG cannot be pre-purged.
2. BGG can be pre-purged.

4.28.6 Parameters

WTMASS - Input-real-default value (in DMAP calling sequence) = 1.0. WTMASS is the scalar value by which the generated mass matrix will be multiplied before the columns are packed onto the output file. WTMASS is the ratio of mass to weight.

NØMGG - Output-integer-no default value. NØMGG is set equal to -1 if the generated mass matrix is the zero matrix. Otherwise it is set = +1.

NØBGG - Output-integer-no default value. If the BGG matrix is either pre-purged or is generated as the zero matrix, NØBGG is set = -1. Otherwise it is set = +1.

CØUPMASS - Input-integer-default value = -1. If CØUPMASS = -1, "consistent" mass matrices for all elements will not be generated; if CØUPMASS > 0, "consistent" mass matrices for all elements will be generated. If CØUPMASS = 0 "consistent" mass matrices will be generated for element types depending on the values of CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, and CPTRBSC.

CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT and CPTRBSC - Input - integer-default value = -1.

These parameters choose between "consistent" mass and normal mass algorithms for their respective element types as given below.

Parameter	Element Types
CPBAR	BAR
CPRØD	RØD, CØNRØD
CPQUAD1	QUAD1
CPQUAD2	QUAD2
CPTRIA1	TRIA1
CPTRIA2	TRIA2
CPTUBE	TUBE
CPQDPLT	QDPLT
CPTRPLT	TRPLT
CTRBSC	TRBSC

These parameters function in conjunction with CØUPMASS and have no effect if CØUPMASS $\neq$ 0. If CØUPMASS = 0 a negative value for these parameters will cause the "normal" mass matrix to be generated. A value equal to or greater than zero will cause the "consistent" mass matrices to be generated for all element types controlled by this parameter.

4.28.7 Method

SMA2 is structured similarly to module SMA1. A separate module was written to generate the mass and damping matrices in order to maximize the amount of open core space available for element matrices during matrix generation. This core space was especially critical on the development computer, the IBM 7094-7040 DCS. Since SMA2 is so similar to SMA1, the details of the similarities will not be repeated here; the differences will be pointed out. The reader is referred to the Module Functional Description (MFD) for SMA1 (section 4.27).

When all rows (or, in the case of spill, the number of rows in core) for each pivot point have been computed, each matrix element of $[M_{gg}]$ is multiplied by WTMASS before being packed onto the output data block MGG.

4.28.8 Subroutines

SMA2, like SMA1, uses the utility routines PRETRD, PREMAT and GMMATD.

The principal means of communicating an element entry of the ECPT to an element mass or damping matrix generation routine is through /SMA2ET/. This fact is not explicitly stated in each of the descriptions of the element routines (e.g., MRØD) given below.

The following list gives a correspondence between SMA1 and SMA2 routines that are used only (directly or indirectly) by the axisymmetric shell element routines TRIARG and TRAPRG. All of the SMA2 routines are the same as their SMA1 counterparts except for name. The reason for duplicating these routines with different names was to maximize open core for element matrices in SMA1 and SMA2, which both reside in the same NASTRAN link. For details on each of the routines, see the corresponding SMA1 counterpart (section 4.27.8).

SMA1	SMA2
DKI	DMI
DKK	DMK
DKM	DMM
DKINT	DMINT
DKJ	DMJ
DKEF	DMEF

FUNCTIONAL MODULE SMA2 (STRUCTURAL MATRIX ASSEMBLER - PHASE 2)

SMA1	SMA2
DK89	DM89
DK100	DM100
KFAC	MFAC
DKJAB	DMJAB
DK219	DM219
DK211	DM211

4.28.8.1 Subroutine Name: SMA2

1. Entry Point: SMA2

2. Purpose: The module driver which parallels SMA1. For further details see the method section of the MFD for SMA1 (section 4.27.7).

3. Calling Sequence: CALL SMA2

4.28.8.2 Subroutine Name: SMA2A

1. Entry Point: SMA2A

2. Purpose: To generate $[M_{gg}]$ and $[B_{gg}]$. This routine parallels SMA1A. See the MFD for SMA1 for details on SMA1A (section 4.27.8).

3. Calling Sequence: CALL SMA2A.

4.28.8.3 Subroutine Name: SMA2B

1. Entry Point: SMA2B

2. Purpose: To add a double precision 6 by 6 or 1 by 1 matrix $[K^e]$ to the "submatrix" of $[M_{gg}]$ or $[B_{gg}]$ corresponding to the current pivot point.

3. Calling Sequence: CALL SMA2B (KE,J,II,IFILE,DUMDP).

KE,J,II are as defined for subroutine SMA1B (see section 4.27.8).

IFILE - GINØ file number of the matrix in core being added to $[M_{gg}]$ or $[B_{gg}]$-integer-input.

DUMDP - A dummy double precision argument added so that the calling sequence to SMA2B would conform to that of SMA1B.

4.28.8.4 Block Data Program Name: SMA2BD.

1. Purpose: To set GINØ file numbers, I/Ø parameters and SMA2 overlay parameters in /SMA2IØ/ and /SMA2CL/.

4.28.8.5 Subroutine Name: MRØD

1. Entry Point: MRØD

2. Purpose: To generate the element mass matrix for a RØD element.

3. Calling Sequence: CALL MRØD.

4.28.8.6 Subroutine Name: MTUBE

1. Entry Point: MTUBE

2. Purpose: To generate the element mass matrix for a TUBE element.

3. Calling Sequence: CALL MTUBE

4.28.8.7 Subroutine Name: MASSTQ

1. Entry Point: MASSTQ

2. Purpose: To generate an element mass matrix for any of the two-dimensional structural elements listed under the Calling Sequence.

3. Calling Sequence: CALL MASSTQ(IARG)

$$\text{IARG} = \begin{cases} 4 = \text{TRMEM} \\ 1 = \text{QDMEM} \\ 3 = \text{TRBSC} \\ 3 = \text{TRPLT} \\ 7 = \text{QDPLT} \\ 5 = \text{TRIA1} \\ 4 = \text{TRIA2} \\ 2 = \text{QUAD1} \\ 1 = \text{QUAD2} \\ 6 = \text{SHEAR} \\ 6 = \text{TWIST} \end{cases}$$

4.28.8.8 Subroutine Name: MBAR

1. Entry Point: MBAR

2. Purpose: To generate the "diagonal" (uncoupled) element mass matrix for a BAR element.

3. Calling Sequence: CALL MBAR

4.28.8.9 Subroutine Name: MCBAR

1. Entry Point: MCBAR

2. Purpose: To generate the "consistent" (coupled) element mass matrix for a BAR element.

3. Calling Sequence: CALL MCBAR

4.28.8.10 Subroutine Name: MCØNMX

1. Entry Point: MCØNMX

2. Purpose: To generate an element mass matrix for either of the two concentrated-mass-elements listed under Calling Sequence.

3. Calling Sequence: CALL MCØNMX(IARG)

$$\text{IARG} - \begin{cases} 1 = \text{CØNM1} \\ 2 = \text{CØNM2} \end{cases}$$

4.28.8.11 Subroutine Name: MCØNE

1. Entry Point: MCØNE

2. Purpose: To generate an element mass matrix for the axisymmetric conical shell element (CØNE).

3. Calling Sequence: CALL MCØNE

4.28.8.12 Subroutine Name: MASSD

1. Entry Point: MASSD

2. Purpose: To generate 1 by 1 element mass matrices for scalar elements MASSi, i = 1,2,3,4; and 1 by 1 element damping matrices for scalar damping elements DAMPi, i = 1,2,3,4.

3. Calling Sequence: CALL MASSD(I)

I -
- 1 - Generate element mass matrix for a MASS1 element,
- 2 - Generate element mass matrix for a MASS2 element,
- 3 - Generate element mass matrix for a MASS3 element,
- 4 - Generate element mass matrix for a MASS4 element,
- 5 - Generate element damping matrix for a DAMP1 element,
- 6 - Generate element damping matrix for a DAMP2 element,
- 7 - Generate element damping matrix for a DAMP3 element,
- 8 - Generate element damping matrix for a DAMP4 element.

4.28.8.13 Subroutine Name: MTRIRG

1. Entry Point: MTRIRG

2. Purpose: To generate an element mass matrix for a triangular cross-section ring, TRIARG, element.

3. Calling Sequence: MTRIRG.

4.28.8.14 Subroutine Name: MTRAPR

1. Entry Point: MTRAPR

2. Purpose: To generate an element mass matrix for a trapezoidal cross-section ring, TRAPRG, element.

3. Calling Sequence: CALL MTRAPR.

4.28.8.15 Subroutine Name: MTØRDR

1. Entry Point: MTØRDR

2. Purpose: To generate an element mass matrix for a toroidal thin shell ring, TØRDRG, element.

3. Calling Sequence: CALL MTØRDR.

4.28.8.16 Subroutine Name: BVISC

1. Entry Point: BVISC

2. Purpose: To generate an element damping matrix for a VISC element.

3. Calling Sequence: Call BVISC

4.28.8.17 Subroutine Name: MBEAM

1. Entry Point: MBEAM

2. Purpose: To generate an element mass matrix for a BEAM element.

3. Calling Sequence: CALL MBEAM

4.28.8.18 Subroutine Name: MCRØD

1. Entry Point: MCRØD

2. Purpose: To generate the "consistent" (coupled) element mass matrix for any of the elements listed under calling sequence.

3. Calling Sequence: CALL MCRØD (IARG)

$$IARG = \begin{cases} 1 - RØD \\ 1 - CØNRØD \\ 3 - TUBE \end{cases}$$

4.28.8.19 Subroutine Name: MTRBSC

1. Entry Point: MTRBSC

2. Purpose: To generate the "consistent" (coupled) element mass matrix for a basic bending triangle element.

3. Calling Sequence: CALL MTRBSC

4.28.8.20 Subroutine Name: MTRPLT

1. Entry Point: MTRPLT

2. Purpose: To generate the "consistent" (coupled) element mass matrix for a triangular plate element.

3. Calling Sequence: CALL MTRPLT

4.28.8.21 Subroutine Name: MQDPLT

1. Entry Point: MQDPLT

2. Purpcse: To generate the "consistent" (coupled) element mass matrix for a quadrilateral plate element.

3. Calling Sequence: CALL MQDPLT

4.28.8.22 Subroutine Name: MTRIQD

1. Entry Point: MTRIQD

2. Purpose: To generate the "consistent" (coupled) element for any of the following elements: TRIA1, TRIA2, QUAD1, QUAD2.

3. Calling Sequence: CALL MTRIQD (IARG)

IARG =
- 1 - TRIA1 element.
- 2 - TRIA2 element.
- 3 - QUAD1 element.
- 4 - QUAD2 element.

4.28.8.23 Subroutine Name: MFLUD2

1. Entry Point: MFLUD2

2. Purpose: To generate the psuedo mass matrix terms for the FLUID2 and AXIF2 elements.

3. Calling Sequence: CALL MFLUD2

4.28.8.24 Subroutine Name: MFLUD3

1. Entry Point: MFLUD3

2. Purpose: To generate the psuedo mass matrix terms for the FLUID3 and AXIF3 elements.

3. Calling Sequence: CALL MFLUD3

4.28.8.25 Subroutine Name: MFLUD4

1. Entry Point: MFLUD4

2. Purpose: To generate the psuedo mass matrix terms for the FLUID4 and AXIF4 elements.

3. Calling Sequence: CALL MFLUD4

4.28.8.26 Subroutine Name: MFREE

1. Entry Point: MFREE

2. Purpose: To generate the psuedo mass matrix terms for the free surface element. This element is internally generated in IFP4 from FSLIST data.

3. Calling Sequence: CALL MFREE

4.28.8.27 Subroutine Name: MSLØT

1. Entry Point: MSLØT

2. Purpose: To generate psuedo mass matrix terms for the SLØT3 and SLØT4 elements.

3. Calling Sequence: CALL MSLØT (IARG)

$$IARG = \begin{cases} 0 = SL\text{Ø}T3 \\ 1 = SL\text{Ø}T4 \end{cases}$$

4.28.8.28 Subroutine Name: MSØLID

1. Entry Point: MSØLID

2. Purpose: To generate the mass matrix terms for the three-dimensional solid elements.

3. Calling Sequence: CALL MSØLID(I)

I	Element
1	TETRA
2	WEDGE
3	HEXA1
4	HEXA2

4.28.9 Design Requirements

4.28.9.1 Open Core Design

The open core design for SMA2 is the same as that in SMA1 with the exception that /SMA2X/ defines the beginning of open core and only four buffers are needed, one each for MGG, BGG, ECPT and GPCT.

4.28.9.2 Common Storage Requirements

The common storage requirements for SMA2 are similar to those in SMA1. The common blocks /SMA2IØ/, /SMA2BK/, /SMA2CL/, /SMA2ET/ and /SMA2DP/ of SMA2 correspond to /SMA1IØ/, /SMA1BK/, /SMA1CL/, /SMA1ET/ and /SMA1DP/ of SMA1. See the MFD for SMA1 (see section 4.27.9). The following differences are worthy of note.

1. In /SMA2IØ/, words 15 and 16 are undefined and words 23 through 36 define matrix control blocks for MGG and BGG.

2. /SMA2CL/ is only 131 words in length, the last two words of /SMA1CL/ being reserved for variables unique to SMA1.

4.28.9.3 Arithmetic Considerations

Floating point arithmetic operations are carried out in double precision. Both $[M_{gg}]$ and $[B_{gg}]$ are real symmetric double precision matrices.

4.28.10 Diagnostic Messages

See the diagnostic message section in the MFD for SMA1 (section 4.27.10).

4.29 FUNCTIONAL MODULE GPWG (GRID POINT WEIGHT GENERATOR)

4.29.1 Entry Point: GPWG

4.29.2 Purpose

To compute the center of mass of the structure relative to a given point and find the principal inertias about the center of gravity.

4.29.3 DMAP Calling Sequence

```
GPWG     BGPDT,CSTM,EQEXIN,MGG/ØGPWG/V,Y,GRDPNT/V,Y,WTMASS  $
```

4.29.4 Input Data Blocks

BGPDT - Basic Grid Point Definition Table.

CSTM - Coordinate System Transformation Matrices.

EQEXIN - Equivalance between external grid or scalar numbers and internal numbers.

MGG - Partition of mass matrix - g set.

Notes: 1. BGPDT,EQEXIN and MGG cannot be purged.

2. CSTM must be present if some grid point of the model is not in basic coordinates.

4.29.5 Output Data Blocks

ØGPWG - Grid Point Weight Generator Output Table.

Notes: This data block cannot be purged.

4.29.6 Parameters

GRDPNT - Input-integer-default = -1. GRDPNT selects the grid point about which the inertias will be calculated. If GRDPNT is not the external ID of a geometric grid point, the basic origin is used.

WTMASS - Input-real-default = 1.0. WTMASS gives the ratio of mass to weight for the structure. All output quantities are in weight units.

4.29.7 Method

The Grid Point Weight Generator module calculates the masses, centers of gravity, and inertias of the general mathematical model of the structure. The data are extracted from the $[M_{gg}]$ matrix by using a rigid body transformation calculation. The transformation is defined by the global coordinate displacements resulting from unit translations and rotations of the whole body about a reference point.

Because of the scalar mass effects, the total mass may have directional properties, and the center of gravity may not be a unique location. This effect is shown in the output by giving for each of the three masses its own direction and center of gravity. The inertia terms are calculated by using the directional mass effects. The axes about which the inertia terms are calculated may not intersect. However, these axes are those which provide uncoupled rotation and translation effects. This is the significance of the term "center of gravity". If the structural model has been constructed using only real masses, the three masses printed out will be equal, the center of gravity will be unique, and the axes of the inertia terms will intersect at the center of gravity.

The actual computation proceeds in 4 parts.

1. Computation of the $[D]^T$ matrix takes place in subroutine GPWG1A. Six vectors are formed which will describe the six motions about the reference point. The matrix [D] formed from the vectors which describe rigid body displacements in global coordinates in terms of the six unit displacements and rotations in basic coordinates at the reference point:

$$\{\ddot{u}_g\} = [D]\{\ddot{u}_o\} \quad \text{(reference point)}. \tag{1}$$

The method of generation is as follows:

EQEXIN is placed in core and searched for GRDPNT to obtain its internal sequence number. If the value of the parameter GRDPNT is not the ID number of a physical grid point, the basic origin is used. Assuming GRDPNT is a physical grid point, BGPDT is read to obtain $\{R_o\}$ for the reference point. The BGPDT file is then rewound. CSTM (if present) is placed in core and readied for use by subroutine PRETRS. Each grid point in the BGPDT is considered in order. If it is a scalar point, zero is stored in each of the six columns of $[D]^T$.

If it is a grid point,

$$\{r_i\} = \{R_i\} - \{R_o\} = \begin{Bmatrix} r_1 \\ r_2 \\ r_3 \end{Bmatrix}, \tag{2}$$

is computed where $\{R_i\}$ is the basic coordinate location of the i^{th} grid point given in the BGPDT table and $\{R_o\}$ is the location of the reference point.

The transformation matrix to the grid point,

$$[T_r] = \begin{bmatrix} 0 & r_3 & -r_2 \\ -r_3 & 0 & r_1 \\ r_2 & -r_1 & 0 \end{bmatrix} , \tag{3}$$

is formed. Subroutine TRANSS calculates the 3x3 transformation matrix $[T_i]$ from global coordinates to basic coordinates for the grid point. The matrix

$$[d] = \left[\begin{array}{c:c:c} T_i^T & T_i^T & T_r \\ \hdashline 0 & T_i^T & \end{array}\right] , \tag{4}$$

is computed. The rows of [d] form the columns of $[D]^T$. The matrix $[D]^T$ is generated a column at a time and is packed out onto a scratch file.

2. If all points were scalar points, GPWG returns; otherwise subroutine TRANP1 is called to form [D] from $[D]^T$.

3. $[M_o]$ is computed by two calls to subroutine SSG2B,

$$[M_o] = [D]^T [M_{gg}] [D]. \tag{5}$$

4. Output quantities are computed as follows:

M_o is unpacked, output and partitioned as follows:

$$[M_o] \Longrightarrow \left[\begin{array}{c:c} \bar{M}^t & \bar{M}^{tr} \\ \hdashline \bar{M}^{rt} & \bar{M}^r \end{array}\right] \tag{6}$$

(The matrix is symmetric, where the superscripts t and r refer to translation and rotation respectively.)

A check is made for inconsistent scalar masses. Let

$$\delta = \sqrt{\Sigma(M_{ij}^t)^2} \tag{7}$$

and

$$\varepsilon = \sqrt{\Sigma(\bar{M}_{ij}^t)^2} \qquad i \neq j. \tag{8}$$

If $\frac{\varepsilon}{\delta} > 10^{-3}$, the coordinates should be rotated. Otherwise [S] = [I]. If rotation is necessary, the eigenvectors of $[\bar{M}^t]$, $\{e_1\}$, $\{e_2\}$, and $\{e_3\}$, are determined by the Jacobi technique. Define

$$[S] = [\ \{e_1\}\ ,\ \{e_2\}\ ,\ \{e_3\}\ ]. \tag{9}$$

The [S] matrix is output. $[M^t]$, $[M^r]$ and $[M^{tr}]$ are computed as follows:

$$[M^t] = [S]^T\ [\bar{M}^t]\ [S], \tag{10}$$

$$[M^{tr}] = [S]^T\ [\bar{M}^{tr}]\ [S], \tag{11}$$

$$[M^r] = [S]^T\ [\bar{M}^r]\ [S]. \tag{12}$$

The following terms, defined in the principal axis system $\{e_1\}$, $\{e_2\}$, and $\{e_3\}$, are calculated and output: The mass terms are:

$$M_x = M^t_{11}, \tag{13}$$

$$M_y = M^t_{22}, \tag{14}$$

$$M_z = M^t_{33}, \tag{15}$$

the "centers of gravity" are:

$$X_x = \frac{M^{tr}_{11}}{M_x}, \quad Y_x = \frac{-M^{tr}_{13}}{M_x}, \quad Z_x = \frac{M^{tr}_{12}}{M_x}, \tag{16}$$

$$X_y = \frac{M^{tr}_{23}}{M_y}, \quad Y_y = \frac{M^{tr}_{22}}{M_y}, \quad Z_y = \frac{-M^{tr}_{21}}{M_y}, \tag{17}$$

$$X_z = \frac{-M^{tr}_{32}}{M_z}, \quad Y_z = \frac{M^{tr}_{31}}{M_z}, \quad Z_z = \frac{M^{tr}_{33}}{M_z}. \tag{18}$$

and the inertias are:

$$I_{11} = M^r_{11} - M_y\ Z_y^2 - M_z\ Y_z^2\ , \tag{19}$$

$$I_{12} = I_{21} = -M^r_{12} - M_z\ X_z\ Y_z\ , \tag{20}$$

$$I_{13} = I_{31} = -M^r_{13} - M_y\ X_y\ Z_y\ , \tag{21}$$

$$I_{22} = M^r_{22} - M_z\ X_z^2 - M_x\ Z_x^2\ , \tag{22}$$

$$I_{32} = I_{23} = -M^r_{23} - M_x Y_x Z_x , \tag{23}$$

$$I_{33} = M^r_{33} - M_x Y_x^2 - M_y X_y^2 . \tag{24}$$

These terms form the symmetric matrix [I].

For principle inertias eigenvalues and eigenvectors are found such that:

$$\begin{bmatrix} I^p_{11} & 0 & 0 \\ 0 & I^p_{22} & 0 \\ 0 & 0 & I^p_{33} \end{bmatrix} = [Q]^T [I] [Q]. \tag{25}$$

[Q] contains the normalized eigenvectors (the directions of the principal inertias), and the I^p_{ii} terms are the eigenvalues. The matrices [S] and [Q] are actually coordinate rotation matrices and show the directions of the principal masses and inertias.

4.29.8 Subroutines

Utility Subroutines PRETRS,TRANSS,TRANP1,SSG2B and GMMATS are used. See subroutine descriptions, section 3.

4.29.8.1 Subroutine Name: GPWG1A

1. Entry Point: GPWG1A

2. Purpose: To form the $[D]^T$ matrix.

3. Calling Sequence: CALL GPWG1A(PØINT,BGPDT,CSTM,EQEXIN,DT,NØGØ)

   PØINT - External grid point id of reference point - integer - input.

   BGPDT - GINØ file number of ØGPWG - integer - input.

   CSTM - GINØ file number of CSTM - integer - input.

   EQEXIN - GINØ file number of EQEXIN - integer - input.

   DT - GINØ file number of file on which $[D]^T$ will be written - integer - input.

   NØGØ - Flag for all scalar problem - integer - output. NØGØ = 0 implies all scalars.

4.29.8.2 Subroutine Name: GPWG1B

1. Entry Point: GPWG1B

2. Purpose: To form output quantities as given in paragraph 4 of section 4.29.7.

3. Calling Sequence: CALL GPWG1B (MØ,ØGPWG,WTMASS,IP)

MØ - GINØ file number of [M_o] matrix - integer - input.

ØGPWG - GINØ file number of ØGPWG - integer - input.

WTMASS - Mass to weight ratio parameter - real - input.

IP - External grid point id of reference point (=0 if basic origin was used) - integer - input.

4.29.8.3 Subroutine Name: GPWG1C

1. Entry Point: GPWG1C

2. Purpose: To compute eigenvectors and values of a 3 by 3 matrix by the classical Jacobi method.

3. Calling Sequence: CALL GPWG1C (B,E,EV,IFLAG)

B - 3 by 3 input matrix - real - input.

E - 3 by 3 matrix of eigenvectors - real - output.

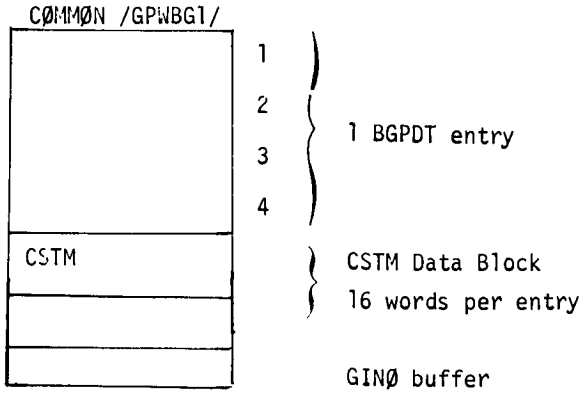
EV - 3 eigenvalues - real - output.

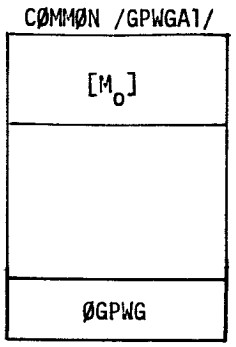
IFLAG - Error termination flag - integer - output. If IFLAG > 0, GPWG1C could not converge.

4.29.9 Design Requirements

GPWG requires four scratch files. Open core for GPWG1A is defined at /GPWGA1/. Open core for GPWG1B is defined at /GPWGB1/.

The layout of open core is as follows:





4.29.10 Diagnostic Messages

The following fatal error messages may occur: 3007, 3008.

4.30 FUNCTIONAL MODULE SMA3 (STRUCTURAL MATRIX ASSEMBLER - PHASE 3)

4.30.1 Entry Point: SMA3

4.30.2 Purpose

To generate the final stiffness matrix, $[K_{gg}]$, by generating a matrix of order g for each general element in the model, and successively adding this matrix to $[K^{x}_{gg}]$, the stiffness matrix exclusive of general elements.

4.30.3 DMAP Calling Sequence

```
SMA3    GEI,KGGX/KGG/V,N,LUSET/V,N,NØGENL/V,N,NØSIMP $
```

4.30.4 Input Data Blocks

GEI - General Element Input.

KGGX - Partition of stiffness matrix exclusive of general elements - g set.

Note:

1. GEI cannot be pre-purged.

2. KGGX may be pre-purged. This implies that the model consists entirely of general elements (i.e., there are no simple elements).

4.30.5 Output Data Blocks

KGG - Partition of stiffness matrix - g set. Contains contributions from all elements in the model, including general elements.

Note: KGG may not be pre-purged.

4.30.6 Parameters

LUSET - Input-integer-no default value. LUSET is the total number of degrees of freedom in the g displacement set. It is the order of the $[K^{x}_{gg}]$ and $[K_{gg}]$ matrices.

NØGENL - Input-integer-no default value. NØGENL is the number of general elements in the GEI data block.

NØSIMP - Input-integer-no default value. If NØSIMP < 0, $[K^{x}_{gg}]$ does not exist, i.e., all elements of the model are general elements. If NØSIMP $\geq$ 0, $[K^{x}_{gg}]$ does exist.

4.30.7 Method

4.30.7.1 Mathematical Considerations

Two matrices can be used to form a stiffness matrix for each general element in the GEI data block: a flexibility influence coefficient matrix, [Z], and a rigid body matrix, [S]. The former must be present and must be non-singular; the latter may or may not be present. The set of degrees of freedom (scalar index numbers) used by [Z] is designated the "u_i" set; the set of degrees of freedom used by [S] is designated the "u_d" set. Call the length of the u_i set m, and call the length of the u_d set n. [Z] is m by m, and [S] is m by n.

For each general element in the model, the stiffness matrix corresponding to the general element, $[K^{ge}]$, is made up of four partitions if the u_d set exists. They are:

$$[K_{ii}] = [Z]^{-1} \quad , \tag{1}$$

$$[K_{id}] = -[Z]^{-1}[S] \quad , \tag{2}$$

$$[K_{di}] = -[S]^{T}[Z]^{-1} = [K_{id}]^{T} \quad , \tag{3}$$

$$[K_{dd}] = [S]^{T}[Z]^{-1}[S] \quad . \tag{4}$$

The four matrices must be merged such that 1):

$$[K^{ge}] = \left[\begin{array}{c|c} K_{ii} & K_{id} \\ \hline K_{di} & K_{dd} \end{array}\right] \quad ; \tag{5}$$

and 2) the rows and columns of $[K^{ge}]$ must correspond to a merged list of both u_i and u_d coordinates in order of ascending scalar index numbers.

If the u_d set does not exist, then

$$[K^{ge}] = [K_{ii}] = [Z]^{-1} \quad . \tag{6}$$

4.30.7.2 Initialization

The GEI data block is opened, and the header record is skipped. It is determined whether the number of general elements, f, is even or odd. This is done to insure that the result of the final matrix addition,

$$[K_{gg}] = [K^{rs}] + [K^{gef}] , \tag{7}$$

where

$$[K^{rs}] = [K^{x}_{gg}] + \sum_{i=1}^{f-1} [K^{gei}] , \tag{8}$$

and $[K^{gef}]$ is the final general element matrix, will be written on the output data block, KGG.

If $[K^{x}_{gg}]$ does not exist, and there is only one general element, then the GINØ file number (201) for the KGG data block is stored in IFA, the variable which contains the GINØ file number of the file onto which the current $[K^{ge}]$ matrix will be packed.

The principal logic of the module driver, SMA3, is carried out in a loop in which, during each pass of the loop, a $[K^{ge}]$ matrix is generated and added, using subroutine SSG2C, to the running sum matrix, $[K^{rs}]$.

4.30.7.3 Generation and Addition of a General Element Matrix

The steps involved in the principal loop of the program are as follows:

1. The loop counter is incremented.

2. The first three words of the next logical record are read from GEI: the element id; the length of the u_i set, m; and the length of the u_d set, n.

3. The matrix control blocks for the scratch files IFB and IFC are interchanged provided that:

   a. this is not the first pass through the loop;

   b. this is not the second pass through the loop and the number of general element is odd and there are only general elements in the model;

   and

   c. this is not the second time through the loop and $[K^{x}_{gg}]$ exists.

4. It is determined whether the orders of the [Z] and [S] matrices are such that the in-core matrix routines GMMATD and INVERD can be used. This is accomplished as follows. Define

$$p = 2(m + n + m^2 + n^2 + 2mn) , \tag{9}$$

$$q = 2(m + n + m^2) + 3m , \tag{10}$$

and

$$r = \max(p,q) . \tag{11}$$

p is the number of computer words needed to store: 1) the u_i and u_d sets in two different sorts; 2) the double precision m by m [Z] matrix; 3) the double precision n by n $[S]^T[Z]^{-1}[S]$ matrix; and 4) the double precision m by n [S] matrix and the double precision m by n $[Z]^{-1}[S]$ matrix.

q is the number of computer words needed to store: 1) the u_i and u_d in two different sorts; 2) the double precision m by m [Z] matrix; and 3) 3m cells of scratch storage to be used by subroutine INVERD.

If r is less than the available amount of core, the in-core routine, SMA3A, is called to compute $[K^{ge}]$. Otherwise: 1) SMA3B generates [Z] and $-[S]^T$; 2) FACTØR decomposes [Z] into its triangular factors; 3) SSG3A computes $[Z]^{-1}$; 4) SSG2B computes $-[S]^T[Z]$; 5) TRANP1 transposes $-[S]^T$; 6) SSG2B computes $-[Z][S]^T$; 7) SSG2B computes $[S]^T[Z]^{-1}[S]$; and 8) SMA3C builds the final $[K^{ge}]$ matrix of order g by g.

5. The matrix $[K^{ge}]$ having been generated as in step 4, SSG2C is called to add $[K^{ge}]$ to $[K^{rs}]$.

4.30.8 Subroutines

Utility routines GMMATD, INVERD, FACTØR, SSG3A, SSG2B, TRANP1 and SSG2C are used in this module.

4.30.8.1 Subroutine Name: SMA3A

1. Entry Point: SMA3A

2. Purpose: To build a g by g general element matrix, $[K^{ge}]$, using the in-core matrix routines GMMATD and INVERD.

3. Calling Sequence: CALL SMA3A (MCBA)

CØMMØN /GENELY/ - see description below (section 4.30.9.2).

MCBA - The matrix control block corresponding to $[K^{ge}]$. Word 1 is input; words 2 through 7 are output.

4. Method: The u_i set and the u_d set (if present) of scalar index numbers are read into core, and a list L is formed of length m + n, such that L(k) = ℓ implies the ℓ^{th} entry of the string: $\{u_{i1},u_{i2},\ldots,u_{im},u_{d1},u_{d2},\ldots,u_{dn}\}$ is the k^{th} smallest. The m^2 single precision elements of [Z] are read and stored at double precision locations. $[Z]^{-1}$ is computed using INVERD. [S], if present, is read and stored at double precision locations. GMMATD is called twice to compute $[Z]^{-1}[S]$ and $[S]^T[Z]^{-1}[S]$. The elements of $[K^{ge}]$, as defined in Equation 5, are output to the GINØ file corresponding to MCBA(1) with non-zero terms in the row and column positions specified by the u_i and u_d sets. The list L determines the sequence of elements to be output for any one column.

4.30.8.2 Subroutine Name: SMA3B

1. Entry Point: SMA3B

2. Purpose: To create [Z] and [S] from the GEI data.

3. Calling Sequence: CALL SMA3B (IFLAG)

CØMMØN /GENELY/ - see description below (section 4.30.9.2).

IFLAG - $\left\{\begin{array}{l}\text{IFLAG = -1 implies [S] does not exist.}\\ \text{IFLAG = 1 implies [S] exists.}\end{array}\right\}$ - integer - output.

4. Method: The GEI data block is read for the row numbers and non-zero terms of [Z]. These are output in standard NASTRAN matrix format by subroutine BLDPK. - $[S]^T$ is generated in a similar manner. (- $[S]^T$ is created rather than [S] for computational ease in subsequent calculations - see paragraph 4 in section 4.30.7.3 above).

4.30.8.3 Subroutine Name: SMA3C

1. Entry Point: SMA3C

2. Purpose: To create the $[K^{ge}]$ matrix from $[Z]^{-1}$, $-[Z]^{-1}[S]$, $-[S]^T[Z]^{-1}$ and $[S]^T[Z]^{-1}[S]$.

3. Calling Sequence: CALL SMA3C (IFLAG, KE)

CØMMØN /GENELY/ - see description below (section 4.30.9.2).

CØMMØN //LUSET - size of problem.

IFLAG is as described in SMA3B. Here it implies $[K^{ge}] = [Z]^{-1}$.

KE - Matrix control block for $[K^{ge}]$ - integer - input/output.

4. Method: A matrix of g size is created from $[Z]^{-1}$, $-[Z]^{-1}[S]$, $-[S]^T[Z]$ and $[S]^T[Z]^{-1}[S]$ with the non-zero terms in the row and column positions specified by the u_i and u_d lists. This matrix can be added to the existing $[K^{rs}]$ to reflect the stiffness terms of this general element.

4.30.8.4 Block Data Subprogram: SMA3BD

Purpose: To initialize the GINØ file numbers and GINØ options indicators in /GENELY/, which is discussed below.

4.30.9 Design Requirements

4.30.9.1 Open Core Design

The open core common block for the module driver SMA3 and subroutine SMA3A is defined by the following FØRTRAN statements:

1. DØUBLE PRECISIØN DQ(1)
2. INTEGER IQ(1)
3. DIMENSIØN Q(1)
4. CØMMØN /GENELX/ Q
5. EQUIVALENCE (IQ(1),DQ(1),Q(1))

SMA3 uses open core only for one GINØ buffer, which is reserved for the GEI data block while SMA3A, SMA3B, or SMA3C is executing, and which is reserved for use by SSG2C when this routine adds $[K^{ge}]$ to $[K^{rs}]$ at the end of the principal loop in the driver.

SMA3A uses low order open core as outlined in paragraph 4 in section 4.30.7 above.

The open core for subroutine SMA3B is defined at /SMAB3/ and is used for two GINØ buffers in high order open core.

The open core for subroutine SMA3C is defined at /SMAC3/ and is used for: 1) the u_i and u_d sets in low order open core and 2) six GINØ buffers in high order open core.

4.30.9.2 Common Storage Requirements

The common block /GENELY/ is used for: 1) GINØ file numbers; 2) GINØ option indicators; 3) matrix control blocks; and 4) zero pointers to sub-arrays in /GENELX/ when SMA3A executes. It is defined as follows:

```
CØMMØN /GENELY/ IFGEI,IFKGGX,IFØUT,IFA,IFB,IFC,IFD,IFE,IFF,INRW,ØUTRW,CLSRW,CLSNRW,EØR,
NEØR,MCBA(7),MCBB(7),MCBC(7),MCBE(7),MCBF(7),MCBKGG(7),IUI,IUD,IZI,IS,IZIS,ISTZIS,IBUFF3(3),
LEFT
```

Variable	Definition
IFGEI,IFKGGX,IFØUT	GINØ file numbers for the two input data blocks and the output data block respectively.
IFA	GINØ file number for the current $[K^{ge}]$ being computed.
IFB,IFC	GINØ file numbers for $[K^{rs}]$ and $[K^{rs}] + [K^{ge}]$ matrices. They are "flip-flopped" such that IFC = IFØUT for the final matrix addition.
IFD,IFE,IFF	GINØ file numbers for scratch files which are used in subroutine SMA3C.
INRW,ØUTRW,CLSRW,CLSNRW,EØR,NEØR	GINØ option indicators as defined in section 4.27.9.3.
MCBA,MCBB,...,MCBF,MCBKGG	Matrix control blocks for the matrices corresponding to IFA, IFB, ..., IFF, and IFKGXX.
IUI,IUD,IZI,IS,IZIS,ISTZIS	Zero pointers to the sub-arrays in /GENELX/ corresponding to: 1) u_i set; 2) u_d set; 3) $[Z]^{-1}$; 4) $[S]$; 5) $[Z]^{-1}[S]$ and 6) $[S]^T[Z]^{-1}[S]$. Note that IZI, IZIS, ISTZIS are zero pointers into double precision arrays.
IBUFF3(3)	Three word buffer which contains the general element id, m and n.
LEFT	The number of computer words currently remaining in /GENELX/.

4.30.9.3 Arithmetic Considerations

All floating point arithmetic operations are carried out in double precision.

4.30.10 Diagnostic Messages

In SMA3A, system fatal error 2028 can occur. See section 6 of the User's Manual for details.

4.31 FUNCTIONAL MODULE GP4 (GEOMETRY PROCESSOR - PHASE 4)

4.31.1 Entry Point: GP4

4.31.2 Purpose

GP4 assembles the various displacement sets and builds the displacement set definition table (USET). Additionally, for statics problems, GP4 analyzes subcases based on single-point and multipoint constraint sets, and set parameters to control execution of the Rigid Format.

4.31.3 DMAP Calling Sequence

```
GP4     CASECC,GEØM4,EQEXIN,SIL,GPDT / RG,YS,USET,XX / V,N,LUSET / V,N,MPCF1 / V,N,MPCF2 /
        V,N,SINGLE / V,N,ØMIT / V,N,REACT / V,N,NSKIP / V,N,REPEAT / V,N,NØSET / V,N,NØL /
        V,N,NØA / C,N,SSID $
```

4.31.4 Input Data Blocks

CASECC - Case Control Data Table.

GEØM4 - Displacement set definitions.

EQEXIN - Equivalence between external grid or scalar and internal numbers.

SIL - Scalar Index List.

GPDT - Grid Point Definition Table.

Note: Only GEØM4 may be purged.

4.31.5 Output Data Blocks

RG - Multipoint constraint equations matrix.

YS - Constrained displacement vector(s) set.

USET - Displacement set definition table.

XX - Reserved for future use.

Note: YS may be purged.

4.31.6 Parameters

LUSET - Input-integer-no default. Degrees of freedom in the g-displacement set.

MPCF1 - Output-integer-no default. +1 if the current subcase contains multipoint constraints, -1 otherwise.

MPCF2 - Output; integer, no default. +1 if the current subcase contains a different multipoint constraint set from the last subcase, -1 if no new multipoint constraint set or no multipoint constraints in the current subcase.

SINGLE - Output, integer, no default. +1 if the current subcase contains single-point constraints, -1 otherwise.

ØMIT - Output, integer, no default. +1 if the model contains omitted coordinates, -1 otherwise.

REACT - Output, integer, no default. +1 if the model contains supports, -1 otherwise.

NSKIP - Input and output, integer, deault = 0. Number of records to skip to reach the first record in the Case Control Data Block for the next subcase. (NSKIP = 0 for the first subcase).

REPEAT - Output, integer, no default. -1 if the current subcase is the last subcase in the problem, +1 otherwise.

NØSET - Output, integer, no default. -1 if MPCF1 = -1 and SINGLE = -1 and ØMIT = -1 and REACT = -1, +1 otherwise.

NØL - Output, integer, default = +1. -1 if all degrees of freedom in the model belong to dependent displacement sets (i.e., no degree of freedom belongs to an independent set), +1 otherwise.

NØA - Output, integer, default = +1. -1 if MPCF1 = -1 and SINGLE = -1 and ØMIT = -1, +1 otherwise.

SSID - Input, integer, default = 0. Reserved for future use.

4.31.7 Method

CASECC is read for each subcase. Parameters are set to control the return point for the next subcase. The user-requested constraint set numbers are extracted and saved for control of the following steps.

The multi-point constraint cards (MPC) each define a row of a constraint matrix equation:

$$[R_m] \{u_m\} + [R_n] \{u_n\} = 0 \qquad (1)$$

For each requested MPC set, the MPC card images are read from GEØM4, and the grid points and their scalar coordinates (or scalar points) are converted to the scalar degree of freedom numbers. The EQEXIN and SIL data blocks are placed in core, the point "id" number is found as the first entry of a pair in the first record of EQEXIN, the corresponding number in the second entry of the pair is the internal grid point index. The i^{th} position of the SIL contains the value of the scalar degree of freedom number for the first degree of freedom of point i. The SIL value, SIL_u, for the component c, (c = 1,2,...,6) of a grid point p is found by the equation:

$$SIL_u = SIL_p + (c - 1) \quad . \tag{2}$$

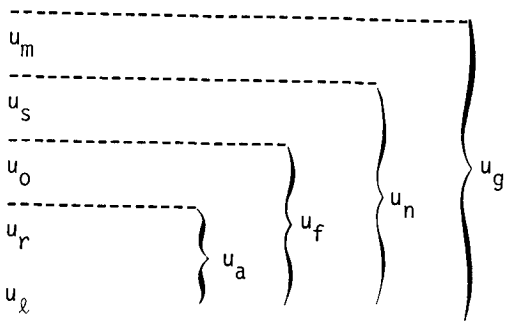
The SIL of a point is the scalar index of its first degree of freedom. The point "id's" and components given on the MPC cards are converted to scalar index numbers, a sorted list is formed of the u_m scalar indices, (see definition below of the sets defined in USET), and the data are written on SCR1, a scratch file. Each term in the equation is paired with a packed word giving its equation number and its SIL value. The equation data are now sorted to group the data by each scalar index number in order of increasing dependent u_m point number. This essentially creates a column stored matrix $[R_g]$. Each row in the matrix corresponds to a u_m point. Each column corresponds to a unique scalar index (u_g point).

The SUPØRT (u_r), ASET (u_a) and ØMIT (u_o) card images are read from GEØM4. The grid and component numbers are sorted and written on SCR1. The GPDT is read, and a list is formed of the permanent single-point constraints (u_{sg}) which were identified on the GRID bulk data cards. This list is written on SCR1.

The SPCADD, SPC1 and SPC bulk data card images identify the sets of single-point constraints used as boundary points (u_{sb}) and include any possible constrained displacement values (Y_s). The user-requested set of SPC cards are extracted from the CASECC data block and the SPCADD cards. The requested SPC and SPC1 card images are read, the grid and component "id" numbers are converted to scalar indices, and a paired list of scalar indices and their corresponding displacement values is written on SCR1. The non-zero Y_s values formed in the previous step form a packed vector with indices given by their position in the list. This is the YS data block, a vector packed relative to the u_s set.

The USET data block contains one coded word for each scalar degree of freedom in the entire structure. The word is coded to identify the set or sets of coordinates to which the scalar

degree of freedom belongs (see Section 2.3.13). An area of core is set equal to zero, and the lists of u_m, u_o, u_r and u_s points are read from SCR1. The scalar index of a coordinate corresponds to a position in core. The word in that position is modified to identify the set to which that scalar index belongs. With the u_m, u_o, u_r and u_s points known, the u_g, u_n, u_f, u_a and u_ℓ points may be identified. The "nesting" of these sets follows the scheme:



USET is written as one logical record on the USET data block.

The final operation is to process each degree of freedom in USET to insure that the displacement set definitions are consistent and assign any otherwise undefined degrees of freedom in USET. The governing rule (as may be noted in the nesting scheme) is that each degree of freedom may belong to at most one dependent subset. If any inconsistent definitions are found, they are written on SCR1. When each point has been analyzed, EQEXIN and SIL are read into core. Then SCR1 is read, and, for each entry, an error message is queued. MESAGE is then called to abnormally terminate GP4.

Unassigned degrees of freedom are assigned according to the following:

1. If any ASET (or ASET1) cards are present, undefined degrees of freedom will be placed in the u_o set.
2. If ØMIT (or ØMIT1) cards are present, undefined degrees of freedom will be placed in the u_a set. These degrees of freedom may also be redundantly specified on ASET (or ASET1) cards if desired. In this case <u>all</u> non-u_o set degrees of freedom <u>must</u> be specified since rule 1 applies.
3. If neither ASET (or ASET1) nor ØMIT (or ØMIT1) cards are present, all free degrees of freedom will be assigned to the u_a set.

4.31.7.1 Definitions of the Sets Defined in USET

u_g - All structural degrees of freedom defined by grid and scalar points.

u_m - Dependent coordinates used in the multipoint constraint equations. Defined as the first degree of freedom of an MPC card.

u_n - All structural degrees of freedom except u_m.

u_s - All fixed points. The u_{sg} points are defined by the GRID cards and have a displacement of zero. The u_{sb} points are defined by the SPC cards and may have a constrained displacement.

u_f - All degrees of freedom in the structure except u_m and u_s.

u_o - These are "omitted coordinates" defined by ØMIT and ØMIT1 cards. In statics, the structural matrix is partitioned, and these degrees of freedom are solved separately. In dynamics, the displacements of these points are approximated by their static displacements under mass loads.

u_a - These are the unconstrained degrees of freedom of the system. They include rigid body modes in dynamics.

u_r - These are fictitious supports defined by the SUPØRT cards. In dynamics and inertia relief the elastic displacements are measured relative to these points.

u_ℓ - This set includes all degrees of freedom not defined by the u_m, u_s, u_o and u_r points. The stiffness matrix defined by these points is used for the solution of displacements versus loads.

4.31.8 Subroutines

The module GP4 consists of a main subroutine, GP4, and an auxiliary subroutine, GP4PRT.

4.31.8.1 Subroutine Name: GP4PRT

1. Entry Point: GP4PRT

2. Purpose:

   a. Prints, at user request via DIAG 21, a list of degrees of freedom. For each degree of freedom, an indication is made identifying the sets to which it belongs.

   b. Prints, at user request via DIAG 22, the contents of selected displacement sets. For each set, a list of all degrees of freedom belonging to the set is given.

3. Calling Sequence: CALL GP4PRT (BUF)

4. Method: The DIAG flags are tested and local variables set. Table EQEXIN is then read into open core and sorted. If DIAG 21 is on, table USET (already in open core) is examined and the external degree of freedom is extracted from EQEXIN and printed along with the set indications. If DIAG 22 is on, transpose process takes place.

4.31.8.2 Subroutine Name: SCALEX

1. Entry Point: SCALEX

2. Purpose: Decodes packed component codes.

3. Calling Sequence: CALL SCALEX (I,C,L)

   I = Value to be decoded

   C = If non-positive, return after loading I into L(1).

   L = Array into which the decoded values are placed.

4.31.9 Design Requirements

The maximum storage requirement for GP4 is one word per degree of freedom (i.e., LUSET = 6* (number of grid points) + number of scalar points) plus one GINØ buffer. Its open core is defined by /GP4CØR/. Two scratch files are used by GP4.

4.31.10 Diagnostic Messages

The following messages may be issued by GP4:

2045, 2048, 2049, 2050, 2051, 2052, 2053, 2101, 3008, 3001, 3002, 2110

4.32 FUNCTIONAL MODULE GPSP (GRID PØINT SINGULARITY PRØCESSØR).

4.32.1 Entry Point: GPSP.

4.32.2 Purpose

The GPST data block contains data on possible stiffness matrix singularities. These singularities may be removed through the application of single or multipoint constraints. The GPSP module checks each singularity against the list of constraints, and if the singularity is not removed, writes data for warning the user.

4.32.3 DMAP Calling Sequence

```
GPSP    GPL,GPST,USET,SIL/ØGPST  $
```

4.32.4 Input Data Blocks

GPL - Grid Point List.

GPST - Grid Point Singularity Table.

USET - Displacement set definitions table.

SIL - Scalar Index List.

Note: No input data block can be purged.

4.32.5 Output Data Blocks

ØGPST - Unremoved Grid Point Singularities. This data block will be processed by the ØFP (Output File Processor) module.

4.32.6 Parameters

None.

4.32.7 Method

USET is read into core. The USET data block contains one word for each degree of freedom in the structural model. This word identifies the displacement coordinate sets to which the coordinate belongs. Each entry in the GPST data block contains the order of the singularity and the scalar index numbers of the degrees of freedom involved. The logic of the algorithm depends on the order of the singularity. For each type the logic is:

1. If order = 1, the contents of the GPST data are:

    a. ØRDER = 1

b. Number of words following

c. N_1

d. N_2 } may not appear

e. N_3 }

N_1, N_2 and N_3 are the scalar indices of the degrees of freedom which will remove the singularity if constrained. If the singularity is not removed, the ØGPST data is output.

2. If order = 2:

a. ØRDER = 2

b. Number of words following

c. N_{11}

d. N_{21}

e. N_{12}

f. N_{22} } may not appear

g. N_{13}

h. N_{23}

Each pair of indices identifies two degrees of freedom which cause the singularity. If both indices for any pair belong to the USET (UM or US), the singularity is removed. If only one of the degrees of freedom in a pair is constrained by a u_s or u_m coordinate, the singularity order is now ØRDER = 1. The numbers listed are not unique, and more than one of the N_{ij} indices may belong to the u_s or u_m sets. Keeping the same sequence, the unconstrained scalar indices in each partially constrained pair is listed in the ØGPST in the form for ØRDER = 1.

3. If order = 3:

a. ØRDER = 3

b. Number of words following

c. N_1

d. N_2

e. N_3

All three indices (N_1, N_2, and N_3) must belong to the u_s or u_m sets to remove the

singularity. If one or two of the coordinates are constrained, the order is two or one, and the remaining scalar indices or index is listed in the ØGPST.

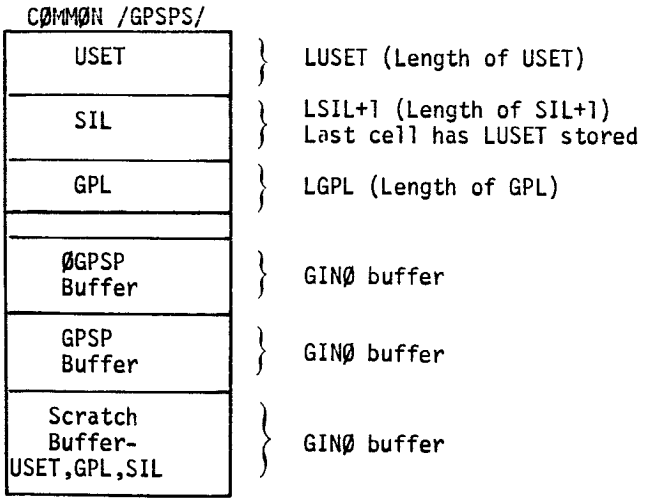
If any singularities are unremoved, a message is given to this effect. Also the SIL values must be converted to external grid point-component notation for user readability. The first time an unremoved singularity is detected, SIL is read into core beneath USET, and GPL is placed beneath SIL. Each SIL value is looked up in SIL for a pointer into GPL to the external grid point ID. Scalar points are differentiated from grid points. Data is output to the ØGPST in the order: grid point ID, type, singularity order and components. When all entries in the GPST have been processed, the routine returns.

4.32.8 Subroutines

None.

4.32.9 Design Requirements

Open core is defined at /GPSPA/.



4.32.9.1 Allocation of Core Storage

If no singularities exist, USET plus two GINØ buffers must be held in core. If singularities exist, USET, SIL, GPL plus three GINØ buffers must be held in core.

4.32.10 Diagnostic Messages

The following diagnostic messages may occur: 3007 (if the GPST does not contain legal SIL numbers, indicating a programming error); 3008 (if the core storage requirements given in section 4.32.9.1 are not met).

4.33 FUNCTIONAL MODULE MCE1 (MULTIPOINT CONSTRAINT ELIMINATOR - PHASE 1)

4.33.1 Entry Point: MCE1

4.33.2 Purpose

MCE1 partitions $[R_g]$ into $[R_m]$ and $[R_n]$ and then solves the matrix equation $[R_m]\ [G_m] = -[R_n]$ for $[G_m]$.

4.33.3 DMAP Calling Sequence

```
MCE1    USET,RG/GM  $
```

4.33.4 Input Data Blocks

USET - Displacement set definitions table.

RG - Multipoint constraint equations matrix.

Note: Neither USET nor RG may be purged.

4.33.5 Output Data Blocks

GM - Multipoint constraint transformation matrix - m set.

Note: GM may not be purged.

4.33.6 Parameters

None

4.33.7 Method

$[R_g]$ is a matrix with each row defining a constraint equation. The row scalar indices correspond to the u_m set of coordinates and the column indices correspond to the u_g set. The first operation of MCE1 is to partition $[R_g]$ into $[R_m]$ and $[R_n]$. MCE1A performs this operation by initializing /PARMEG/ and calling PARTN (see section 3.5.6 for PARTN details).

The second operation of MCE1 is to solve the matrix equation

$$[R_m]\ [G_m] = -[R_n] \qquad (1)$$

for $[G_m]$. If $[R_m]$ is diagonal, the operation is straightforward. In this case MCE1D is called. The terms $-r_{ii}$ are stored in core, the $[R_n]$ matrix is read interpretively by INTPK, and the terms of $[G_m]$ are formed from the equation

$$g_{ij} = - \frac{r_{ij}}{r_{ii}}, \qquad (2)$$

where the terms in the numerator belong to $[R_n]$ and those in the denominator belong to $[R_{mm}]$. If $[R_m]$ is not diagonal, Equation 1 is solved by decomposition and forward-backward substitution. In this case, MCE1B is called. MCE1B performs an unsymmetric decomposition of $[R_{mm}]$ by initializing /DCØMPX/ and calling DECØMP. MCE1C is then called by MCE1. MCE1C performs a forward-backward substitution to solve for $[G_m]$ by initializing /GFBSX/ and calling GFBS. See section 3.5.15 and 3.5.19 for further details on DECØMP and GFBS, respectively.

4.33.8 Subroutines

4.33.8.1 Subroutine Name: MCE1A

1. Entry Point: MCE1A
2. Purpose: To partition $[R_g]$ into $[R_m]$ and $[R_n]$.
3. Calling Sequence: CALL MCE1A

4.33.8.2 Subroutine Name: MCE1B

1. Entry Point: MCE1B
2. Purpose: To decompose $[R_m]$ into lower and upper triangular factors.
3. Calling Sequence: CALL MCE1B

4.33.8.3 Subroutine Name: MCE1D

1. Entry Point: MCE1D
2. Purpose: To solve the matrix equation $[R_m]\ [G_m] = [R_n]$ for $[G_m]$ where $[R_m]$ is diagonal.
3. Calling Sequence: CALL MCE1D

4.33.9 Design Requirements

4.33.9.1 Allocation of Core Storage

The maximum core storage requirement in the module is one double precision vector in the u_m displacement set plus three GINØ buffers.

4.33.9.2 Environment

Communication of GINØ file names to each of the phases of MCE1 occurs through blank CØMMØN. The four phases are designed so that each may be in a separate overlay segment. Open core for each of the phases is as follows:

MCE1A: /MCEA1/

MCE1B: /MCEB1/

MCE1C: /MCEC1/

MCE1D: /MCED1/.

4.33.10 Diagnostic Messages

The following messages may be issued by MCE1:

3005, 3016

4.34 FUNCTIONAL MODULE MCE2 (MULTIPOINT CONSTRAINT ELIMINATOR - PHASE 2)

4.34.1 Entry Point: MCE2

4.34.2 Purpose

MCE2 partitions the stiffness matrix $[K_{gg}]$ into $[\overline{K}_{nn}]$, $[\overline{K}_{mn}]$ and $[\overline{K}_{mm}]$ and then performs the matrix reduction $[K_{nn}] = [\overline{K}_{nn}] + [G_m]^T [\overline{K}_{mn}] + [\overline{K}_{mn}]^T [G_m] + [G_m]^T [\overline{K}_{mm}] [G_m]$

Similar partitions and reductions are performed on $[M_{gg}]$, $[B_{gg}]$ and $[K^4_{gg}]$ if these matrices are not purged.

4.34.3 DMAP Calling Sequence

```
MCE2    USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN  $
```

4.34.4 Input Data Blocks

USET - Displacement set definitions table.

GM - Multipoint constraint transformation matrix - m set.

KGG - Partition of stiffness matrix - g set.

MGG - Partition of mass matrix - g set.

BGG - Partition of damping matrix - g set.

K4GG - Partition of structural damping matrix - g set.

Note: MGG, BGG and K4GG may be purged.

4.34.5 Output Data Blocks

KNN - Partition of stiffness matrix - n set.

MNN - Partition of mass matrix - n set.

BNN - Partition of damping matrix - n set.

K4NN - Partition of structural damping matrix - n set.

Note: MNN, BNN or K4NN may be purged only if MGG, BGG or K4GG is purged.

4.34.6 Parameters

None

4.34.7 Method

Using subroutine UPART to generate row and column partitioning vectors and subroutine MPART to perform the actual partitioning, $[K_{gg}]$ is partitioned as follows:

$$[K_{gg}] \Longrightarrow \left[\begin{array}{c|c} \overline{K}_{nn} & \overline{K}_{nm} \\ \hline \overline{K}_{mn} & \overline{K}_{mm} \end{array}\right]. \qquad (1)$$

Subroutine ELIM is called to perform the following matrix reduction:

$$[K_{nn}] = [\overline{K}_{nn}] + [G_m]^T [\overline{K}_{mn}] + [\overline{K}_{mn}]^T [G_m] + [G_m]^T [\overline{K}_{mm}] [G_m]. \qquad (2)$$

For each of the data blocks corresponding to the matrices $[M_{gg}]$, $[B_{gg}]$, $[K^4_{gg}]$ which is not purged, the above partitioning and matrix reductions are performed.

4.34.8 Subroutines

Calls are made to the following matrix utility routines:

UPART see section 3.5.9 for details

MPART see section 3.5.9 for details

ELIM see section 3.5.22 for details

4.34.9 Design Requirements

4.34.9.1 Allocation of Core Storage

The maximum storage requirement for MCE2 is four times the number of degrees of freedom in the u_n displacement set plus one GINØ buffer.

4.34.9.2 Environment

The module MCE2 consists of one subroutine, MCE2. Calls are made to the matrix utility routines as indicated above. Six scratch files are used.

4.35 FUNCTIONAL MODULE SCE1 (SINGLE-POINT CONSTRAINT ELIMINATOR)

4.35.1 Entry Point: SCE1

4.35.2 Purpose

To reduce the n set matrices to f set matrices by removing the single-point constraints.

4.35.3 DMAP Calling Sequence

```
SCE1  USET,KNN,MNN,BNN,K4NN/KFF,KFS,KSS,MFF,BFF,K4FF/  $
```

4.35.4 Input Data Blocks

USET - Displacement set definitions table.

KNN - Partition of stiffness matrix - n set.

MNN - Partition of mass matrix - n set.

BNN - Partition of damping matrix - n set.

K4NN - Partition of the structural damping matrix - n set.

Notes: 1. USET cannot be purged.

2. KNN,MNN,BNN and K4NN can be purged.

3. At least one degree of freedom must belong to the f and s sets.

4.35.5 Output Data Blocks

KFF - Partition of stiffness matrix after single-point constraints have been removed - f set.

KFS - Partition of stiffness matrix after single-point constraints have been removed.

KSS - Partition of stiffness matrix after single-point constraints have been removed - s set.

MFF - Partition of mass matrix after single-point constraints have been removed - s set.

BFF - Partition of damping matrix after single-point constraints have been removed - f set.

K4FF - Partition of structural damping matrix with single-point constraints removed - f set.

4.35.6 Parameters

None

4.35.7 Method

The matrices are partitioned using USET(UN,UF,US) as follows (see section 1.7 for details):

1. If $[K_{nn}]$ exists:

$$[K_{nn}] \Rightarrow \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right]. \qquad (1)$$

The $[K_{ff}]$, $[K_{fs}]$ and $[K_{ss}]$ partitions are generated and saved.

2. If $[M_{nn}]$ exists:

$$[M_{nn}] \Rightarrow \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right]. \qquad (2)$$

3. If $[B_{nn}]$ exists:

$$[B_{nn}] \Rightarrow \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right]. \qquad (3)$$

4. If $[K^4_{nn}]$ exists:

$$[K^4_{nn}] \Rightarrow \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right]. \qquad (4)$$

For the $[M_{nn}]$, $[B_{nn}]$ and $[K^4_{nn}]$ matrices, only the "ff" partition is generated and saved.

One call to UPART followed by 4 calls to MPART accomplishes the above tasks.

4.35.8 Subroutines

UPART and MPART are called. See subroutine description in section 3.5.9.

4.35.9 Design Requirements

One scratch file is necessary.

4.36 FUNCTIONAL MODULE SMP1 (STRUCTURAL MATRIX PARTITIONER - PHASE 1)

4.36.1 Entry Point: SMP1

4.36.2 Purpose

SMP1 partitions $[K_{ff}]$ into $[\bar{K}_{aa}]$, and $[K_{oa}]$ and $[K_{oo}]$. The matrix equations $[K_{oo}]\,[G_o] = -[K_{oa}]$ is solved for $[G_o]$. $[K_{ff}]$ is then reduced by the matrix equation $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}]^T\,[G_o]$. If $[M_{ff}]$ is not purged, it is reduced by the equation $[M_{aa}] = [\bar{M}_{aa}] + [G_o]^T\,[M_{oa}] + [M_{oa}]^T\,[G_o] + [G_o]^T\,[M_{oo}]\,[G_o]$. Similarly, $[B_{ff}]$ and $[K^4_{ff}]$ are reduced.

4.36.3 DMAP Calling Sequence

```
SMP1   USET,KFF,MFF,BFF,K4FF/GØ,KAA,KØØ,LØØ,UØØ,MAA,MØØ,MØA,BAA,K4AA $
```

4.36.4 Input Data Blocks

USET - Displacement set definitions table.

KFF - Partition of stiffness matrix - f set.

MFF - Partition of mass matrix - f set.

BFF - Partition of damping matrix - f set.

K4FF - Partition of structural damping matrix - f set.

Note: MFF, BFF or K4FF may be purged.

4.36.5 Output Data Blocks

GØ - Structural matrix partitioning transformation matrix.

KAA - Partition of stiffness matrix - a set.

KØØ - Partition of stiffness matrix - o set.

LØØ - Lower triangular factor of KØØB - o set.

UØØ - Upper triangular factor of KØØB - o set.

MAA - Partition of mass matrix - a set.

MØØ - Partition of mass matrix - a set.

MØA - Partition of mass matrix.

BAA - Partition of damping matrix - a set.

K4AA - Partition of structural damping matrix - a set.

Note:

1. UØØ and LØØ are not standard form matrices. Their format is compatible only for input to subroutine FBS.

2. MAA, MØØ, MØA, BAA or K4AA may be purged only if MFF, BFF or K4FF are purged.

4.36.6 Parameters

None.

4.36.7 Method

Using subroutine UPART to generate row and column partitioning vectors and subroutine MPART to perform the actual partitioning, $[K_{ff}]$ is partitioned as follows:

$$[K_{ff}] \Rightarrow \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] \tag{1}$$

Subroutine FACTØR is called to decompose $[K_{oo}]$ into triangular factors. Subroutine SØLVER is called to perform a forward-backward substitution solving for $[G_o]$ in the matrix equation

$$[K_{oo}]\,[G_o] = -[K_{oa}]\,, \tag{2}$$

and computing $[K_{aa}]$ from the equation

$$[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}]\,[G_o]\,. \tag{3}$$

For each of the data blocks $[M_{ff}]$, $[B_{ff}]$, $[K^4_{ff}]$ which is not purged, the above partitioning operation is performed and the matrix reductions:

$$[M_{aa}] = [\bar{M}_{aa}] + [G_o]^T\,[M_{oa}] + [M_{oo}]^T\,[G_o] + [G_o]^T\,[M_{oo}]\,[G_o]\,, \tag{4}$$

$$[B_{aa}] = [\bar{B}_{aa}] + [G_o]^T\,[B_{oa}] + [B_{oa}]^T\,[G_o] + [G_o]^T\,[B_{oo}]\,[G_o]\,, \tag{5}$$

$$[K^4_{aa}] = [\bar{K}^4_{aa}] + [G_o]^T\,[K^4_{oa}] + [K^4_{oa}]^T\,[G_o] + [G_o]^T\,[K^4_{oo}]\,[G_o]\,, \tag{6}$$

are performed by subroutine ELIM.

4.36.8 Subroutines

Calls are made to the following matrix utility routines:

UPART See subroutine descriptions - Section 3.5.9 for details

MPART See subroutine descriptions - Section 3.5.9 for details

FACTØR See subroutine descriptions - Section 3.5.23 for details

SØLVER See subroutine descriptions - Section 3.5.20 for details

ELIM See subroutine descriptions - Section 3.5.22 for details

4.36.9 Design Requirements

4.36.9.1 Allocation of Core Storage

The maximum storage requirement for SMP1 is four times the number of degrees of freedom in the u_a displacement set plus one GINØ buffer.

4.36.9.2 Environment

The module SMP1 consists of one subroutine, SMP1. Calls are made to the matrix utility routines indicated above. Six scratch files are used.

The matrix multiply-add routine is used by ELIM to perform the matrix reductions described by equations 3, 4, 5 and 6. For equations 4, 5 and 6, the reduction is done in three phases as shown below for the mass matrix.

$$[A] = [M_{oo}] [G_o] + [M_{oa}] \quad (7)$$

$$[B] = [M_{oa}]^T [G_o] + [\bar{M}_{aa}] \quad (8)$$

$$[M_{aa}] = [G_o]^T [A] + [B] \quad (9)$$

4.37 FUNCTIONAL MODULE RBMG1 (RIGID BODY MATRIX GENERATOR - PHASE 1)

4.37.1 Entry Point: RBMG1

4.37.2 Purpose

RBMG1 partitions $[K_{aa}]$ into $[K_{\ell\ell}]$, $[K_{\ell r}]$ and $[K_{rr}]$. If $[M_{aa}]$ is not purged, it is partitioned similarly.

4.37.3 DMAP Calling Sequence

```
RBMG1     USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR  $
```

4.37.4 Input Data Blocks

USET - Displacement set definitions table.

KAA - Partition of stiffness matrix - a set.

MAA - Partition of mass matrix - a set.

Note: USET may not be purged.

4.37.5 Output Data Blocks

KLL - Partition of stiffness matrix - ℓ set.

KLR - Partition of stiffness matrix.

KRR - Partition of stiffness matrix - r set.

MLL - Partition of mass matrix - ℓ set.

MLR - Partition of mass matrix.

MRR - Partition of mass matrix - r set.

Note: Output data blocks may be purged only if the corresponding input data block is purged.

4.37.6 Parameters

None

4.37.7 Method

Using subroutine UPART to generate row and column partitioning vectors and subroutine

MPART to perform the actual partitioning, $[K_{aa}]$ is partitioned as follows:

$$[K_{aa}] \Longrightarrow \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right]. \qquad (1)$$

Similarly, if $[M_{aa}]$ is not purged, it is partitioned.

4.37.8 Subroutines

RBMG1 calls the following matrix utility routines:

UPART, MPART } see section 3.5.9 for details.

4.37.9 Design Requirements

4.37.9.1 Allocation of Core Storage

Storage requirements for RBMG1 are minimal since no unpacked vectors are held in core.

4.37.9.2 Environment

The module RBMG1 consists of one subroutine, RBMG1. Calls are made to the matrix utility routines indicated above. One scratch file is used.

4.38 FUNCTIONAL MODULE RBMG2 (RIGID BODY MATRIX GENERATOR - PHASE 2)

4.38.1 Entry Point: RBMG2

4.38.2 Purpose

RBMG2 decomposes $[K_{\ell\ell}]$ into its triangular factors $[L_{\ell\ell}]$ and $[U_{\ell\ell}]$.

4.38.3 DMAP Calling Sequence

```
RBMG2    KLL/LLL,ULL/V,N,PØWER/V,N,DET  $
```

4.38.4 Input Data Blocks

KLL - Partition of stiffness matrix - ℓ set.

Note: KLL may not be purged.

4.38.5 Output Data Blocks

LLL - Lower triangular factor of KLL - ℓ set.

ULL - Upper triangular factor of KLL - ℓ set.

Notes

1. LLL and ULL may not be purged.
2. ULL is not a standard upper triangular matrix. Its format is compatible only for input to subroutine FBS.

4.38.6 Parameters

PØWER - Output-integer-default = 1. Power of 10 in the determinant of KLL.

DET - Output-real-default = 1.0. Magnitude of determinant of KLL, i.e., $\det [K_{\ell\ell}] = \text{DET} * 10^{\text{PØWER}}$

4.38.7 Method

RBMG2 calls subroutine FACTØR to perform the decomposition of $[K_{\ell\ell}]$ into $[L_{\ell\ell}]$ and $[U_{\ell\ell}]$.

4.38.8 Subroutines

RBMG2 calls the matrix utility routine FACTØR (see section 3.5.23 for FACTØR details).

4.38.9 Design Requirements

For allocation of core storage, see subroutine SDCØMP (section 3.5.14). The module RBMG2 consists of one subroutine, RBMG2. Three scratch files are used.

4.38.10 Diagnostic Messages

Message number 3005 may be issued by RBMG1.

4.39 FUNCTIONAL MODULE RBMG3 (RIGID BODY MATRIX GENERATOR - PHASE 3)

4.39.1 Entry Point: RBMG3

4.39.2 Purpose

RBMG3 solves for the rigid body transformation matrix [D] from the equation

$$[K_{\ell\ell}]\,[D] = -[K_{\ell r}] \tag{1}$$

The rigid body error ratio, ε, is computed from

$$\varepsilon = \frac{||[K_{rr}] + [K_{\ell r}]^T\,[D]||}{||[K_{rr}]||} \tag{2}$$

Note: The absolute value || || is the square root of the sum of the squares (this is not a determinant).

4.39.3 DMAP Calling Sequence

```
RBMG3   LLL,ULL,KLR,KRR/DM $
```

4.39.4 Input Data Blocks

LLL - Lower triangular factor of KLL - ℓ set.

ULL - Upper triangular factor of KLL - ℓ set.

KLR - Partition of stiffness matrix.

KRR - Partition of stiffness matrix - r set.

Note: Input data blocks may not be purged.

4.39.5 Output Data Blocks

DM - Rigid body transformation matrix.

Note: The DM data block corresponds to the matrix [D] and may not be purged.

4.39.6 Parameters

None.

4.39.7 Method

Subroutine SØLVER is called to perform the operations in Equation 1and 2.

4.39.8 Subroutines

RBMG3 calls the matrix utility routine SØLVER and has no auxiliary subroutines. See section 3.5.20 for SØLVER details.

4.39.9 Design Requirements

For allocation of core storage, see subroutines FBS (section 3.5.17) and MPYAD (section 3.5.12). Two scratch files are used.

4.40 FUNCTIONAL MODULE RBMG4 (RIGID BODY MATRIX GENERATOR - PHASE 4)

4.40.1 Entry Point: RBMG4

4.40.2 Purpose

RBMG4 computes the rigid body mass matrix $[m_r]$ from the matrix equation

$$[m_r] = [M_{rr}] + [D]^T [M_{\ell r}] + [M_{\ell r}]^T [D] + [D]^T [M_{\ell\ell}] [D]. \qquad (1)$$

4.40.3 DMAP Calling Sequence

```
RBMG4     DM,MLL,MLR,MRR/MR  $
```

4.40.4 Input Data Blocks

DM - Rigid body transformation matrix.

MLL - Partition of mass matrix - ℓ set.

MLR - Partition of mass matrix.

MRR - Partition of mass matrix - r set.

Notes:

1. No input data block may be purged.
2. The DM data block corresponds to the matrix [D] in Equation 1.

4.40.5 Output Data Blocks

MR - Rigid body mass matrix - r set.

4.40.6 Parameters

None

4.40.7 Method

Subroutine ELIM is called to compute $[m_r]$ as in Equation 1 (see section 3.5.22 for ELIM details).

4.40.8 Subroutines

RBMG4 consists of one subroutine, RBMG4.

Matrix utility routine ELIM (section 3.5.22) is called by RBMG4.

4.40.9 Design Requirements

For allocation of core storage, see subroutine MPYAD (section 3.5.12). Three scratch files are used.

4.41 FUNCTIONAL MODULE SSG1 (STATIC SOLUTION GENERATOR - PHASE 1)

4.41.1 Entry Point: SSG1

4.41.2 Purpose

To compute the static loads, thermal loads, and enforced deformation loads selected by the user.

4.41.3 DMAP Calling Sequence

```
SSG1    SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/V,N,LUSET/V,N,NSKIP   $
```

4.41.4 Input Data Blocks

SLT - Static Loads Table.

BGPDT - Basic Grid Point Definition Table.

CSTM - Coordinate System Transformation Matrices.

SIL - Scalar Index List.

EST - Element Summary Table.

MPT - Material Property Table.

GPTT - Grid Point Temperature Table.

EDT - Element Deformation Table.

MGG - Partition of mass matrix - g set.

CASECC - Case Control Data Table.

DIT - Direct Input Tables.

Notes:

1. SLT, BGPDT, SIL cannot be purged if external static loads or LØAD cards are selected in CASECC.

2. CSTM cannot be purged if any grid point or load references a coordinate system other than basic.

3. EST, MPT cannot be purged if thermal or element deformation loads are selected.

4. GPTT cannot be purged if thermal loads are applied.

5. EDT cannot be purged if element deformation loads are selected.

6. MGG cannot be purged if GRAVITY or RFØRCE loads are applied.

7. CASECC cannot be purged.

8. DIT cannot be purged if temperature dependent materials are loaded.

4.41.5 Output Data Blocks

PG - Static load vector matrix giving static loads - g set.

Note: PG can never be purged.

4.41.6 Parameters

LUSET - Input-integer-no default. LUSET defines length of PG.

NSKIP - Input-integer-no default. One static load is built for each CASECC record starting with NSKIP + 1 as long as the boundary conditions are constant.

4.41.7 Overview of the Method Used in SSG1

The purpose of the first phase of static solution calculation (module SSG1) is the generation of the load vectors on the whole structure. The structure may be loaded in three different ways:

1. Simple applied loads and moments may be given to grid and scalar points. Pressure loads may be applied to an area defined by three or four grid points. Centrifugal force fields may also be defined.

2. Thermal and enforced deformation loads are generated by using the structural element characteristics. The loads on the connected grid points are equivalent to fixing the displacements and replacing the element by the load it would apply to the points.

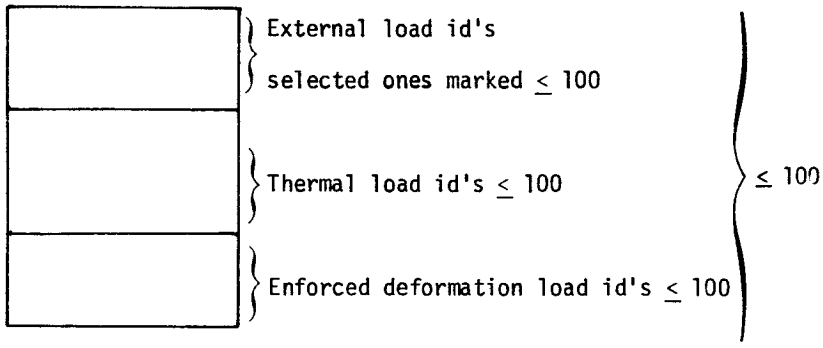
3. Gravity loads are dependent on the mass characteristics of the structure. A gravity load is produced by generating a vector of accelerations on all grid points in the structure and pre-multiplying the vector by the structural mass matrix.

The details on load vector generation for these three different types of loading are given in sections 4.41.8, 4.41.9 and 4.41.10 below. The function of module SSG1 is to read the case control data and extract the necessary load set data, calculate load vectors for each requested load set, and combine these sets to produce the loads requested for all subcases using the same boundary condition.

4.41.7.1 Module Initialization

Common block /LØADX/, which contains GINØ file numbers for input data files and position pointers, is initialized.

A list of all external load sets is extracted from the SLT. (This must be less than 101.) CASECC is skipped forward NSKIP records (in case several boundary conditions are being solved in one run). For each succeeding record which is not an eigenvalue record, not a symmetry record, not a differential stiffness record, and for which the boundary conditions are those for the current loop (SPC and MPC sets), a list is made of each thermal or enforced deformation load. The external loads selected are marked in the above list. If a selected external load is not in the above list, the LØAD cards are read in and their component id's searched. A LØAD card may cause additional members to be selected. A composite list is created which contains:



If there is no record which allows construction of a load, SSG1 aborts. If a selected external load id does not exist either as a LØAD card or simple load set, SSG1 aborts. (Subroutine SSG1A).

4.41.7.2 Individual Load Vector Generation

Each requested set of loads is used to generate a $\{P_g^j\}$ load vector. The vectors are generated one at a time in core and written on the PG temporary file, a scratch file. Files PG temporary, SLT, BGPDT, CSTM and SIL are opened. The vector generation depends on the type of load and type of input data. Details are given in sections 4.41.8, 4.41.9 and 4.41.10 below.

4.41.7.3 Subcase Load Vector Generation

Each simple load set, j, produces a $\{P_g^j\}$ load vector, and each subcase may be a combination of various simple load sets. As each load set vector is formed, it is written on PG temporary. When all sets have been generated, the CASECC data block and the LØAD card images are read again. A table is formed for each subcase consisting of the required set number and the scale factor for each set if given on a LØAD card. The file containing the load vectors for the sets is read for each subcase, c, and added to a $\{P_g^c\}$ load vector. The $\{P_g^c\}$ load vectors are packed and written as the PG data block in standard NASTRAN matrix form.

4.41.8 Direct Applied Loads

Direct loads are applied to the structural model by means of FØRCE, FØRCE1, FØRCE2, GRAV, MØMENT, MØMENT1, MØMENT2, PLØAD, PLØAD2, RFØRCE, and SLØAD Bulk Data Cards and the PRESAX card which is used for the axisymmetric conical shell problem only.

4.41.8.1 FØRCE and MØMENT Card Processing

The data described by a FØRCE or MØMENT data card are given as follows:

N_p = Grid point index;
N_c = Coordinate system number;
S = Scalar factor; and

$$\{P\} = \begin{Bmatrix} A_1 \\ A_2 \\ A_3 \end{Bmatrix} . \qquad (1)$$

The BGPDT data for the point are determined. If the global coordinate number, N_g, for the point equals N_c, the vector is

$$\{P_g\} = S\,\{P\} , \qquad (2)$$

where the row index is determined from SIL. If $N_g \neq N_c$, $[T_g]$ and $[T_c]$ are calculated using the location coordinates and the two local coordinate systems (subroutines GLBBAS and BASGLB). The

load in global coordinates is:

$$\{P_g\} = S\,[T_g]^T[T_c]\,\{P\}\ . \qquad (3)$$

If a FØRCE card is used, the loads are added to the first three positions for the grid point in the load vector. If a MØMENT card is used, the loads are added to the last three positions. (Subroutine DIRECT).

4.41.8.2 FØRCE1 and MØMENT1 Card Processing

The data described by FØRCE1 or MØMENT1 card are given as follows:

N_p = Application point number;

S = Load magnitude;

N_1, N_2 = Grid point numbers describing the vector direction of the load.

The basic coordinates of the points N_1, N_2 and N_p are found in the BGPDT. (Subroutines PERMUT and FNDPNT). If $\{R_1\}$ and $\{R_2\}$ are the vectors corresponding to N_1 and N_2, the load direction is:

$$\{d\} = \frac{\{R_2\} - \{R_1\}}{|\{R_2\} - \{R_1\}|}. \qquad (4)$$

The coordinate transformation $[T_g]$ for point N_p is calculated (Subroutine BASGLB). The load vector in global coordinates is:

$$\{P_g\} = S\,[T_g]^T\{d\}\ . \qquad (5)$$

If a FØRCE1 card was used the values are added to the first three coordinates, starting with the SIL number, in the load vector. If a MØMENT1 card was used, the values are added to the last three (subroutine TPØNT).

4.41.8.3 FØRCE2 and MØMENT2 Card Processing

The data on a FØRCE2 or MØMENT2 card are as follows:

N_p = Application point number;

S = Load magnitude;

N_1,N_2,N_3,N_4 are such that the direction of the force is determined by Equation 6 below.

The algorithm is similar to the one for the FØRCE1 and MØMENT1 case except that four basic coordinate system vectors, $\{R_1\}$, $\{R_2\}$, $\{R_3\}$, $\{R_4\}$, are formed for the four points and:

$$\{d\} = \frac{(\{R_2\} - \{R_1\}) \times (\{R_4\} - \{R_3\})}{|(\{R_2\} - \{R_1\}) \times (\{R_4\} - \{R_3\})|} , \tag{6}$$

(Subroutine FPØNT).

4.41.8.4 PLØAD and PLØAD2 Card Processing

The data contents for a PLØAD card are (a PLØAD2 card is transformed into a PLØAD card by GP3):

p = Pressure value;

N_1,N_2,N_3,N_4 = Points describing area over which pressure load is acting. (N_4 is optional.)

For each of the four points, N_i, the basic coordinate system vector, $\{R_i\}$, is formed.

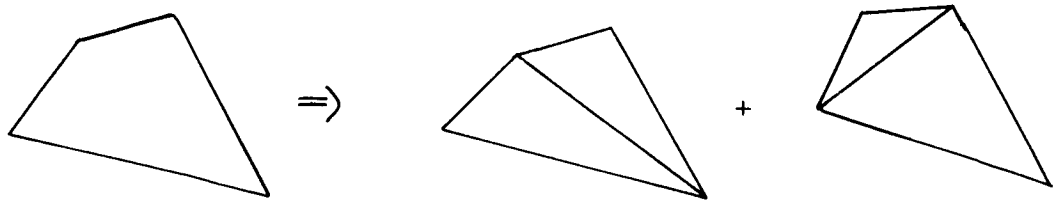
If $N_4 = 0$, the load on each point is:

$$\{F\} = -\frac{p}{6}\left[(\{R_1\} - \{R_2\}) \times (\{R_3\} - \{R_2\})\right] . \tag{7}$$

The load vector in global coordinates for each point is:

$$\{P_{g_i}\} = [T_i]^T\{F\} . \tag{8}$$

If $N_4 \neq 0$, the quadrilateral is subdivided into four triangles as shown.



For each triangle $\{P_{g_i}\}$ is calculated for the three connected points using a pressure value $p_T = 1/2\ p$. The equations are the same as the previous case except that the points are interchanged each time the triangle calculation is done. (Subroutine PLØAD.)

4.41.8.5 SLØAD Card Processing

The data contents for a SLØAD card are:

N_p = Scalar point id and

S = Load on point.

The scalar index is computed by subroutine FNDSIL, and S is added in. (Subroutine SLØAD.)

4.41.8.6 RFØRCE Card Processing

The data contents for an RFØRCE card are:

N_p = Index of grid point through which rotation vector passes;

N_c = Coordinate system number defining the rotation vector;

A = Factor for vector;

R_x, R_y, R_z are components of rotation vector in cps.

The following sequence of operations comprises RFØRCE card processing which is carried out in subroutine RFØRCE.

1. The local to basic coordinate transformation matrix, $[T_c]$, for the reference coordinate system N_c is extracted from the CSTM data block.

2. The rotation vector in basic coordinates, and in radians per second, is:

$$\{\omega_b\} = 2\pi A [T_c] \begin{Bmatrix} R_x \\ R_y \\ R_z \end{Bmatrix} \qquad (9)$$

3. Define the basic location vector of the reference point N_p as $\{r_a\}$. If $N_p = 0$, set $\{r_a\} = \{0\}$.

4. Extract the basic coordinate system vector $\{r_i\}$ for each point from BGPDT.

5. Using $\{r_i\}$ and the local coordinate system referenced by the point, calculate the global-to-basic transformation matrix $[T_i]$.

6. For the six columns of the mass matrix $[M_{gg}]$ corresponding to the grid point i, the 6x6 matrix partition on the diagonal is extracted. Define this as $[M^i]$.

7. Partition the 6x6 matrix into 3x3 matrices

$$[M^i] \Longrightarrow \left[\begin{array}{c|c} M_t^i & M_{tr}^i \\ \hline M_{rt}^i & M_r^i \end{array}\right] , \tag{10}$$

and transform the rotational velocity vector to global coordinates

$$\{\omega_g\} = [T_i]^T \{\omega_b\} . \tag{11}$$

8. Calculate the forces and moments on the grid point by the equations:

$$\{F\} = -\{\omega_g\} \times [M_t^i] [T_i]^T(\{\omega_b\} \times [\{r_i\} - \{r_a\}]) - \{\omega_g\} \times [M_{tr}^i] \{\omega_g\} \tag{12}$$

$$\{M\} = -\{\omega_g\} \times [M_{rt}^i] [T_i]^T (\{\omega_b\} \times [\{r_i\} - \{r_a\}]) - \{\omega_g\} \times [M_r^i] \{\omega_a\} \tag{13}$$

9. The load vector partition in global coordinates is:

$$\{P_i\} = \left\{\begin{array}{c} F \\ \hline M \end{array}\right\} \tag{14}$$

4.41.8.7 PRESAX Card Processing

The data contents for a PRESAX card (which applies only to pressure loading of an AXISYMMETRIC shell) are:

P = Pressure;

N_a = Index value of harmonic Ring A;

N_b = Index value of harmonic Ring B;

ϕ_1 = (degrees);

ϕ_2 = (degrees);

n = Harmonic number of harmonic being added.

The algorithm given in the following steps is performed in subroutine PRESAX.

1. ϕ_1 and ϕ_2 are converted to radians.

2. BGPDT data are extracted for both RINGA and RINGB, giving {r} and {z}.

3. The calculations for harmonic n are:

$$\ell = \sqrt{(r_b - r_a)^2 + (z_b - z_a)^2}, \tag{15}$$

$$\sin \psi = \frac{r_b - r_a}{\ell}, \tag{16}$$

$$\cos \psi = \frac{z_b - z_a}{\ell} . \tag{17}$$

For the cosine case, if n = 0, we calculate:

$$P^i_{ro} = P\ell \left(\frac{r_i}{3} + \frac{r_j}{6}\right)(\phi_2 - \phi_1) \cos \psi , \tag{18}$$

$$P^i_{zo} = -P\ell \left(\frac{r_i}{3} + \frac{r_j}{6}\right)(\phi_2 - \phi_1) \sin \psi . \tag{19}$$

If n > 0

$$P^i_{rn} = P \frac{\ell}{n} \left(\frac{r_i}{3} + \frac{r_j}{6}\right) (\sin (n\phi_2) - \sin (n\phi_1)) \cos \psi , \tag{20}$$

$$P^i_{zn} = -P \frac{\ell}{n} \left(\frac{r_i}{3} + \frac{r_j}{6}\right) (\sin (n\phi_2) - \sin (n\phi_1)) \sin \psi . \tag{21}$$

For the sine case, if n > 0,

$$P^i_{rn} = - P \frac{\ell}{n} \left(\frac{r_i}{3} + \frac{r_j}{6} \right) (\cos (n\phi_2) - \cos (n\phi_1)) \cos \psi, \tag{22}$$

$$P^i_{zn} = P \frac{\ell}{n} \left(\frac{r_i}{3} + \frac{r_j}{6} \right) (\cos (n\phi_2) - \cos (n\phi_1)) \sin \psi. \tag{23}$$

4. The above equations are solved for i = a, j = b and i = b, j = a. The loads are added to the corresponding grid point location in the PG load vector

$$\left\{ P^i_g \right\} = \left\{ P^i_g \right\} + \begin{Bmatrix} P^i_r \\ 0_i \\ P_z \\ 0 \\ 0 \\ 0 \end{Bmatrix} \tag{24}$$

(Subroutine PRESAX).

4.41.8.8 GRAV Card Processing

Each GRAV input card describes a uniform acceleration field with the following parameters:

N = Coordinate system ID;

G = Scale factor;

{V} = Vector of load in coordinate system N.

The gravity vector in basic coordinates is:

$$\{g_b\} = G [T_{0N}] \{V\}. \tag{25}$$

where $[T_{0N}]$ is the 3x3 orientation matrix of coordinate system N. (Subroutines GRAV, FDCSTM, MPYL). This vector $\{g_b\}$ is saved for later processing. Subroutine EXTERN then returns, noting the number of gravity loads listed.

4.41.9 Thermal and Enforced Deformation Loads

The thermal and enforced deformation loads are calculated using the stiffness properties of the structural elements. The EDT data for each load set and the MPT, DIT and SIL data blocks are placed in core. The EST data block and the GPTT data for the selected set are read one element at a time. The loads produced by that element are placed in the PG load vector. The actual algorithms for generating element loads are given in Section 4.87.

4.41.10 Gravity Loads

Acceleration vectors are computed for each gravity load by two means, one for an axisymmetric shell problem, the other for non-shell problems.

4.41.10.1 Gravity Loads for an Axisymmetric Shell Problem

m (number of rings) and n (number of harmonics) are extracted from the /SYSTEM/ common block. The first m points in the BGPDT define the "zero" harmonic. The second m entries define the "one" harmonic etc. The acceleration vectors are calculated by the formulae:

$$g = \sqrt{g_x^2 + g_y^2 + g_z^2}\ , \tag{26}$$

$$g_{xy} = \sqrt{g_x^2 + g_y^2}\ , \tag{27}$$

$$\cos\theta_g = \frac{g_z}{g}\ , \tag{28}$$

$$\sin\theta_g = \frac{g_{xy}}{g}\ , \tag{29}$$

$$\sin\phi_g = \frac{g_y}{g_{xy}}\ , \tag{30}$$

$$\cos\phi_g = \frac{g_x}{g_{xy}}\ . \tag{31}$$

The vectors {a} for harmonics n = 0 and n = 1 are defined for load set cosine by:

$$\{a_0^c\} = g \cos \theta_g \begin{Bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{Bmatrix} \text{(all rings)}, \tag{32}$$

$$\{a_1^c\} = g \sin \theta_g \cos \phi_g \begin{Bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}; \tag{33}$$

(all rings)

and for load set sine by:

$$\{a_1^s\} = g \sin \theta_g \sin \phi_g \begin{Bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix} \tag{34}$$

These vectors are used as in the normal case. They are merged into $\{a_g\}$ which in turn is pre-multiplied by $[M_{gg}]$ to give the $\{P_g\}$ vector (subroutine GRAVL3).

4.41.10.2 Gravity Loads for Non-Shell Problems

The acceleration vector must be transferred to the global coordinate system at each grid point and expanded to a vector acting on the u_g coordinates. For each grid point (i) the BGPDT data is read, and using the CSTM data, a 3x3 basic to global transformation matrix $[T_i]$ is formed. The acceleration at the point i in basic coordinates is:

$$\{a_g^i\} = [T_i] \{g_b\}, \tag{35}$$

where $\{g_b\}$ is the gravity vector saved in Equation 25. The vector $\{a_g^i\}$ is placed in the total acceleration vector in positions SIL_i, SIL_i+1, and SIL_i+2. No values are calculated for scalar points or rotation coordinates (Subroutine GRAVL1).

When all $\{a_g\}$ vectors have been calculated for the whole structure, they are pre-multiplied by the structural mass matrix to produce a load vector:

$$\{P_g\} = [M_{gg}] \{a_g\}, \tag{36}$$

(subroutine SSG2B).

The gravity vectors are appended to the other load vectors, and scalar points are zeroes in case interaction occurred. Gravity loads on scalar points are not supported.

4.41.10.3 Direct-Applied Thermal Loads

Direct loads are applied to the heat transfer model by means of the QHBDY data cards. These cards contain the following data:

Symbol	Description
FLAG,	Identified type of load
Q_0,	Flux density
A_f,	Area factor
G_1, G_2, G_3, G_4	Internal grid point numbers

The word "FLAG" indicates the type of load, "PØINT," "LINE," "REV," "AREA3," or "AREA4," and the number of grid points defined by G_1, G_2, etc. The loads are formed into a vector {P} with a length equal to the number of points. The values of {P} are:

$$\{P\} = \bar{A}Q_0\{V\}.$$

The values for $\bar{A}$ and {V} are given in the following table:

FLAG	Number of grid-points at which load vector is applied	$\bar{A}$	{V}
1	1	$-A_f$	{1}
2	2	$-\frac{A_f(\text{length})}{2}$	$\begin{Bmatrix}1\\1\end{Bmatrix}$
3	2	$-\frac{\pi(\text{length})}{3}$	$\begin{Bmatrix}2x_1 + x_2\\x_1 + 2x_2\end{Bmatrix}$
4	3	$-\frac{(\text{area})}{3}$	$\begin{Bmatrix}1\\1\\1\end{Bmatrix}$
5	4	make into overlapping triangles, as in FLAG = 4 (divide loads by two)	

where the values x_i, y_i, z_i are the BGPDT values for point i and:

$$(\text{length}) = [(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2]^{1/2}$$

$$(\text{area}) = \frac{1}{2} |r_{12} \times r_{13}|$$

$$\text{where } r_{1j} = \begin{Bmatrix} x_j - x_1 \\ y_j - y_1 \\ z_j - z_1 \end{Bmatrix} \quad j = 2,3$$

The load is to be inserted into all three translational degrees of freedom at the gridpoints. The scalar indices may be found in the SIL table.

4.41.11 Subroutines

4.41.11.1 Subroutine Name: SSG1A.

1. Entry Point: SSG1A.

2. Purpose: To build a list of external loads, thermal loads and enforced deformation loads selected by the user in CASECC.

3. Calling Sequence: CALL SSG1A (N1,ILIST,NEDT,NTEMP,NCENT,CASECC,IHARM)

N1 - Number of external loads present - integer - output.

ILIST - List of load ID's with selected load ID's set negative - integer - output.

NEDT - Number of enforced deformation loads - integer - output.

NTEMP - Number of thermal loads - integer - output.

NCENT - Not used (set to zero) - integer - output.

CASECC - GINØ number of Case Control Data Block - integer - input.

IHARM - Boundary conditions for axisymmetric shell problem.

1 = sine, 2 = cosine - integer - output.

CØMMØN//XX,LØADNN

LØADNN - Number of records in CASECC to skip before beginning to build loads - integer - input.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ common block below (section 4.41.11.8).

4.41.11.2 Subroutine Name: EXTERN.

1. Entry Point: EXTERN

2. Purpose: To compute user-selected external loads.

3. Calling Sequence: CALL EXTERN (NLIST,NGRAV,GVECT,ILIST,PG,N1,IHARM)

NLIST - Number of load id's in ILIST array - integer - input.

NGRAV - Number of gravity loads selected - integer - output.

GVECT - Array of gravity vectors, 3 numbers per vector - real - output.

ILIST - List of all load id's - integer - input.

PG - Matrix control block for file on which external loads will be written - integer - input/output.

N1 - Number of external load id's - integer - input.

IHARM - Boundary condition for axisymmetric shell problem
1 = sine, 2 = cosine.

CØMMØN//LUSET

LUSET - Length of PG - integer - input.

CØMMØN/LØADX/ - See /LØADX/ description in section 4.41.11.8.

4.41.11.3 Subroutine Name: TEMPL.

1. Entry Point: TEMPL

2. Purpose: To compute thermal loads for each element.

3. Calling Sequence: CALL TEMPL (NTEMP,ILIST (N1+1),PG(1))

NTEMP - Number of thermal loads - integer - input.

ILIST(N1+1) - Beginning of thermal load list - integer - input.

PG - Matrix control block for load file - integer - input/output.

CØMMØN/LØADX/ - See /LØADX/ description in section 4.41.11.8.

CØMMØN//LUSET

LUSET - Length of PG - integer - input.

4.41.11.4 Subroutine Name: EDTL.

1. Entry Point: EDTL

2. Purpose: To compute enforced deformation loads for each element.

3. Calling Sequence: CALL EDTL (NEDT,ILIST(N1+1),PG(1))

NEDT - Number of enforced deformation loads - integer - input.

The remainder of the variables has the same meaning as in TEMPL (section 4.41.11.3).

4.41.11.5 Subroutine Name: GRAVL1.

1. Entry Point: GRAVL1

2. Purpose: To build acceleration vectors for gravity loads.

3. Calling Sequence: CALL GRAVL1 (NGRAV,GVECT,SCR1,IHARM)

NGRAV - Number of gravity loads selected - integer - input.

GVECT - Array of gravity vectors, three words per gravity vector - real - input.

SCR1 - GINØ file number on which to build the acceleration vectors - integer - input.

IHARM - Boundary condition for axisymmetric shell problem.
1 = sine, 2 = cosine - integer - output.

4.41.11.6 Subroutine Name: GRAVL2.

1. Entry Point: GRAVL2

2. Purpose: To add gravity loads onto previously generated load vectors and check scalar points.

3. Calling Sequence: CALL GRAVL2 (NGRAV,PGG,PG(1))

NGRAV - Number of gravity vectors - integer - input.

PGG - GINØ file number of gravity loads - integer - input.

PG - Matrix control block for all other (non-gravity) loads - integer - input/output.

CØMMØN/LØADX/

LØADX - See /LØADX/ common block (section 4.41.11.8).

CØMMØN//LUSET

LUSET - Length of PG vector - integer - input.

4.41.11.7 Subroutine Name: CØMBIN.

1. Entry Point: CØMBIN

2. Purpose: To combine subloads into subcase loads.

3. Calling Sequence: CALL CØMBIN (PG,ILIST,N1)

PG - Matrix control block for PG vector - integer - input/output.

ILIST - List of all load ID's - integer - input.

N1 - Number of entries in ILIST - integer - input.

CØMMØN/LØADX/

LØADX - See /LØADX/ description, section 4.41.11.8)

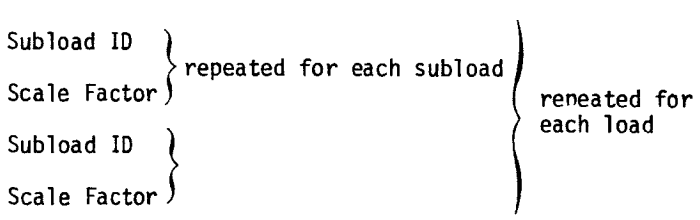
CØMMØN//LUSET

LUSET - Length of PG vector - integer - input.

CØMMØN/LØADS/NLØADS,IARY(300)

NLØADS - Number of loads to build.

IARY - For each load:



4.41.11.8 Common Block LØADX.

1. Purpose: To transmit file numbers and pointers.

2. Variable List: CØMMØN/LØADX/LC,SLT,BGPDT,ØLD,CSTM,SIL,ISIL,EST,MPT,GPT,EDT,IMPT,IGPTT, IEC,LØADF,MGG,NØBLD,DIT,ICM

SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,DIT - GINØ file numbers for respective data blocks - integer - input.

LC - Length of open core - integer - input.

ØLD - Current grid point position of the BGPDT - integer - input.

ISIL - Current SIL position - integer.

LØADF - GINØ file number of load file - integer - input.

NØBLD - Build-nobuild flag for direct load routines - integer.

IMPT -
IGPTT - } Unused at present.
IEC -

4.41.11.9 Subroutine Name: DIRECT.

1. Entry Point: DIRECT
2. Purpose: To apply loads due to FØRCE and MØMENT cards.
3. Calling Sequence: CALL DIRECT

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.10 Subroutine Name TPØNT.

1. Entry Point: TPØNT
2. Purpose: To apply loads due to FØRCE1 and MØMENT1 cards.
3. Calling Sequence: CALL TPØNT

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.11 Subroutine Name: FPØNT.

1. Entry Point: FPØNT
2. Purpose: To apply loads due to FØRCE2 and MØMENT2 cards.
3. Calling Sequence: CALL FPØNT

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.12 Subroutine Name: SLØAD.

1. Entry Point: SLØAD
2. Purpose: To apply loads due to SLØAD cards.
3. Calling Sequence: CALL SLØAD

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.13 Subroutine Name: PLØAD.

1. Entry Point: PLØAD
2. Purpose: To apply loads due to PLØAD cards.
3. Calling Sequence: CALL PLØAD

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.14 Subroutine Name: RFØRCE.

1. Entry Point: RFØRCE
2. Purpose: To apply loads due to RFØRCE cards.
3. Calling Sequence: CALL RFØRCE (LCØRE)

   LCØRE - Current buffer top - integer - input.

   CØMMØN/LØADX/

   LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.15 Subroutine Name: PRESAX.

1. Entry Point: PRESAX

2. Purpose: To apply loads due to axisymmetric pressure loads.

3. Calling Sequence: CALL PRESAX (IHARM)

IHARM - Axisymmetric boundary condition - integer - input.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.16 Subroutine Name: GRAV.

1. Entry Point: GRAV

2. Purpose: To extract gravity vector and convert to basic coordinates.

3. Calling Sequence: CALL GRAV (NGRAV,GVECT,NEX,ILIST,NLØØP)

NGRAV - Number of gravity loads - integer - output.

GVECT - Array of gravity vectors - real - output.

NEX - Number of external loads - integer - input.

ILIST - List of external load ID's - integer - input/output.

NLØØP - Current pointer into ILIST.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.17 Subroutine Name: PERMUT.

1. Entry Point: PERMUT

2. Purpose: To reorder a list of grid point ID's to allow the most efficient extraction of these grid points from the BGPDT.

3. Calling Sequence: CALL PERMUT (PØNT,IØRD,NP,ØLD)

PØNT - List of points - integer - input.

IØRD - Pointers to PØNT, i.e., IØRD (1) contains subscript of PØNT which should be extracted first from the BGPDT - integer - output.

NP - Number of points - integer - output.

ØLD - Current position of BGPDT - integer - input.

4.41.11.18 Subroutine Name: FNDPNT.

1. Entry Point: FNDPNT
2. Purpose: To extract BGPDT data from the BGPDT.
3. Calling Sequence: CALL FNDPNT (BGPDD,PØNT)

BGPDD - Four-word BGPDT entry - output.

PØNT - Grid point id of desired BGPDT entry - integer - input.

4.41.11.19 Subroutine Name: CRØSS.

1. Entry Point: CRØSS
2. Purpose: To compute the cross product of two vectors.
3. Calling Sequence: CALL CRØSS (V1,V2,V3)

V1 - Three-word vector - real - input.

V2 - Three-word vector - real - input.

V3 = V1 x V2 - real - output.

4.41.11.20 Subroutine Name: NØRM.

1. Entry Point: NØRM
2. Purpose: To normalize a vector.
3. Calling Sequence: CALL NØRM (V1, XLV)

V1 - Three-word vector - real - input/output.

XLV - Norm of V1.

V1 on output = V1/XL unless XL = 0.0, then V1 = V1.

4.41.11.21 Subroutine Name: FNDSIL.

1. Entry Point: FNDSIL (in subroutine FNDPNT)

2. Purpose: To find the SIL value of a particular grid point id.

3. Calling Sequence: CALL FNDSIL (GPID)

GPID - Grid point id on input, SIL value on output - integer - input/output.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.22 Subroutine Name: BASGLB.

1. Entry Point: BASGLB

2. Purpose: To convert a vector from the basic to the global coordinate system.

3. Calling Sequence: CALL BASGLB (VIN,VØUT,GRDPNT,CSYS)

VIN - Three-word input vector - real - input.

VØUT - Three-word output vector - real - output.

VIN may equal VØUT.

GRDPNT - Location of grid point at which vector is to be applied (not used unless coordinate system type is spherical or cylindrical) - real - input.

CSYS - Coordinate system id - integer - input.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.23 Subroutine Name: GLBBAS.

1. Entry Point: GLBBAS

2. Purpose: To convert a vector from global to basic coordinates.

3. Calling Sequence: CALL GLBBAS (VIN,VØUT,GRDPNT,CSYS)

Where the variables have the same names as in BASGLB.

4.41.11.24 Subroutine Name: MPYL.

1. Entry Point: MPYL

2. Purpose: To multiply two in-core matrices together: [A] · [B] = [C].

3. Calling Sequence: CALL MPYL (A,B,NCØLA,NRØWA,NCØLB,C)

A (NCØLA,NRØWA) matrix
B (NCØLB,NCØLA) matrix } These matrices are stored row-wise.
C (NCØLB,NRØWA) matrix

Note: A or B ≠ C

4.41.11.25 Subroutine Name: MPYLT.

1. Entry Point: MPYLT

2. Purpose: To multiply two in-core matrices together $[A]^T \cdot [B] = [C]$.

3. Calling Sequence: CALL MPYLT (A,B,NRØWB,NCØLA,NCØLB,C)

A (NCØLA,NRØWB) matrix
B (NCØLB,NRØWB) matrix } These matrices are stored row-wise.
C (NCØLB,NCØLA) matrix

4.41.11.26 Subroutine Name: FDCSTM.

1. Entry Point: FDCSTM

2. Purpose: To extract the orientation matrix from the CSTM.

3. Calling Sequence: CALL FDCSTM (ICSTM)

ICSTM - Coordinate system id desired.

CØMMØN/TRANX/XX(5),TØ(3,3)

TØ - 3x3 orientation matrix.

CØMMØN/LØADX/

LØADX - See description of /LØADX/ above (section 4.41.11.8).

4.41.11.27 Subroutine Name: FGPTT.

1. Entry Point: FGPTT

2. Purpose: To find temperature in the GPTT.

3. Calling Sequence: CALL FGPTT (SILAR,TAR,NP)

   SILAR - Array of SIL's for which temperatures are desired - integer - input.

   TAR - Array of temperatures at SIL's - real - output.

   NP - Number of entries in SILAR.

   CØMMØN/FPT/TØ,NSIL,NGPTT,NRØWSP

   TØ - Default temperature - real - input.

   NSIL - Number of SIL entries - integer - input.

   NGPTT - Length of GPTT.

   NROWSP - Beginning of SIL table - integer - input.

4.41.11.28 Subroutine Name: FEDT.

1. Entry Point: FEDT (in subroutine FNDPNT)

2. Purpose: To extract one enforced deformation from the EDT given one element id.

3. Calling Sequence: CALL FEDT (EID,DELTA,IDEFM)

   EID - Element id - integer - input.

   DELTA - Deformation of element EID - real - output.

   IDEFM - Set id of current deformation set.

4.41.11.29 Subroutine Name: GRAVL3.

1. Entry Point: GRAVL3

2. Purpose: To compute an acceleration vector for an axisymmetric shell problem.

3. Calling Sequence: CALL GRAVL3 (NGRAV,GVECT,AG,IHARM)

   NGRAV - Number of gravity vectors - integer - input.

   GVECT - Gravity vector array - real - input.

   AG - GINØ file number of acceleration vector - integer - input.

IHARM - Boundary condition flag

1 = sine, 2 = cosine

CØMMØN//LUSET

LUSET - Length of PG vector.

CØMMØN/SYSTEM/IX(26),MN

MN - Packed word giving number of rings/number of harmonics.

4.41.11.30 Subroutine Name: TTRIRG

1. Entry Point: TTRIRG

2. Purpose: To calculate an element thermal load vector for a triangular cross-section ring in the SSG1 module.

3. Calling Sequence: CALL TTRIRG (TI,PG)

TI - Array of four temperatures at the four points of the ring - real - input.

PG - Load vector array - real - input.

CØMMØN/TRIMEX/

TRIMEX - This contains the EST entry for the element.

4.41.11.31 Subroutine Name: TTRAPR.

1. Entry Point: TTRAPR

2. Purpose: To calculate an element thermal load vector for a trapezoidal cross-section ring in the SSG1 module.

3. Calling Sequence: CALL TTRAPR (TI, PG)

CØMMØN/TRIMEX/

The arguments are the same as in TTRIRG.

4.41.11.32 Subroutine Name: TTØRDR.

1. Entry Point: TTØRDR

2. Purpose: To calculate an element thermal load vector for a toroidal thin shell ring in the SSG1 module.

3. Calling Sequence: CALL TTØRDR (TI,PG)

CØMMØN/TRIMEX/

The arguments are the same as those in TTRIRG (section 4.41.11.30).

4.41.11.33 Subroutine Name: FCURL.

1. Entry Point: FCURL

2. Purpose: To form the element thermal load matrices in field coordinates for the toroidal thin shell ring in subroutine TTØRDR.

3. Calling Sequence: CALL FCURL (FME0,FME1,FFE0,FFE1,YI,S,LAM1)

FME0, FME1
FFE0, FFE1 — The resultant thermal load matrices.

YI - Array of integral values.

S, LAM1 - Terms used in the evaluation of the thermal load matrices.

4.41.11.34 Subroutine Name: CØNE.

1. Entry Point: CØNE

2. Purpose: To calculate an element thermal load vector for an axisymmetric shell in the SSG1 module.

3. Calling Sequence: CALL CØNE (TI,PG)

CØMMØN/TRIMEX/

The arguments are the same as in TTRIG (section 4.41.11.30).

4.41.11.35 Subroutine Name: QDMEM.

1. Entry Point: QDMEM

2. Purpose: To calculate an element thermal load vector for quadrilateral elements in the SSG1 module.

3. Calling Sequence: CALL QDMEM (TI,PG)

COMMON/TRIMEX/

The arguments are the same as in TTRIRG (section 4.41.11.30).

4.41.11.36 Subroutine Name: TRIMEM.

1. Entry Point: TRIMEM

2. Purpose: To calculate an element thermal load vector for triangular elements in the SSG1 module.

3. Calling Sequence: CALL TRIMEM (TYPE,TBAR,PG)

COMMON/TRIMEX/

TYPE - Flag indicating normal entry (0) or subelement call from a QDMEM (1) - integer - input.

TBAR - Average temperature over the element - real - input.

PG and /TRIMEX/ are as in TTRIRG (section 4.41.11.30).

4.41.11.37 Subroutine Name: BAR.

1. Entry Point: BAR

2. Purpose: To calculate an element thermal load vector or deformation load vector for the bar element in the SSG1 module.

3. Calling Sequence: CALL BAR (PG, IDEFM, ITEMP, IDEFT)

COMMON/TRIMEX/

IDEFM - 0 if element deformation load vector is not to be computed - integer - input.

ITEMP - 0 if element thermal load vector is not to be computed - integer - input.

IDEFT - Set ID of the element deformation set. This is used only if IDEFM ≠ 0 - integer - input.

PG,/TRIMEX/ are as in Section 4.41.11.30.

4.41.11.38 Subroutine Name: FEDTST

1. Entry Point: FEDTST (in FNDPNT)
2. Purpose: To put in core the element id's and associated values for a given deformation set from the EDT.
3. Calling sequence: CALL FEDTST (IDEF)

   IDEF - Set id of current deformation

   CØMMØN /FPT/DUM(3),NRØW1,LCØRE

   NRØW - Number of words of open core used.

   LCØRE - End of available open core.

   CØMMØN /SSG1BX/CØRE

   CØRE - First cell of open core available.

4.41.11.39 Subroutine Name: FEDTED

1. Entry Point: FEDTED (in FNDPNT)
2. Purpose: To determine if all elements in a selected deformation set were used.
3. Calling Sequence: CALL FEDTED (IDEF)

   IDEF - Set id of current deformation set.

4.41.11.40 Subroutine Name: HBDY

1. Entry Point: HBDY.
2. Purpose: To calculate heat transfer flux loads due to convective film coefficients and temperatures of the surrounding fluid (heat transfer analysis only).
3. Calling sequence: CALL HBDY.

4.41.11.41 Subroutine Name: QHBDY

1. Entry Point: QHBDY.
2. Purpose: To generate heat flux loads in a heat transfer problem.
3. Calling sequence: CALL QHBDY.

4.41.11.42 Subroutine Name: QDPLT

1. Entry Point: QDPLT

2. Purpose: To generate the element thermal load data for quadrilateral plate elements.

3. Calling Sequence: CALL QDPLT (TI)

TI - Array of grid point temperatures

CØMMØN /TRIMEX/

4.41.11.43 Subroutine Name: RØD

1. Entry Point: RØD

2. Purpose: To generate the element thermal load data and enforced deformation load data for the RØD, CØNRØD and TUBE elements.

3. Calling Sequence: CALL RØD

CØMMØN /TRIMEX/

4.41.11.44 Subroutine Name: SØLID

1. Entry Point: SØLID

2. Purpose: To generate the element thermal load data for all solid elements except TETRA.

3. Calling Sequence: CALL SØLID (T,P,I)

T = Temperature vector
P = Load vector
I = 1, element is WEDGE
2, element is HEXA1
3, element is HEXA2

4. Method: Calls are made to TETRA.

4.41.11.45 Subroutine Name: TETRA

1. Entry Point: TETRA

2. Purpose: Computes element thermal load data for tetrahedra either directly (for the TETRA element) or indirectly via SØLID (for the other solid elements).

3. Calling Sequence: CALL TETRA (T,P,K)

   T = Temperature vector

   P = Load vector

   K = Option Flag

   = 0, divide by 6.0
   ≠ 0, divide by 12.0

4.41.11.46 Subroutine Name: TRBSC

1. Entry Point: TRBSC

2. Purpose: To compute the thermal load data for the basic bending triangle element TRBSC.

3. Calling Sequence: CALL TRBSC (I,T)

   I = 0 (basic bending triangle)
   1 (sub-computations for SQDPL1)
   2 (sub-computations for STRPL1)

   T = Temperature vector

4.41.11.47 Subroutine Name: TRIQD

1. Entry Point: TRIQD

2. Purpose: To compute the thermal load data for the triangular and quadrilateral elements.

3. Calling Sequence: CALL TRIQD (N,T)

   N = 1 implies TRIA1
   2 implies TRIA2
   3 implies QUAD1
   4 implies QUAD2

   T = Temperature vector

4.41.11.48 Subroutine Name: TRPLT

1. Entry Point: TRPLT

2. Purpose: To compute the thermal load data for the triangular bending elements.

3. Calling Sequence: CALL TRPLT (T)

   T = Temperature vector

4.41.11.49 Subroutine Name: SSGKHI

1. Entry Point: SSGHKI

2. Purpose: Computes element thermal load and enforced deformation load data for use by TRBSC, TRPLT and QDPLT.

3. Calling Sequence: CALL SSGKHI (TR,TI,FN)

TR - Real Temperature Vector
TI - Integer Temperature Vector
FN - Multiplication fraction

4.41.11.50 Subroutine Name: SSGETD

1. Entry Point: SSGETD

2. Purpose: Computes element temperature from a pre-positioned record.

3. Calling Sequence: CALL SSGETD (E,T,G)

E - Element identification number for which temperature is desired.
T - Area into which temperature data is returned.
G - = 0, element temperature format data is desired
≠ 0, number of grid points.

4.41.11.51 Subroutine Name: BASGLB

1. Entry Point: GBTRAN

2. Purpose: Finds a Global to Basic transformation matrix stored by rows.

3. Calling Sequence: CALL GBTRAN (IC, P, T)

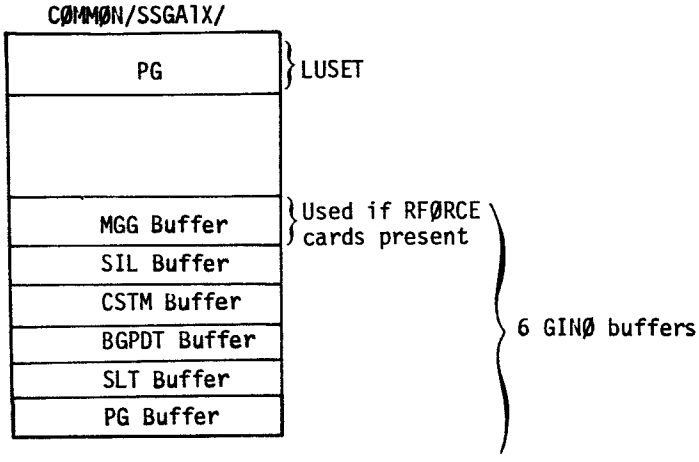
IC - Coordinate system identification number.
P - Location of grid point at which vector is to be applied.
T - Transformation matrix stored by rows.

4.41.12 Design Requirements

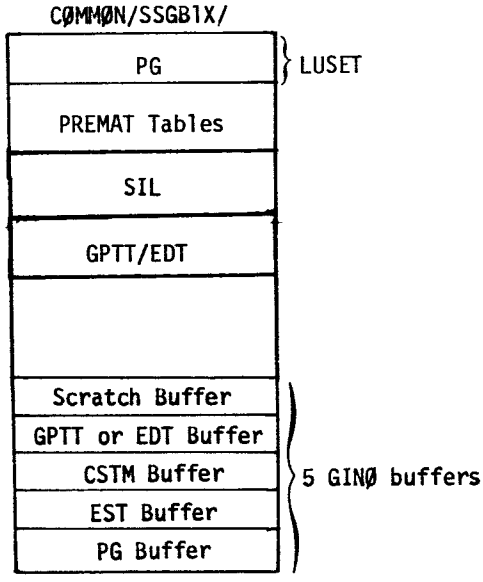
Three scratch files are needed.

Open core is defined as follows:

1. /SSGA1X/ during EXTERN phase



2. /SSGB1X/ during EDTL, TEMPL phase



100 LØAD ID's maximum.

4.41.13 Diagnostic Messages

If the core storage requirements as depicted in the above diagrams are not met, SSG1 will issue fatal error message 3008.

4.42. FUNCTIONAL MODULE SSG2 (STATIC SOLUTION GENERATOR - PHASE 2)

4.42.1 Entry Point: SSG2

4.42.2 Purpose

To reduce the applied load vectors and enforced displacements into equivalent load vectors applied to the independent displacement coordinate sets.

4.42.3 DMAP Calling Sequence

```
SSG2  USET,GM,YS,KFS,GØ,DM,PG/QR,PØ,PS,PL/  $
```

4.42.4 Input Data Blocks

USET - Displacement set definitions table.

GM - Multipoint constraint transformation matrix - m set.

YS - Constrained displacements - s set.

KFS - Partition of stiffness matrix after single-point constraints have been removed.

GØ - Structural matrix partitioning transformation matrix.

DM - Rigid body transformation matrix.

PG - Static load vector matrix giving static loads - g set.

Notes:
1. USET must be present.
2. GM must be present if m set is not null.
3. YS must be present if s set is not null.
4. KFS must be present if s set is not null.
5. GØ must be present if o set is not null.
6. DM must be present if r set is not null.
7. PG must be present.

4.42.5 Output Data Blocks

QR - Determinate support forces matrix - r set.

PØ - Partition of the load vector matrix giving loads due to static force - o set.

PS - Partition of load vector matrix giving loads in s set.

PL - Partition of load vector matrix giving static loads on ℓ set.

Notes: 1. QR must be present if r set is non-null.

2. PØ must be present if o set is non-null.

3. PS must be present if s set is non-null.

4. PL must be present if ℓ set is non-null.

5. If the problem has no sets, SSG2 will return.

4.42.6 Parameters

None

4.42.7 Method

The fifth word of the USET trailer control block is analyzed to determine the presence of m's, s's, o's, or r's.

Each of the following steps is omitted if the appropriate set is null. The following steps indicate the operations on one load set vector. The actual algorithm uses all vectors in each step by performing matrix operations.

1. If m's are present, the PG vectors are partitioned using USET (UG,UN,UM) and subroutines CALCV and SSG2A:

$$\{P_g\} \Longrightarrow \left\{ \begin{matrix} \overline{P}_n \\ \hline \overline{P}_m \end{matrix} \right\} \quad . \tag{1}$$

The loads on the u_n set are calculated as:

$$\{P_n\} = \{\overline{P}_n\} + [G_m]^T \{P_m\} \quad , \tag{2}$$

by calling subroutine SSG2B.

2. If s's are present, the $\{P_n\}$ load vectors are partitioned using USET (UN,UF,US) and subroutines CALCV, and SSG2A:

$$\{P_n\} \Longrightarrow \left\{ \begin{matrix} \overline{P}_f \\ \hline P_s \end{matrix} \right\} \tag{3}$$

The $\{P_s\}$ vectors are output in data block PS. The loads on the u_f set are calculated as:

$$\{P_f\} = \{\bar{P}_f\} - [K_{fs}] \{Y_s\} \quad . \tag{4}$$

The $\{Y_s\}$ vector normally is zero. If more than one load vector is being reduced, $\{Y_s\}$ is expanded to have N identical columns such that the above matrix equation is dimensionally consistent. This is accomplished in subroutine SSG2B1 (see below).

3. If o's are present, the $\{P_f\}$ vectors are partitioned using USET (UF,UA,UØ) and subroutines CALCV and SSG2A:

$$\{P_f\} \Rightarrow \begin{Bmatrix} \bar{P}_a \\ \hline P_o \end{Bmatrix} \quad . \tag{5}$$

$\{P_o\}$ vectors are written on data block PØ.

The equivalent loads on the u_a set are calculated as:

$$\{P_a\} = \{\bar{P}_a\} + [G_o]^T \{P_o\} \quad . \tag{6}$$

Subroutine SSG2B is called to perform this operation.

4. If r's are present, the $\{P_a\}$ vectors are partitioned using USET (UA,UL,UR) and subroutines CALCV and SSG2A:

$$\begin{Bmatrix} P_a \end{Bmatrix} \Rightarrow \begin{Bmatrix} P_\ell \\ \hline P_r \end{Bmatrix} . \tag{7}$$

$\{P_\ell\}$ vectors are written on data block PL.

The reaction vectors on the support points are:

$$\{q_r\} = - \{P_r\} - [D_m]^T \{P_f\} \tag{8}$$

where $[D_m]$ corresponds to the data block DM. $\{q_r\}$ vectors are written on data block QR.

4.42.8 Subroutines

SSG2 uses matrix subroutines CALCV and SSG2A for matrix partitioning operations and subroutine SSG2B to drive subroutine MPYAD. See section 3 for details.

4.42.8.1 Subroutine Name: SSG2B1

1. Entry Point: SSG2B1

2. Purpose: SSG2B1 is exactly like SSG2B. It computes [A] [B] + [C] = [D] except YS is first expanded onto SCR1 which then plays the role of [B] .

3. Calling Sequence: CALL SSG2B1 (A,SCR1,C,D,T,PREC,ISIGN,YS,SCR2)

The variables have the meaning as SSG2B except for YS, which is the GINØ file number of the YS data block - integer - input. See 3.5.13 for SSG2B details.

4.42.9 Design Requirements

/SSG2X/ is open core for CALCV. Four scratch files are used.

SSG2B1 is an entry point in SSG2B.

4.43 FUNCTIONAL MODULE SSG3 (STATIC SOLUTION GENERATOR - PHASE 3)

4.43.1 Entry Point: SSG3

4.43.2 Purpose:

To perform the actual static solutions. A displacement solution is produced for each applied load and tested for possible matrix decomposition errors.

4.43.3 DMAP Calling Sequence

```
SSG3  LLL,ULL,KLL,PL,LØØ,UØØ,KØØB,PØ/ULV,UØØV,RULV,RUØV/V,N,ØMIT/V,Y,IRES    $
```

4.43.4 Input Data Blocks

LLL - Lower triangular factor of KLL - ℓ set.

ULL - Upper triangular factor of KLL - ℓ set.

KLL - Partition of stiffness matrix - ℓ set.

PL - Partition of the load vector matrix giving static loads on ℓ set

LØØ - Lower triangular factor of KØØB - o set.

UØØ - Upper triangular factor of KØØB - o set.

KØØB - Partition of stiffness matrix - o set.

PØ - Partition of the load vector matrix giving loads due to static forces - o set.

Notes: 1. ULL,LLL and PL must be present.

2. KLL can be purged if RULV is purged.

3. UØØ, LØØ, PØ can be purged if ØMIT < 0.

4. KØØB can be purged if ØMIT < 0 or RUØV is purged.

4.43.5 Output Data Blocks

ULV - Partition of the displacement vector matrix giving displacements - ℓ set.

UØØV - Partition of the displacement vector matrix giving displacements - o set.

RULV - Residual vector matrix for the ℓ set.

RUØV - Residual vector matrix for the o set.

Notes: 1. ULV must be present.

2. UØØV can be purged if ØMIT < 0.
3. RULV and RUØV can be purged.
4. [RULV] = [KLL] [ULV] - [PL].
   [RUØV] = [KØØB][UØØV] - [PØ].

4.43.6 Parameters

ØMIT - Input-integer-no default. ØMIT controls operations on o-set matrices.

IRES - Not used-integer-no default. IRES is a user-controlled parameter that he may set to +1 on a Bulk Data PARAM card so that residual vectors may be printed. It is included here to define an initial value for IRES.

4.43.7 Method

4.43.7.1 Solution Algorithim

For normal statics problems PL and PØ vectors are used; for inertia relief problems the PLI and PØI vectors are generated in the SSG4 module and used instead of PL and PØ. The equations to be solved are:

$$[K_{\ell\ell}]\ \{u_\ell\} = \{P_\ell\}, \tag{1}$$

and if o's are present (ØMIT $\geq$ 0)

$$[K_{oo}]\ [u_o^o] = \{P_o\}, \tag{2}$$

where

$$[K_{\ell\ell}] = [L_{\ell\ell}]\ [U_{\ell\ell}]\ , \tag{3}$$

$$[K_{oo}] = [L_{oo}]\ [U_{oo}]\ . \tag{4}$$

$[L_{\ell\ell}]$ and $[L_{oo}]$ are lower traingular matrices. $[U_{\ell\ell}]$ and $[U_{oo}]$ are upper triangular matrices. The equations are solved in the following manner:

$$[L]\ [U]\ \{u\} = \{P\}, \tag{5}$$

or

$$[L]\ \{y\} = \{P\}\ . \tag{6}$$

In turn the solution for the displacement vector is:

$$[U]\ \{u\} = \{y\}\ . \tag{7}$$

4.43.7.2 Error Check Algorithm

If RULV is not purged, an error check is made. Since it is possible for the stiffness matrices to be nearly singular or ill-conditioned, the module calculates the following error analysis terms for both the $\{u_\ell\}$ and $\{u_o\}$ solutions:

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\ \{u_\ell\}\ , \tag{8}$$

$$\varepsilon_e = \frac{\{u_\ell\}^T\ \{\delta P_\ell\}}{\{P_\ell\}^T\ \{u_\ell\}}\ . \tag{9}$$

$\{\delta P_\ell\}$ forms data block RULV or RUØV. ε_e is printed for each solution.

4.43.8 Subroutines

SSG3A - is the only auxiliary subroutine in module SSG3 (see section 3.5.18 for description).

4.43.9 Design Requirements

Two scratch files are needed.

4.44 FUNCTIONAL MODULE SSG4 (STATIC SOLUTION GENERATOR - PHASE 4).

4.44.1 Entry Point: SSG4

4.44.2 Purpose

The purpose of this module is to calculate mass loads in a Static Analysis with Inertia Relief problem. The rigid body accelerations are functions of the reactions on the fictitious supports. The inertia loads on the structure are proportional to these accelerations.

4.44.3 DMAP Calling Sequence

```
SSG4    PL,QR,PØ,MR,MLR,DM,MLL,MØØB,MØAB,GØ,USET/PLI,PØI/V,N,ØMIT  $
```

4.44.4 Input Data Blocks

PL - Partition of the load vector matrix giving static loads - ℓ set.

QR - Determinate support forces matrix - r set.

PØ - Partition of the load vector matrix giving loads due to static force - o set.

MR - Rigid body mass matrix - r set.

MLR - Partition of mass matrix.

DM - Rigid body transformation matrix.

MLL - Partition of mass matrix - ℓ set.

MØØB - Partition of mass matrix - o set.

MØAB - Partition of mass matrix.

GØ - Structural matrix partitioning transformation matrix.

USET - Displacement set definitions table.

Note: All matrices must be present if their appropriate set is non-null.

4.44.5 Output Data Blocks

PLI - Partition of load vector for inertia relief matrix giving loads due to static and inertial forces on ℓ set.

PØI - Partition of load vector for inertia relief matrix giving loads due to inertial and static forces on o set.

Note: Both matrices must be present if their appropriate set is non-null.

4.44.6 Parameters

ØMIT - Input-integer-no default. If ØMIT > 0, the o set is non-null.

4.44.7 Method

1. The accelerations of the u_r degrees of freedom are:

$$\{a_r\} = -[m_r]^{-1}\{q_r\}. \tag{1}$$

$[m_r]$ corresponds to data block MR. Subroutines FACTØR and SSG3A are used to solve for $\{a_r\}$.

2. The total load vectors on the structure are:

$$\{P_\ell^i\} = \{P_\ell\} + \left[[M_{\ell\ell}]\,[D] + [M_{\ell r}]\right]\{a_r\}. \tag{2}$$

[D] corresponds to data block DM. Subroutine SSG2B is used to drive MPYAD.

3. If ØMIT ≥ 0:

$$\{P_o^i\} = \{P_o\} + \left[[M_{oo}]\,[G_o] + [M_{oa}]\right]\left[\frac{D}{I}\right]\{a_r\}. \tag{3}$$

The product $\left[\frac{D}{I}\right]\{a_r\}$ is formed by merging columns of $[D]\{a_r\}$ with $\{a_r\}$ using USET (UA,UL,UR). Subroutine SDR1B is used to drive MERGE, and SSG2B for the matrix products.

4.44.8 Subroutines

SSG2B - See subroutine description, section 3.5.13

SSG3A - See subroutine description, section 3.5.18

SDR1B - See subroutine description, section 3.5.8

4.44.9 Design Requirements

Five scratch files are necessary.

4.45 FUNCTIONAL MODULE SDR1 (STRESS DATA RECOVERY - PHASE 1)

4.45.1 Entry Point: SDR1

4.45.2 Purpose

The SDR1 module utilizes solution vectors to produce displacements, eigenvectors, velocities, accelerations, applied loads and reaction loads. The vectors input to SDR1 are in the form of packed matrices with each column a solution vector for a different subcase. eigenvalue, frequency/load, or transient output time. The row position of each term in a vector corresponds to a degree of freedom in a unique displacement set. The relative position of the term must be converted to a relative position in the vector which includes all displacement components in the system. The dependent components of the displacement vector are recovered and merged to produce a complete vector describing all degrees of freedom in the structural or dynamics model. In the Static Analysis or Static Analysis with Inertia Relief Rigid Formats, SDR1 collects solutions for each boundary condition onto a single file, convenient for the solution of symmetry problems.

4.45.3 DMAP Calling Sequence

```
SDR1  USET,PG,ULV,UØØV,YS,GØ,GM,PS,KFS,KSS,QR/UGV,PGG,QG/V,N,APPEND/V,N,FØRMAT   $
```

4.45.4 Input Data Blocks

USET - Displacement set definitions table.

PG - Static load vector matrix giving static loads - g set.

ULV - Partition of the displacement vector matrix giving displacements - ℓ set.

UØØV - Partition of the displacement vector matrix giving displacements in the o set.

YS - Constrained displacements - s set.

GØ - Structural matrix partitioning transformation matrix.

GM - Rigid body transformation matrix.

PS - Partition of load vector matrix giving loads in s set.

KFS - Partition of stiffness matrix after single-point constraints have been removed - s set.

KSS - Partition of stiffness matrix after single-point constraints have been removed - s set.

QR - Determinate support forces matrix - r set.

Notes: 1. USET must always be present.

2. PG may or may not be present.

3. ULV must always be present.

4. UØØV must be present unless the o set is null or FØRMAT = DYNAMICS (see below).

5. YS may or may not be present.

6. GØ must be present unless the o set is null.

7. GM must be present unless the m set is null.

8. PS may or may not be present.

9. KFS must be present unless the s set is null or QG is not present.

10. KSS must be present unless YS is absent or the s set is null or QG is not present.

11. QR may or may not be present.

4.45.5 Output Data Blocks

UGV - Displacement vector matrix giving displacements in the g set.

PGG - Static load vector appended to include all boundary conditions - g set.

QG - Single-point constraint forces and determinate support forces matrix - g set.

Notes: 1. If PG is present, PGG must be present.

2. UGV must be present.

3. QG must be present.

4. If APPEND $\neq$ 1, UGV, PGG, QG will be appended to the data already on these files.

4.45.6 Parameters

APPEND - Input-integer- no default. See note 4 above.

FØRMAT - Input-BCD-no default. Format indicates the problem type.

STATICS - Statics type problem.

REIGEN - Real eigenvalue problem.

DYNAMICS - Dynamic problem.

4.45.7 Method

The following steps are performed by the SDR1 module in the most general case. Most problems, however, do not use all of the constraint options. In these cases certain steps

are skipped. The task SDR1 performs also varies from Rigid Format to Rigid Format.

1. If PG is present, it is copied or appended onto PGG. (Subroutine SDR1A).

2. If r's are present and the problem type is not DYNAMICS or REIGEN:

$$\left\{\begin{matrix} u_\ell \\ \hline o \end{matrix}\right\} \Rightarrow \left\{u_a\right\} \quad . \tag{1}$$

This is accomplished by subroutine SDR1B, the driver for MERGE. See section 3.5.8 for details.

If s's are also present:

$$\left\{\begin{matrix} q_r \\ \hline o \end{matrix}\right\} \Rightarrow \left\{q_f\right\} . \tag{2}$$

Otherwise,

$$\left\{\begin{matrix} q_r \\ \hline o \end{matrix}\right\} \Rightarrow \left\{q_g\right\} , \tag{3}$$

which is then copied or appended onto QG. (Subroutine SDR1B and SDR1A).

3. If o's are present, the dependent degrees of freedom of the "omitted" coordinates $\{u_o\}$ are computed. For statics problems:

$$\left\{u_o\right\} = \left[G_o\right] \left\{u_a\right\} + \left\{u_o^o\right\} \quad . \tag{4}$$

For Dynamic problems:

$$\left\{u_o\right\} = \left[G_o^d\right] \left[u_d\right] . \tag{5}$$

This is accomplished by calling SSG2B (see section 3.5.13). The independent degrees of freedom $\{u_a\}$ or $\{u_d\}$ are merged with the dependent coordinates $\{u_o\}$, using subroutine SDR1B:

$$\left\{\begin{matrix} u_a \\ \hline u_o \end{matrix}\right\} \Rightarrow \left\{u_f\right\} . \tag{6}$$

4. If s's are present, the coordinates fixed by single-point constraints, $\{u_s\}$,

may have constrained displacements, $\{Y_s\}$, in a statics problem. These are merged with the $\{u_f\}$ vector using subroutine SDR1B:

$$\left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} \Longrightarrow \{u_n\} \tag{7}$$

The forces of single-point constraint $\{q_s\}$ are calculated using SSG2B from the equation:

$$\{q_s\} = -\{P_s\} + [K_{fs}]^T \{u_f\} + [K_{ss}] \{Y_s\}. \tag{8}$$

Subroutine SDR1B is used to merge $\{q_s\}$ with $\{q_f\}$ to form $\{q_g\}$. $\{q_f\}$ is $\{q_r\}$ expanded to the f-set:

$$\left\{\begin{array}{c} q_f \\ \hline q_s \end{array}\right\} \Longrightarrow \{q_g\} \cdot \tag{9}$$

$\{q_g\}$ is copied or appended onto data block QG (Subroutine SDR1A). If YS is not present,

$$\left\{\begin{array}{c} u_f \\ \hline o \end{array}\right\} \Longrightarrow \{u_n\} . \tag{10}$$

The forces of single-point constraint are computed as in Equation 7 except the $\{Y_s\}$ term is omitted.

If e-points (extra points) are present in a dynamics problem, $[K_{fs}]$ must be converted to $[K^d_{fs}]$ by subroutine SDR1C. If the problem is a transient problem, $\{u_f\}$ must be reduced to displacement vectors only, since $\{u_f\}$ contains triples - displacement, velocity and acceleration in transient problems. This reduction is accomplished in SDR1D.

5. If m's are present, the dependent coordinates, $\{u_m\}$, of the multipoint constraint equations are calculated using:

$$\{u_m\} = [G_m] \{u_n\} . \tag{11}$$

In dynamics problems $[G_m] = [G^d_m]$. The two vectors $\{u_m\}$ and $\{u_n\}$ are merged

$$\left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} \Rightarrow \{u_g\} \ . \qquad (12)$$

6. $\{u_g\}$ (or $\{u_p\}$ for dynamics problems) is copied or appended onto UGV.

4.45.8 Subroutines

SSG2B and SDR1B are used as utility routines. See section 3.5.13 and 3.5.8 for details.

4.45.8.1 Subroutine Name: SDR1A

1. Entry Point: SDR1A

2. Purpose: To copy or append vectors.

3. Calling Sequence: CALL SDR1A (IN,IØUT)

IN - GINØ file number of input file - integer - input.

IØUT - GINØ file number of output file - integer - input.

CØMMØN//IAPEND- Append flag. If IAPEND ≠ 1, IØUT will be positioned after the last record and IN copied onto IØUT at this point. Otherwise IN is copied onto IØUT.

4.45.8.2 Subroutine Name: SDR1C

1. Entry Point: SDR1C

2. Purpose: To expand a file (KFS) from the f set to the fe set for dynamics.

3. Calling Sequence: CALL SDR1C (IPVECT,KFS,KDFS)

IPVECT - GINØ file number of the partitioning vector previously generated - integer - input.

KFS - GINØ file number of $[K_{fs}]$ - integer - input.

KDFS - GINØ file number of $[K^d_{fs}]$ - integer - input.

4. Design Requirement: SDR1C depends on a previous call to SDR1B to initialize set parameters.

4.45.8.3 Subroutine Name: SDR1D

1. Entry Point: SDR1D

2. Purpose: To strip velocity and acceleration vectors from $\{u_f\}$.

3. Calling Sequence: CALL SDR1D (PS,IUF,IUF1,ITRAN)

   PS - GINØ file number of PS - integer - input.

   IUF - GINØ file number of $\{u_f\}$ - integer - input.

   IUF1 - GINØ file number of $\{u_f\}$ stripped - integer - input.

   ITRAN - Flag which shows whether problem is a transient analysis or not - integer - input. Its values are:

   1 $\Longrightarrow$ not transient

   0 $\Longrightarrow$ transient.

4.45.9 Design Requirements

Six scratch files are required.

4.46 FUNCTIONAL MODULE SDR2 (STRESS DATA RECOVERY - PHASE 2)

4.46.1 Entry Point: SDR2

4.46.2 Purpose

The SDR2 module processes the output requests for forces of single-point constraint, loads, point displacements, point velocities, point accelerations, element stresses, and element forces, formatting the output data blocks with these final output results for: a) direct outputing by the Output File Processor (ØFP) module or b) input to the SØRT2 processor (SDR3) module and then the XY-output modules (XYTRAN and XYPLØT).

4.46.3 DMAP Calling Sequence

```
SDR2    {CASECC},CSTM,MPT,DIT,{EQEXIN},{SIL },GPTT,EDT,
        {CASEXX}              {EQDYN }{SILD}

BGPDT,{PGG  },{QG  },{UGV  },{EST },XYCDB /
      {PGV1 }{QBG }{UGV1 }{ESTL}
      {PPF  }{BQG }{UPV  }
      {PPT  }{QG1 }{UPVC }
      {LAMA }{QPC }{UBGV }
      {CLAMA}{QP  }{PHIG }
                   {CPHIP}

{ØPG1 },{ØQG1 },{ØUGV1 },{ØES1 },{ØEF1 },{PUPV },
{ØPPC1}{ØQBG1}{ØUPV1 }{ØESC1}{ØEFC1}{PUGV1}
{ØPP1 }{ØBQG1}{ØUPVC1}{ØESB1}{ØEFB1}{PPHIG}
       {ØQPC1}{ØUBGV1}{ØBES1}{ØBEF1}{PUBGV1} /
       {ØQP1 }{ØPHIG }
              {ØCPHIP}

C,N,{STATICS}
    {REIGEN }
    {DSO    }
    {DS1    }
    {FREQ   }
    {TRANSNT} /V,N,NØSØRT2  $
    {BLKO   }
    {BLK1   }
    {CEIGEN }
    {PLA    }
```

4.46.4 Input Data Blocks

CASECC - Case Control Data Table.

CASEXX - Case Control Data Table for Dynamics problems.

CSTM - Coordinate System Transformation Matrices.

MPT - Material Property Table.

DIT - Direct Input Tables.

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers.

EQDYN - Equivalence between external points and scalar index values.

SIL - Scalar Index List.

SILD - Scalar Index List for Dynamics.

GPTT - Grid Point Temperature Table.

EDT - Element Deformation Table.

BGPDT - Basic Grid Point Definition Table.

PGG - Static load vector appended to include all boundary conditions.

PGV1 - Matrix of successive sums of incremental load vectors.

PPF - Dynamic loads for frequency response.

PPT - Linear dynamic loads for transient analysis.

LAMA - Real Eigenvalue Table.

CLAMA - Complex Eigenvalue Table.

QG - Single-point constraint forces and determinant support forces matrix.

QBG - Single-point forces of constraint matrix for Differential Stiffness - g set.

BQG - Single-point forces of constraint matrix for a Buckling Analysis problem - g set.

QG1 - Matrix of successive sums of incremental vectors of single-point constraint forces.

QPC - Complex single-point forces of constraint - p set.

QP - Transient single-point forces of constraint - p set.

UGV - Displacement vector matrix giving displacements in the g set.

UGV1 - Matrix of successive sums of incremental displacement vectors.

UPV - Transient solution vectors - p set.

UPVC - Frequency response solution vectors - p set.

UBGV - Displacement vector matrix for differential stiffness giving displacements in the g set.

PHIG - Eigenvector matrix giving eigenvectors.

CPHIP - Complex eigenvectors in the p set.

EST - Element Summary Table.

ESTL - Element Summary Table for Linear Elements.

XYCDB - XY Case Control Data Block.

Notes:

1. If the first input data block is purged, it is a fatal error. This data block is called "Case Control" in this Module Functional Description.

2. The CSTM may be purged if no coordinate systems are referenced, or if stresses and/or forces are not requested.

3. The MPT may be purged if no stress or force requests are present.

4. The DIT may be purged if no stress or force requests are present, or if no temperature dependent materials are referenced.

5. The second record of EQEXIN or EQDYN must exist if a request exists for any of: loads, forces of single-point constraint, displacements, velocities, accelerations, or plots.

6. SIL or SILD may be purged if no stress or force requests exist, or there are no extra-points and no thermal loads. (The second record is used by SDR2).

7. The GPTT may be purged if no thermal loading exists, or there are no requests for stresses or forces.

8. The EDT may be purged if there are no element requests for forces or stresses, or if there are no enforced element deformations in the problem.

9. The BGPDT may be purged if the problem is in basic coordinates and no element requests for stresses or forces exist.

10. LAMA or CLAMA may not be purged if an eigenvalue or frequency response problem.

11. If input data block 11 (QG or QBG etc.) is purged, forces of single-point constraint requests are ignored.

12. If input data block 12 (UGV or UGV1 etc.) is purged, SDR2 will process only loads and forces of single-point constraint requests.

13. If the EST or ESTL is purged, element stresses and force requests are ignored.

14. The XYCDB may be purged.

4.46.5 Output Data Blocks

ØPG1
ØPPC1
ØPP1 } Output load vector requests.

ØQG1
ØQBG1
ØBQG1
ØQPC1
ØQP1 } Output forces of single-point constraint requests.

ØUGV1
ØUPVC1
ØUBGV1 } Output displacement vector requests.

ØPHIG
ØCPHIP } Output eigenvector requests.

ØES1
ØESC1
ØESB1
ØBES1 } Output element stress requests.

ØEF1
ØEFC1
ØEFB1
ØBEF1 } Output element force requests.

PUPV
PUGV1
PPHIG
PUBGV1 } Translation components of the displacement vector rotated to basic coordinates.

Notes:

Output data blocks purged will result in output requests to those data blocks not being processed.

4.46.6 Parameters

STATICS - BCD constant indicating a Statics solution.

REIGEN - BCD constant indicating a Real Eigenvalue solution.

DSO - BCD constant indicating the Statics phase of a Differential Stiffness solution.

DS1 - BCD constant indicating final phase of a Differential Stiffness solution.

FREQ - BCD constant indicating a Frequency Response solution.

TRANSNT - BCD constant indicating a Transient Response solution.

BKLO - BCD constant indicating the Statics phase of a Buckling solution.

BKL1 - BCD constant indicating the final phase of a Buckling solution.

CEIGEN - BCD constant indicating a Complex Eigenvalue solution.

PLA - BCD constant indicating a Piecewise Linear Analysis solution.

NØSØRT2 - Integer-Output-Set to 0 if there are no SØRT2 requests or requirements, and set to 1 otherwise.

4.46.7 Method

The SDR2 functional module is constructed in a modular form consisting of five stages. A small executive control program (subroutine SDR2) containing the main entry point for the module serially calls the five stages for execution.

1. Stage I, performed by subroutine SDR2AA, prepares, if necessary, a modified Case Control data block, internal to SDR2, to insure that any XY-output requests present and not included in the ØFP output requests of Case Control are included in the output of SDR2 for later processing by functional modules XYTRAN and XYPLØT.

2. Stage II, performed by subroutine SDR2A, analyzes the overall output requests within the subcases of Case Control and sets flags for use by stages III, IV, and V.

3. Stage III, performed by subroutine SDR2B, is executed only if stage II has determined that some element force or stress output requests are present within Case Control. If executed, element stress matrices are computed once and stored along with certain other element properties appearing in the EST for each element appearing in a master set of element requests. (The master set is a set which is the union of all elements for which output requests are present in any subcase of Case Control). These stored data are used in stage V repeatedly as necessary to satisfy the various output request combinations and multiple displacement vectors that may be present.

4. Stage IV, performed by subroutine SDR2C, is executed only if in stage II it has been determined that some output requests are present for any of: forces of single-point constraint, loads, displacement, velocities, accelerations, or deformed structure plots. If they are present, these requests (except for structure plots) are fully processed within this stage.

5. Stage V, performed by subroutine SDR2D, is executed only if stage III was executed. Stage V performs final element stress and force computations. For each subcase of Case Control containing element output requests, the appropriate displacement vector is applied to the stress matrices, computed in Stage III, of the elements requested for output to arrive at the final stress and/or force outputs.

For several of the five stages the main subroutine listed utilizes additional subroutines to accomplish its particular task. The methods employed within each stage are further described in the subroutine descriptions in the next section.

4.46.8 Subroutines

The utility routines PRETRS and PREMAT are called within the SDR2 module for initialization purposes so that the structural element subroutines can call the entry point TRANSS of PRETRS and MAT of PREMAT to fetch Coordinate System Transformation Matrices (CSTM) data and material properties (MPT and DIT) data respectively. GMMATS is used by element routines as a general matrix multiply routine and INVERS is used for inversion of small in-core (order usually $\leq$ 12) matrices. It should be noted that all matrices referenced in the structural element subroutines are stored by rows and are single precision. See the subroutine descriptions for these routines in section 3.

The axisymmetric shell element routines STRIR1, STRAP1, STØRD1, STRIR2, STRAP2, STØRD2 utilize the following functions and subroutines whose double precision versions are described in the Module Functional Description for SMA1 (section 4.27.8).

SDR2 (Single precision)	SMA1 (Double precision)
AI	DKI
AK	DKK
AM	DKM
BINT	DKINT
AJ	DKJ
CØEF	DKEF
F89	DK89
FF100	DK100
IFAC	KFAC
FJAB	DKJAB
F6219	DK219
F6211	DK211
RØMBER	RØMBDK
F4	D4K
F5	D5K
F6	D6K
AMATRX	DMATRX

4.46.8.1 Subroutine Name: SDR2AA

1. Entry Point: SDR2AA

2. Purpose: To perform stage I as defined above, under "Method".

3. Calling Sequence: CALL SDR2AA

4. Method: SDR2AA attempts to open the XYCDB data block. If it is purged, a return is given to SDR2. Otherwise, the header record and first data record of XYCDB are skipped and data applying to all subcases are read from the second data record. If no such data exist a dummy master is created. Otherwise, the master data are reduced to a list of unique pairs. If only master data exist, flags are set appropriately.

For each record in the Case Control data block the following processing occurs.

a. The record is read into core. If no XYCDB subcase corresponds to the Case Control subcase, pointers are set to the master data. Otherwise, the master data and appropriate XYCDB subcase data are merged and reduced to unique pairs.

b. For each request for solution set output in XYCDB, the corresponding request in Case Control is examined. If no request is present in Case Control, the XYCDB request is reduced to a set in Case Control format, and a request for the set is turned on in Case Control. If the Case Control set is "ALL", no further action is taken. If the Case Control request is a set, the set is "merged" with the XYCDB set, and the request is altered to reflect the new set (unless all points in the XYCDB set were already in the Case Control set). A flag is set if any new requests are formed.

c. When all requests for the current Case Control record have been analyzed, the record (as modified) is written on a scratch file.

d. When all Case Control records have been read, the GINØ file name for the Case Control data block is switched to the scratch file (unless no modifications were made to Case Control).

4.46.8.2 Subroutine Name: SDR2A

1. Entry Point: SDR2A

2. Purpose: To perform stage II as defined above, under "Method".

3. Calling Sequence: CALL SDR2A

4. Method: SDR2A analyzes Case Control to determine the overall output requests. Flags are set to zero for all request possibilities, and, as each record of Case Control is analyzed, flags are set to 1 for those requests present. Simultaneously, a master set of all structural elements requested for output is created. The master set is then a union of all element requests present with duplicates removed.

4.46.8.3 Subroutine Name: SDR2B

1. Entry Point: SDR2B

2. Purpose: To perform stage III as defined above, under "Method".

3. Calling Sequence: CALL SDR2B

4. Method: SDR2B performs the "phase I" stress and force recovery computations.

The CSTM is first read into core, if present, and then the material property data are read into core via the routine PREMAT. At this point, the EST is opened and processed with one pass.

SDR2A determined a master set list of all elements requested by the user to be output. This master set list, residing in core, is now used as the EST is processed.

For each record of the EST a particular element type is represented. Thus the first word of an EST record (giving the element type) is read, and the element dependent variables are set. The element summary for each element of this type is read, and, if the element is included in the master set, the phase I stress recovery routine is called to compute the element stress matrices which are functions of element geometry and material properties only. The results of this computation are output to a scratch data block for use by SDR2D (stage V). When the end-of-record is encountered on the EST for this element type, the next element type record is processed, until all records of the EST have been passed.

4.46.8.4 Subroutine Name: SRØD1

1. Entry Point: SRØD1

2. Purpose: To generate element stress matrices for the RØD element.

3. Calling Sequence: CALL SRØD1

4.46.8.5 Subroutine Name: SBEAM1

1. Entry Point: SBEAM1

2. Purpose: To generate element stress matrices for the BEAM element.

3. Calling Sequence: CALL SBEAM1

4.46.8.6 Subroutine Name: STUBE1

1. Entry Point: STUBE1

2. Purpose: To generate element stress matrices for the TUBE element.

3. Calling Sequence: CALL STUBE1

4.46.8.7 Subroutine Name: SPANL1

1. Entry Point: SPANL1

2. Purpose: To generate element stress matrices for the SHEAR and TWIST elements.

3. Calling Sequence: CALL SPANL1 (IARG)

IRAG = { 4 implies SHEAR panel element stress matrices will be generated.
5 implies TWIST panel element stress matrices will be generated.

4.46.8.8 Subroutine Name: STRBS1

1. Entry Point: STRBS1

2. Purpose: To generate element stress matrices for the TRBSC element and perform sub-computations for the SQPDL1 and STRPL1 routines.

3. Calling Sequence: CALL STRBS1 (IARG)

IARG
- 0 = TRBSC element
- 1 = Sub-computations for SQDPL1.
- 2 = Sub-computations for STRPL1.

4.46.8.9 Subroutine Name: STRPL1

1. Entry Point: STRPL1

2. Purpose: To generate element stress matrices for the TRPLT element.

3. Calling Sequence: CALL STRPL1

4.46.8.10 Subroutine Name: SQDPL1

1. Entry Point: SQDPL1

2. Purpose: To generate element stress matrices for the QDPLT element.

3. Calling Sequence: CALL SQDPL1

4.46.8.11 Subroutine Name: STRME1

1. Entry Point: STRME1

2. Purpose: To generate element stress matrices for the TRMEM element and perform sub-computations for the SQDME1 routine.

3. Calling Sequence: CALL STRME1 (IARG)

IARG
- 0 = TRMEM
- 1 = Sub-computations for SQDME1 subroutine.

4.46.8.12 Subroutine Name: SQDME1

1. Entry Point: SQDME1

2. Purpose: To generate element stress matrices for the QDMEM element.

3. Calling Sequence: SQDME1

4.46.8.13 Subroutine Name: SELAS1

1. Entry Point: SELAS1

2. Purpose: To generate element stress matrices for the elements listed under the Calling Sequence.

3. Calling Sequence: CALL SELAS1 (IARG)

IARG
- 1 = ELAS1
- 2 = ELAS2
- 3 = ELAS3
- 4 = ELAS4

4.46.8.14 Subroutine Name: STRQD1

1. Entry Point: STRQD1

2. Purpose: To generate element stress matrices for the elements listed under the Calling Sequence.

3. Calling Sequence: CALL STRQD1 (IARG)

IARG
- 1 = TRIA1
- 2 = TRIA2
- 3 = QUAD1
- 4 = QUAD2

4.46.8.15 Subroutine Name: SBAR1

1. Entry Point: SBAR1

2. Purpose: To generate element stress matrices for the BAR element.

3. Calling Sequence: CALL SBAR1

4.46.8.16 Subroutine Name: SCØNE1

1. Entry Point: SCØNE1

2. Purpose: To generate element stress matrices for the CØNE element.

3. Calling Sequence: CALL SCØNE1

4.46.8.17 Subroutine Name: STRIR1

1. Entry Point: STRIR1

2. Purpose: To generate element stress matrices for the TRIRG element.

3. Calling Sequence: CALL STRIR1

4.46.8.18 Subroutine Name: STRAP1

1. Entry Point: STRAP1

2. Purpose: To generate element stress matrices for the TRAPRG element.

3. Calling Sequence: CALL STRAP1

4.46.8.19 Subroutine Name: STØRD1

1. Entry Point: STØRD1

2. Purpose: To generate stress matrices for the TØRDRG element.

3. Calling Sequence: CALL STØRD1

4.46.8.20 Subroutine Name: SDR2C

1. Entry Point: SDR2C

2. Purpose: To perform stage IV as defined above, under "Method".

3. Calling Sequence: CALL SDR2C

4. Method: SDR2C operations are dependent on the Rigid Format being executed. In all cases the second record of EQEXIN or EQDYN is first read into core. An over-all loop of 3 passes is then executed to process the following: pass 1: displacements, velocities, accelerations; pass 2: single-point constraint forces; and pass 3: loads.

For each pass the Case Control data block is opened for input, and the following operations are performed depending on Rigid Format:

a. For eigenvalue problems, a list of eigenvalues and mode numbers is read into core from LAMA or CLAMA.

b. For Differential Stiffness or Buckling phase 1 problems, the first record of

Case Control, which is used in phase 0 of Buckling or Differential Stiffness, is skipped.

c. For frequency or transient response problems, a list of frequencies or times is read into core from PPF or PPT.

At this point a record in Case Control is read, and it is determined if a symmetry sequence of length LSYM is to be output. If it is, the previous LSYM vectors of the UGV data block are unpacked and a linear combination is formed in core. Otherwise, UGV is opened, if not yet opened, and the next vector present is unpacked into core.

Data items are now assembled for the identification record, and this identification record is output to the output data block. Output line entries for the point-ID's requested are then written on the output data block forming a data record. At this time, if the user requested magnitude/phase for complex outputs, the magnitude/phase computations are performed on the real/imaginary pairs.

When all requests have been processed for this vector, the next Case Control record is read. If no more Case Control records exist and there are more vectors present, those vectors are processed using the last Case Control record's specifications.

When all vectors have been processed for the current loop pass, the next pass may be made for forces of single-point constraint or loads.

If deformed structure plots are requested, an output plot data block is formed during the first loop pass, described above, containing translation components of the displacement vector rotated to basic coordinates.

4.46.8.21 Subroutine Name: SDR2D

1. Entry Point: SDR2D

2. Purpose: To perform stage V as defined above, under "Method".

3. Calling Sequence: CALL SDR2D

4. Method: SDR2D performs the phase 2 stress and force recovery computations. In this phase actual stresses and forces are computed for the user-requested elements. These stresses and forces are a function of the stress matrices computed in Stage III and the displacements at the grid points of the elements.

The operations of SDR2D are dependent upon the Rigid Format being executed. In all cases the Case Control data block is opened first. For eigenvalue problems a list of eigenvalues and mode numbers is read into core from LAMA or CLAMA. For Differential Stiffness or Buckling phase 1 problems, the first record of Case Control, which is used in phase 0 of Buckling or Differential Stiffness, is skipped. For frequency or transient response problems, a list of frequencies or times is read into core from PPF or PPT.

Core and GINØ buffers are then allocated as required for a) the Case Control data block, b) the Element Deformation Table, c) the Grid Point Temperature Table, and d) the element stress matrices. If there is insufficient space in core for the element stress matrices, they are maintained on the scratch data block generated in stage III.

The displacement data block (UGV) is now opened, and the displacement vectors present are processed serially with Case Control as in stage IV. Each element requested for output has its respective phase 2 element stress and force recovery routine called. The element routine outputs form the entries for the output data record of this element type. In the case of a complex displacement vector, the element routine is called first with a pointer to the real displacement vector and then with a pointer to the imaginary displacement vector. The results of these two calls are merged to form the complex output stresses and forces.

4.46.8.22 Subroutine Name: SDR2E

1. Entry Point: SDR2E

2. Purpose: To pass through the element stress matrices once, executing the final element stress and force computations for the requests in the current subcase of Case Control.

3. Calling Sequence: SDR2E ($n)

n = FØRTRAN statement number defining the return taken in the event of an error in SDR2E.

4.46.8.23 Subroutine Name: SRØD2

1. Entry Point: SRØD2

2. Purpose: To perform final stress and force computations for the RØD element.

3. Calling Sequence: CALL SRØD2

4.46.8.24 Subroutine Name: SBEAM2

1. Entry Point: SBEAM2

2. Purpose: To perform final stress and force computations for the BEAM element.

3. Calling Sequence: CALL SBEAM2

4.46.8.25 Subroutine Name: SPANL2

1. Entry Point: SPANL2

2. Purpose: To perform final stress and force computations for the SHEAR and TWIST elements.

3. Calling Sequence: CALL SPANL2 (IARG)

IARG { 4 = SHEAR element.
     { 5 = TWIST element.

4.46.8.26 Subroutine Name: SELAS2

1. Entry Point: SELAS2

2. Purpose: To perform final stress and force computations for the ELAS1, ELAS2, ELAS3, and ELAS4 elements.

3. Calling Sequence: CALL SELAS2

4.46.8.27 Subroutine Name: SBSPL2

1. Entry Point: SBSPL2

2. Purpose: To perform final stress and force computations for the TRBSC, TRPLT, and QDPLT elements.

3. Calling Sequence: CALL SBSPL2 (IARG)

IARG { 0 = TRBSC element.
       3 = TRPLT element.
       4 = QDPLT element.

4.46.8.28 Subroutine Name: STQME2

1. Entry Point: STQME2

2. Purpose: To perform final stress computations for the TRMEM and QDMEM elements.

3. Calling Sequence: CALL STQME2 (IARG)

IARG { 1 = TRMEM element.
       2 = QDMEM element.

4.46.8.29 Subroutine Name: STRQD2

1. Entry Point: STRQD2

2. Purpose: To perform final stress and force computations for the TRIA1, TRIA2, QUAD1, and QUAD2 elements.

3. Calling Sequence: CALL STRQD2 (IARG)

IARG { 3 = TRIA1 or TRIA2 element.
       4 = QUAD1 or QUAD2 element.

4.46.8.30 Subroutine Name: SCØNE2

1. Entry Point: SCØNE2

2. Purpose: To perform final harmonic stress and force computations for the CØNE element.

3. Calling Sequence: CALL SCØNE2

4.46.8.31 Subroutine Name: SCØNE3

1. Entry Point: SCØNE3

2. Purpose: To compute the final stresses and forces for one of the 14 possible points in a CØNE element.

3. Calling Sequence: CALL SCØNE3 (LARG)

LARG = Logical argument set .FALSE. initially and then set .TRUE. by SCØNE3 after the last point defined for a particular element has had its final stresses and forces computed.

4.46.8.32 Subroutine Name: SBAR2

1. Entry Point: SBAR2

2. Purpose: To perform final stress and force computations for the BAR element.

3. Calling Sequence: CALL SBAR2

4.46.8.33 Subroutine Name: STRIR2

1. Entry Point: STRIR2

2. Purpose: To perform final stress and force computations for the TRIRG element.

3. Calling Sequence: CALL STRIR2 (TGRID)

TGRID = 3 word real array giving grid point temperatures at the 3 connection grid points.

4.46.8.34 Subroutine Name: STRAP2

1. Entry Point: STRAP2

2. Purpose: To perform final stress and force computations for the TRAPRG element.

3. Calling Sequence: CALL STRAP2 (TGRID)

TGRID = 4 word real array giving grid point temperatures at the 4 connection grid points.

4.46.8.35 Subroutine Name: STØRD2

1. Entry Point: STØRD2
2. Purpose: To perform final stress and force computations for the TØRDRG element.
3. Calling Sequence: CALL STØRD2 (TGRID)

TGRID = Two-word real array giving grid point temperatures at the two connection grid points.

4.46.8.36 Subroutine Name: MAGPHA

1. Entry Point: MAGPHA
2. Purpose: To compute the magnitude and phase of a complex number, c.
3. Calling Sequence: CALL MAGPHA (A,B)

A - Real part of c on input, magnitude of c on return.

B - Imaginary part of c on input, phase of c on return.

4.46.8.37 Subroutine Name: SAXIF1

1. Entry Point: SAXIF1
2. Purpose: To generate element pressure-velocity matrices for the AXIF elements.
3. Calling Sequence: CALL SAXIF1 (IARG)

IARG = { 0 = AXIF2; 1 = AXIF3; 2 = AXIF4 }

4.46.8.38 Subroutine Name: SAXIF2

1. Entry Point: SAXIF2
2. Purpose: To generate element velocities or accelerations for the AXIF elements.
3. Calling Sequence: CALL SAXIF2 (IØPT, IPART, BRANCH, EIGEN)

IØPT = { 0 = AXIF2; 1 = AXIF3; 2 = AXIF4 }

IPART = { 1 = Real Vector; 2 = Imaginary Vector }

BRANCH = SDR2 Process code word

EIGEN = 3 words for complex or real eigenvalue or real frequency.

4.46.8.39 Subroutine Name: SSLØT1

1. Entry Point: SSLØT1

2. Purpose: To generate element pressure-velocity matrices for the SLØT elements.

3. Calling Sequence: CALL SSLØT1 (IØPT)

IØPT = { 0 = SLØT3
       { 1 = SLØT4

4.46.8.40 Subroutine Name: SSLØT2

1. Entry Point: SSLØT2

2. Purpose: To compute element velocities or accelerations for the SLØT elements.

3. Calling Sequence: CALL SSLØT2 (IØPT, IPART, BRANCH, EIGEN)

IØPT = { 0 = SLØT3
       { 1 = SLØT4

IPART = { 1 = Real Vector
        { 2 = Imaginary Vector

BRANCH = SDR2 Process code word

EIGEN = 3 words for eigenvalue or frequency.

4.46.8.41 Subroutine Name: SSØLD1

1. Entry Point: SSØLD1

2. Purpose: To generate stress matrices for the solid elements.

3. Calling Sequence: CALL SSØLD1 (I)

I	Element Type
1	TETRA
2	WEDGE
3	HEXA1
4	HEXA2

4.46.8.42 Subroutine Name: SSØLD2

1. Entry Point: SSØLD2

2. Purpose: To perform final stress and force computations for the solid elements.

3. Calling Sequence: CALL SSØLD2 (I,T)

I	Element Type
1	TETRA
2	WEDGE
3	HEXA1
4	HEXA2

T - Temperature Vector

4.46.8.43 Subroutine Name: SDRETD

1. Entry Point: SDRETD

2. Purpose: Reads element temperature from a pre-positioned record.

3. Calling Sequence: CALL SDRETD (ID,T,G)

ID - Element identification number for which the data is desired.

T - Area into which data will be stored

G - = 0, element temperature format data is desired.

≠ 0, number of grid points.

4.46.9 Design Requirements

1. Since the five stages of the SDR2 module must be able to operate under all Rigid Formats, a branch design has been used within each stage whereby operations that are variant under different Rigid Formats are grouped into substructures within that stage. At these locations, a branch is always made to the substructure appropriate to the Rigid Format being executed.

2. The following common blocks appear only within the subroutines of the SDR2 module.

a. CØMMØN /SDR2X1/

This common block contains seventeen flag words which are set on the basis of requests in the Case Control data block by SDR2A.

b. CØMMØN /SDR2X2/

This common block contains twenty-nine pointers defining the locations of the various requests and set definitions within the Case Control data block.

c. CØMMØN/SDR2X3/

This common block contains data constants unique to the structural elements.

d. CØMMØN/SDR2X4/

This common block contains local variables and flags set by the subroutines of the SDR2 module for communications between these subroutines.

e. CØMMØN/SDR2X5/

This common block is used by SDR2B to send EST data to the phase 1 element routines and to receive outputs from the phase 1 element routines.

f. CØMMØN/SDR2X6/

This common block consists of a three hundred word scratch area for use by the element routines while performing phase 1 computations.

g. CØMMØN/SDR2X7/

This common block is used by SDR2D for sending and receiving data to the element routines performing phase 2 computations.

h. CØMMØN/SDR2X8/

This common block consists of a three hundred word scratch area in core for use by the element routines while performing phase 2 computations.

4.46.10 Diagnostic Messages

SDR2 being one of the last modules to execute in a problem solution, makes every attempt at execution in any event. Should an error be detected by SDR2, a message is queued for output and, if possible, SDR2 continues to execute portions of the solution not affected by the error, The following NASTRAN messages may be output by SDR2: 2075, 2076, 2077, 2078, 2079, 2080, 3001, 3002, 3003, and 3008.

4.47 FUNCTIONAL MODULE DPD (DYNAMICS POOL DISTRIBUTOR)

4.47.1 Entry Point: DPD

4.47.2 Purpose

DPD is the principal data processing module for dynamics problems. New tables are assembled to account for any extra points in the model and the additional displacement sets used in dynamics. Bulk data cards which control the solution of a dynamics problem are processed and assembled into various data blocks for convenience and efficiency in solution of the dynamics problem.

4.47.3 DMAP Calling Sequence

```
DPD     DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPØØL,DLT,PSDL,FRL,NLFT,TRL,EED,EQDYN/
        V,N,LUSET/V,N,LUSETD/V,N,NØTFL/V,N,NØDLT/V,N,NØPSDL/V,N,NØFRL/V,N,NØNLFT/
        V,N,NØTRL/V,N,NØEED/C,N,O/V,N,NØUE   $
```

4.47.4 Input Data Blocks

DYNAMICS - Collection of bulk data cards for dynamics problem.

GPL - Grid Point List.

SIL - Scalar Index List.

USET - Displacement set definitions table.

Note: DYNAMICS may be purged. Other input data blocks may not be purged.

4.47.5 Output Data Blocks

GPLD - Grid Point List Dynamics.

SILD - Scalar Index List Dynamics.

USETD - Displacement set definition table dynamics.

TFPØØL - Transfer Function Pool.

DLT - Dynamic Loads Table.

PSDL - Power Spectral Density List.

FRL - Frequency Response List.

NLFT - Non-Linear Forcing Table.

TRL - Transient Response List.

EED - Eigenvalue Extraction Data.

EQDYN - Equivalence between external and internal numbers - dynamics.

Note: GPLD, SILD, USETD and EQDYN may not be purged. All other data blocks may be purged.

4.47.6 Parameters

LUSET - Input-integer-no default. Degrees of freedom in the g - displacement set.

LUSETD - Output-integer-no default. Degrees of freedom in the p - displacement set.

NØTFL - Output-integer-no default. Number of transfer function sets in the bulk data, -1 if no sets are defined.

NØDLT - Output-integer-no default. +1 if dynamics load data are present in the bulk data (i.e., DLT is created), -1 otherwise.

NØPSDL - Output-integer-no default. +1 if the PSDL is created, -1 otherwise.

NØFRL - Output-integer-no default. +1 if the FRL is created, -1 otherwise.

NØNLFT - Output-integer-no default. +1 if the NLFT is created, -1 otherwise.

NØTRL - Output-integer-no default. +1 if the TRL is created, -1 otherwise.

NØEED - Output-integer-no default. +1 if the EED is created, -1 otherwise.

NØUE - Output-integer-no default. Number of extra points in the model, -1 if there are no extra points.

4.47.7 Method

4.47.7.1 General

Subroutine DPD is the main control program for the module. It initializes each of the DMAP parameters, allocates buffers in open core (/DPDCØR/), and calls each of the principal routines of the module as follows.

1. DPD1 to assemble GPLD, USETD, SILD and EQDYN.
2. DPD2 to assemble DLT.
3. DPD3 to assemble FRL and PSDL.
4. DPD4 to assemble NLFT and TRL.
5. DPD5 to assemble EED and TFL.

4.47.7.2 Assembly of GPLD, USETD, SILD and EQDYN

The second logical record of GPL, which contains pairs of external point identification and sequence numbers, is read into core. Three words are used for each entry in the GPL. In the third word of each entry the internal index is stored. The list of extra points is read from the EPØINT record in DYNAMICS. For each extra point, a three-word entry is added to the list now in core. The first word contains the extra point identification, the second contains the initial sequence number equal to 1000 times the point ID, and the third word is zero. The SEQEP record in DYNAMICS is read. For each referenced point, the sequence number is replaced by the new sequence number. The list in core is now sorted on sequence number by subroutine SØRT. The sequence number in each entry is replaced by an internal index according to the position of the entry following the sort. The GPLD is now written. It consists of one logical record of one word entries, each entry containing the external point identification. The internal index is implied by the position of the entry in the record.

The SIL is read into core following the table of three-word entries currently in core. Bit masks are initialized for the various displacement sets in statics and dynamics. Files containing the USETD and SILD data blocks are opened to write. The file containing the USET data block is opened to read. Each of the three-word entries in core is processed as follows.

1. If the entry corresponds to a grid point, six words are read from USET, bits for displacement sets in dynamics are turned on according to the statics sets to which the point belongs, six words are written on USETD, one word is written on SILD, the second word of the three-word entry is replaced with the scalar index value in the p-set, the third word is replaced with the scalar index value in the g-set, and the scalar index counter for the p-set is incremented by six.

2. If the entry corresponds to a scalar point, one word is read from USET, and the process proceeds as above except that one word is written on USETD and the scalar index counter is incremented by one.

3. If the entry corresponds to an extra point, one word is written on USETD, the extra point counter is incremented, and the process proceeds as with a scalar point.

When all entries have been processed, USETD is complete and the first logical record of SILD is complete. The second logical record of SILD is now written. It comprises two-word entries, each pair containing a scalar index value in the g-set and the corresponding scalar index value in the p-set.

The third word of each of the three word entries in core is now replaced with a code word which is ten times the scalar index value in the p-set plus the type of point (1 = grid, 2 = scalar, 3 = extra). The table is sorted on external point identification. EQDYN is written as two logical records. The first record contains pairs, each consisting of an external point ID and a scalar index value in the p-set. The second record contains pairs, each consisting of an external point ID and a code word.

4.47.7.3 Assembly of the DLT

The DAREA, DELAY and DPHASE tables are read from DYNAMICS, one table at a time. Grid point and component codes are converted to a scalar index value in the p-set by subroutine DPDAA. When all entries of a table have been read, the table is sorted on scalar index value and written as a logical record on a scratch file (three scratch files are used, one for each of the three types of tables). The table identification is saved in core.

The RLØAD1, RLØAD2, TLØAD1 and TLØAD2 cards are read from DYNAMICS and stored in core. Eleven words are used for each entry. In the first word of each entry, a code for the card type is stored. When all cards have been read and stored in core, the data are sorted on load set identification.

DLØAD cards are read from DYNAMICS and stored in core, and the data within each DLØAD card are sorted on referenced set identification. The file containing the DLT data block is opened to write. The header record is written. It contains the data block name, a list of set

identifications defined on DLØAD cards and a list of set identifications defined on RLØAD1, RLØAD2, TLØAD1 and TLØAD2 cards. The DLØAD data are then written as the first logical record of the DLT. The remainder of the DLT comprises one logical record per load set. For each entry in the 11-word per entry table in core the following processing occurs.

1. The scratch file containing the tables referenced in the entry is positioned to read the referenced table.

2. Entries are read from each of the referenced tables. A four-word entry is written on the DLT consisting of the scalar index value, A, τ, and Θ.

3. When all entries from the tables have been read, the DLT record is closed, and the process repeats for the next load set.

4.47.7.4 Assembly of the FRL and the PSDL

FREQ1, FREQ2 and FREQ cards are read from DYNAMICS and stored in core. Frequencies on FREQ cards are converted to radians. When all the data have been read, a list containing three words per entry is accumulated in core. The first word contains the frequency set identification, the second word contains a pointer to the first word where data belonging to the set are stored, and the third word defines the type (0 = FREQ1, -1 = FREQ2, N = FREQ, where N is the number of words in the frequency set). The list is sorted on set identification. The file containing the FRL data block is opened to write. The header record is written. It contains the data block name and a list of all frequency set identifications. The remainder of the FRL is comprised of one logical record per frequency set.

For each entry in the three-word per entry list in core the following processing occurs.

1. If the entry corresponds to a FREQ1 set, then N+1 frequencies are written as a logical record on the FRL by the following equation:

$$f_i = f_o + (i-1)\,\Delta f,\ i = 1,2,\ldots,N+1. \qquad (1)$$

2. If the entry corresponds to a FREQ2 set, then N+1 frequencies are written as one logical record on the FRL by the following equation:

$$f_i = f_o \; 10^{(i-1)\delta} \quad i = 1,2,\ldots, N+1 \tag{2}$$

where

$$\delta = \frac{1}{N} \log_{10} \left(\frac{f_e}{f_o}\right). \tag{3}$$

3. If the entry corresponds to a FREQ set, the frequencies in the set are sorted, and any duplicate frequencies are discarded. The sorted list is written as one logical record on the FRL.

The RANDPS cards are read into core (if no RANDPS data are present, the PSDL is not assembled). The RANDT1 and RANDT2 cards are read into core, and a list similar to that in the frequency processing is formed. This list is sorted on set identification number. The file containing the PSDL is opened to write, and the set identifications are written in the header record. The RANDPS data are written as the first logical record of the PSDL. The remainder of the PSDL contains one logical record per set. For RANDT2 sets, the data are sorted on time lag, and duplicates are discarded prior to writing the record. For RANDT1 sets, N + 1 time lags, τ_i, are written where

$$\tau_i = \tau_o + (i-1)\Delta\tau \quad i = 1,2,\ldots, N+1 \tag{4}$$

4.47.7.5 Assembly of the NLFT and TRL

The NØLINi (i = 1,2,3,4) cards are read into core. Each referenced grid point and component code is converted to a scalar index value in the u_p-set. The data are sorted on set identification number. USETD is read into core. The file containing the NLFT data block is opened to write, and the set identifications are written in the header record. The remainder of the NLFT contains one logical record per set. Scalar index values within each set are converted to scalar index values in the u_d and u_e sets. The data within each set are sorted on the scalar index value to which the forcing function is applied.

The TIC cards are read, referenced grid points and component codes are converted to scalar index values in the u_p-set, and the data are written on SCR1, one logical record per set. A list of the TIC set identifications is accumulated in core. USETD is read into core. The

file containing the TRL data block is opened to write. The set identifications are written in the header record. The last word of the header contains the degrees of freedom in the u_d-set. Data are read from SCR1. Scalar index values are converted to scalar index values in the u_d-set. Each TIC set is written as one logical record on the TRL. When all the TIC data have been processed, the TSTEP data are copied from DYNAMICS to the TRL, one logical record per TSTEP set.

4.47.7.6 Assembly of the EED and TFL

Processing of EIGB, EIGC, EIGP and EIGR cards is minimal. For each card type present, a corresponding logical record is written on EED. For each of the cards which specify PØINT, the referenced grid point and component code is converted to a scalar index value (u_a set for EIGB and EIGR cards, u_d set for EIGC cards).

Transfer function data are read from the TF record on DYNAMICS one set at a time. For each transfer function set, the point and component codes are converted to scalar index values in the u_p set, which in turn form row and column numbers of the transfer function matrices. The data are written on the TFL, one transfer function set per logical record. The set identification number is the first word of each logical record. Four word entries follow. The first word is 65536*column number plus row number; the next three words are the terms of the matrices.

4.47.8 Subroutines

Auxiliary subroutines DPD1, DPD2, DPD3, DP4 are described above.

4.47.8.1 Subroutine Name: DPDAA

1. Entry Point: DPDAA

2. Purpose: To convert a grid point and component code to a scalar index value in the u_p set.

3. Calling Sequence: CALL DPDAA

4. Method: A flag called INEQ is maintained in /DPDCØM/. If the flag is zero, EQDYN is read into core and INEQ is set to one. The grid point and component to be converted is stored in BUF(L) and BUF(L+1) where BUF and L are in /DPDCØM/. A binary search is performed in EQDYN. If the point is found, the corresponding scalar index value is stored in BUF(L). Otherwise, an error message is queued, and an internal

NØGØ flag is turned on.

4.47.9 Design Requirements

4.47.9.1 Allocation of Core Storage

In general, core storage requirements in DPD are the EQDYN table plus one set of data being processed plus two or three GINØ buffers. In DPD3 where EQDYN is not required, it is assumed that all data required to assemble the FRL or PSDL can be held in core at one time.

4.47.9.2 Environment

The Block Data program DPDCBD initializes /DPDCØM/ with GINØ file names, LØCATE codes for the various card types processed by DPD, and miscellaneous data. It must be resident in core when DPD is executed.

DPD is designed to operate in a single overlay segment. Communication in the module occurs through /DPDCØM/ and open core /DPDCØR/. If an alternate overlay is desired, DPDCDB, DPD and DPDAA could form a local primary segment and each of DPD1, DPD2, DPD3, DPD4 and DPD5 could form separate secondary segments. In this case, /DPDCØR/ must be inserted after the longest of the secondary segments. Four scratch files are used by DPD.

4.47.10 Diagnostic Messages

The following messages may be issued by DPD:

2064, 2066, 2068, 2069, 2071, 2107, 2135, 2136.

4.48 FUNCTIONAL MODULE READ (REAL EIGENVALUE ANALYSIS - DISPLACEMENT)

4.48.1 Entry Point: REIG

4.48.2 Purpose:

To solve the equation

$$\Big([K] - \lambda\,[M]\Big)\{u\} = 0 \qquad (1)$$

for eigenvalues λ and their associated eigenvectors.

4.48.3 DMAP Calling Sequence

```
READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,ØEIGS/V,N,FØRMAT/V,N,NEIGVS/V,N,NSKIP  $
```

4.48.4 Input Data Blocks

KAA - Partition of stiffness matrix - a set.

MAA - Partition of mass matrix - a set.

MR - Rigid body mass matrix - r set.

DM - Rigid body transformation matrix.

EED - Eigenvalue Extraction Data.

USET - Displacement set definitions table.

CASECC - Case Control Data Table.

Notes:

1. KAA must be present.
2. MR may or may not be present.
3. DM and USET must be present if MR is present.
4. EED and CASECC must be present.
5. In Buckling Analysis MAA = -KDAA

4.48.5 Output Data Blocks

LAMA - Real Eigenvalue Table

PHIA - Eigenvectors matrix giving the eigenvectors in the a set.

MI - Modal Mass Matrix.

ØEIGS - Real Eigenvalue Summary Table.

4.48.6 Parameters

FØRMAT - Input-BCD-no default. If FØRMAT ≠ MODES, READ will solve a buckling problem (i.e., $[\lambda \ M - K] \{u\} = 0$) using EIGB data cards where M is the negative of the differential stiffness matrix.

NEIGVS - Output-integer-no default. NEIGVS is the number of eigenvalues found. If none were found, NEIGVS = -1.

NSKIP - Input-integer-default value of one. The method used by READ is taken from the NSKIP record of CASECC.

4.48.7 Method

REIG is the main controlling program for the READ module. Its responsibility is to decide which method was asked for (Inverse Power, Determinant or Givens) and to pass control to the appropriate routine. Once eigenvalues have been extracted, REIG directs the sorting and normalizing of the vectors for final output. The flow of the module can be seen in the flow charts shown in Figure 1.

4.48.8 Subroutines

The subroutines used by READ are divided into five classes: 1) subroutines used by REIG, 2) subroutines used for the Inverse Power Method, 3) subroutines used for the Determinant Method, 4) subroutines used for the Givens Method, and 5) general subroutines. The descriptions for the general subroutines can be found in section 3.

FUNCTIONAL MODULE READ (REAL EIGENVALUE ANALYSIS - DISPLACEMENT)

REIG	INVERSE POWER	DETERMINANT	GIVENS
READ1	INVPWR	DETM SUMM	VALVEC
READ2	INVP1	DETM1 SQRTM	SMLEIG
READ3	INVP2	DETM2 DETFBS	TRIDI
READ4	INVP3	DETM3	SICØX
READ5	NØRM1	DETM4	SINCAS
READ6	MTIMSU	DETM5	RØTAX
ØRTCK	XTRNSY	DETM6	RØTATE
INVERT	SUB	FDVECT	EMPCØR
INVTR	INVFBS	EADD	FILCØR
		DETDET	QRITER
		ARRM	WILVEC

GENERAL

DECØMP

ADD

PRELØC

SSG2B

SDR1B

SDCØMP

FACTØR

TRANP1

TRNSP

MERGE

MPYAD

4.48.8.1 Subroutine Name: READ1

1. Entry Point: READ1

2. Purpose: To compute the eigenvectors for the rigid body modes.

3. Calling Sequence: CALL READ1 (DM,MR,SCR1,SCR2,SCR3,PHIAT,USET,NR,LAMAT,SCR4)

DM,MR,USET are the GINØ file numbers of their respective data blocks - integer - input.

SCR1,...,SCR4 are the GINØ file numbers of 4 scratch files - integer - input.

PHIAT - GINØ file number of a temporary storage file for the eigenvectors - integer - input.

LAMAT - GINØ file number of a temporary storage file for the eigenvalues - integer - input.

NR - Number of rigid body modes - integer - output.

CØMMØN /READ1A/Z(1)

Z(1) - Array of open core for READ1

4. Method: Let r be the number of rigid body modes and let

$$I_1 = \begin{Bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{Bmatrix}, \tag{2}$$

$$I_2 = \begin{Bmatrix} 0 \\ 1 \\ \vdots \\ 0 \end{Bmatrix}, \tag{3}$$

etc.

Set $\{v_1\} = \{I_1\}$ and perform the following three steps for i = 1, 2,...,r.

a. Normalize $\{v_i\}$ by the following equations:

$$S_i = \{v_i\}^T [m_r] \{v_i\}, \tag{4}$$

$$\{\Phi_i\} = \frac{1}{\sqrt{S_i}} \{v_i\}. \tag{5}$$

S_i must be greater than zero for a consistent rigid body system.

b. Calculate using j = 1,2,...,i:

$$\alpha_j = \{\Phi_j\}^T [m_r] \{I_{i+1}\}. \quad (6)$$

c. The next vector is then:

$$\{v_{i+1}\} = \{I_{i+1}\} - \sum_{j=1}^{i} \alpha_j \{\Phi_j\} . \quad (7)$$

(Return to step b).

This procedure is a modification of the Schmidt orthogonalization procedure using the {I} vectors as a starting point. Since the $[m_r]$ matrix is non-singular, the {I} vectors are independent with respect to the matrix. Each new vector $\{I_{i+1}\}$ is made orthogonal with respect to the previous vectors by subtracting its scalar matrix products (α) with the other vectors. The matrix of resulting vectors $[\Phi_{ro}]$ should form a diagonal, unit matrix $[m_{ro}]$ with the equation:

$$[m_{ro}] = [\Phi_{ro}]^T [m_r] [\Phi_{ro}] . \quad (8)$$

The remaining displacements of the rigid body eigenvectors are formed from the equation

$$[\Phi_{\ell o}] = [D] [\Phi_{ro}], \quad (9)$$

where [D] corresponds to the data block DM.

Each column of $[\Phi_{ro}]$ is merged with $[\Phi_{\ell o}]$ using USET (UA,UL,UR).

4.48.8.2 Subroutine Name: READ2

1. Entry Points: READ2, READ5

2. Purpose: To compute the modal mass matrix [MI], to normalize the extracted eigenvalues, and to prepare the output files LAMA and ØEIGS.

3. Calling Sequence: CALL READ2 (MAA,PHIA,SCR1,NØRM,IA,USET,MI,LAMA,ØEIGS,SCR2,EPSI,SCR3)

CALL READ5 (IPØUT)

MAA,PHIA,USET,MI,LAMA,ØEIGS are the GINØ file numbers of their respective data blocks - integer - input.

SCR1,...,SCR3 are GINØ file number of 3 scratch files - integer - input.

NØRM - Normalization method requested.

- MAX - Implies maximum component.
- PØINT - Implies specified component.
- MASS - Implies unit modal mass matrix.

} Input - BCD

IA - If NØRM = PØINT, IA is the component number which is set to 1.0 - integer - input.

EPSI - If EPSI ≠ 0.0, the off-diagonal terms of the modal mass matrix [MI] are checked for the number which exceed EPSI.

CØMMØN /READ2A/Z(1)

Z(1) - Array of open core for READ2.

4.48.8.3 Subroutine Name: READ3

1. Entry Point: READ3

2. Purpose: To sort the eigenvalues in ascending order and to output the eigenvalues and eigenvectors in order. Also, to pack the eigenvectors in standard matrix format.

3. Calling Sequence: CALL READ3 (NØVECT,NCØL,SCR1,SCR2,PHI,LAMBDA)

NØVECT - Number of eigenvectors extracted - integer - input.

NCØL - Length of the vectors - integer - input.

SCR1 - GINØ file containing the unsorted eigenvalues - integer - input.

SCR2 - GINØ file containing the unsorted eigenvectors - integer - input.

PHI - GINØ file for the output sorted vectors - integers - input.

LAMBDA - GINØ file for the output sorted eigenvalues - integer - input.

CØMMØN /READ2A/Z(1)

Z(1) - Area of open core available to READ3.

4.48.8.4 Subroutine Name: READ4

1. Entry Point: READ4

2. Purpose: To test for close and equal roots found by the Determinant Method and make sure the corresponding vectors are orthogonal.

3. Calling Sequence: CALL READ4 (LAMAT,MPHIA,SCR1,EPSI,MAA)

LAMAT - GINØ file number of temporary storage file for the eigenvalues found - integer - input.

MPHIA - Matrix control block for PHIA - integer - input.

SCR1 - GINØ file number of a scratch file - integer - input.

EPSI - Close root test criteria - real - input.

MAA - GINØ file number of MAA - integer - input.

CØMMØN /READ2A/Z(1) - See READ2A

Z(1) - Array of open core for READ4.

4.48.8.5 Subroutine Name: ØRTCK

1. Entry Point: ØRTCK

2. Purpose: ØRTCK will generate the generalized mass matrix for the close roots and make the epsilon test to determine if the vectors should be orthogonalized.

3. Calling Sequence: CALL ØRTCK (X,MAA,BUFFER(1),NUM,NDIM,GM,ACCUM,EPSI)

X - Unorthogonalized eigenvectors - real - input/output.

MAA and EPSI are as described in READ4.

BUFFER - GINØ buffer.

NUM - Number of close roots - integer - input.

NDIM - Order of the problem - integer - input.

GM - Generalized mass for the close roots - real array - output.

ACCUM - Running sum of $[M_{aa}]$ $[\Phi_a]$ - real - input/output.

4.48.8.6 Subroutine Name: INVPWR

1. Entry Point: INVPWR

2. Purpose: INVPWR is the main driver for the Inverse Power Method of eigenvalue extraction.

3. Calling Sequence: CALL INVPWR

CØMMØN /INVPWX/K(7),M(7),LAM(7),PHI(7),SCRFIL(8),EIGSUM,LMIN,LMAX,NØEST,NDPLUS,NDMNUS, EPS,NØRTHØ

K,M - Matrix control blocks for the input stiffness and mass matrices, [K] and [M].

LAM,PHI - Matrix control blocks for the output eigenvalue and eigenvector files.

SCRFIL(8) - GINØ file numbers for eight scratch files.

EIGSUM - GINØ file number for the eigenvalue summary file - integer.

LMIN-LMAX - Desired range for eigenvalues - real.

NØEST - Number of estimated eigenvalues in the range - integer.

NDPLUS - Number of desired positive eigenvalues - integer.

NDMNUS - Number of desired negative eigenvalues - integer.

EPS - Convergence criteria - real.

NØRTHØ - Number of roots extracted - integer.

CØMMØN /INVPX/Z(1)

Z(1) - Area of open core available to INVPWR.

4. Method: Reference can be made to the flow charts in Figure 1 for the program logic. Theoretical implications are handled in section 4.48.11 and in the Theoretical Manual.

4.48.8.7 Subroutine Name: INVP1

1. Entry Point: INVP1

2. Purpose: To set up a call to ADD to form

$$[A] = [K] - \lambda_o [M] \qquad (10)$$

3. Calling Sequence: CALL INVP1

CØMMØN /INVPWX/K(7),M(7),A

CØMMØN /INVPXX/LAMØ

CØMMØN /INVP1X/Z(1)

K,M - Matrix control blocks for the input matrices.

A - GINØ file number for the output matrix.

LAMØ - Double precision scalar multiplier.

Z(1) - Area of open core available to ADD.

4.48.8.8 Subroutine Name: INVP2

1. Entry Point: INVP2

2. Purpose: To initialize and call DECØMP for subroutine INVPWR.

3. Calling Sequence: CALL INVP2

CØMMØN /INVPWX/DUM(14),A(7),L(7),XX(2),U,SCR1,SCR2,SCR3,LL,UU

CØMMØN /INVPXX/DUMM(12),SWITCH

CØMMØN /INVP2X/Z(1)

A - GINØ file number of the input matrix - integer - input.

L,U - GINØ file number for the lower and upper triangular matrices output from DECØMP - integer - input.

SCR1, SCR2, SCR3 } - Three scratch files used by DECØMP - integer - input.

LL,UU - GINØ file numbers for alternate storage of L and U - integer - input.

SWITCH - 0 - Store output matrices in L and U. 1 - Store output matrices in LL and UU - integer - input.

Z(1) - Area of open core available for DECØMP.

4.48.8.9 Subroutine Name: INVP3

1. Entry Point: INVP3

2. Purpose: To solve for an eigenvalue and eigenvector using the Inverse Power Method.

3. Calling Sequence: CALL INVP3

CØMMØN /INVPWX/K(7),M(7),LAM(7),PHI(7),SCRFIL(8),EIGSUM,LMIN,LMAX,NØEST,NDPLUS,NDMNUS,EPS

CØMMØN /INVP3X/Z(1)

See INVPWR for a description of /INVPWX/(section 4.48.8.6).

Z(1) - Open core for INVP3.

4. Method: The logic flow of INVP3 is given in Figure 1 with the mathematical equations supplied in 4.48.11. Theoretical considerations are given in the Theoretical Manual.

INVP3 was designed with two aspects in mind: first to assure that all roots within a given region are found, and second to avoid any possibility of looping uncontrollably. To accomplish these ends, considerable testing was inserted around the mathematical equations.

5. Design Requirements: INVP3 needs sufficient storage to hold seven double precision a set vectors and four GINØ buffers in core.

4.48.8.10 Subroutine Name: NØRM1

1. Entry Point: NØRM1

2. Purpose: To normalize a vector {x} such that its maximum component is one.

3. Calling Sequence: CALL NØRM1 (X,DIV)

CØMMØN /INVPWX/XX,N

N - Length of the double precision vector {x}.

X - Double precision vector {x}.

DIV - Double precision value of the divisor used to normalize {x}- output.

4.48.8.11 Subroutine Name: MTIMSU

1. Entry Point: MTIMSU

2. Purpose: To pre-multiply a vector by a matrix i.e.,:

$$\{x\} = [M]\{y\}. \qquad (11)$$

3. Calling Sequence: CALL MTIMSU (Y,X,BUF) (BUF is not used)

CØMMØN /INVPWX/DUM(7),M(7)

CØMMØN /INVPXX/DUMM(13),NZERØ

M - Matrix control block for matrix [M].

X,Y - Double precision left and right hand side vectors.

BUF - GINØ buffer.

NZERØ - Number of zero columns of matrix [M].

4.48.8.12 Subroutine Name: XTRNSY

1. Entry Point: XTRNSY

2. Purpose: To form the dot product of two vectors

$$a = \{x\}^T \{y\}. \tag{12}$$

3. Calling Sequence: CALL XTRNSY (X,Y,A)

CØMMØN /INVPWX/XX,N

N - Length of vectors {x} and {y}.

X,Y - Double precision vectors.

A - Double precision value of the dot product.

4.48.8.13 Subroutine Name: SUB

1. Entry Point: SUB

2. Purpose: To evaluate the vector equation

$$\{z\} = a\{x\} - b\{y\}. \tag{13}$$

3. Calling Sequence: CALL SUB (X,Y,A,B)

CØMMØN /INVPWX/XX,N

N - Length of the vectors {x} and {y}.

X,Y - Double precision vectors in the above equation. Y, upon return from SUB, contains the difference vector {z}.

A,B - Double precision scalar multipliers.

4.48.8.14 Subroutine Name: INVFBS (or INVFSP)

1. Entry Point: INVFBS (or INVFSP)

2. Purpose: INVFBS will perform the forward-backward substitution necessary to solve one iteration of the Inverse Power Method given by

$$([K] - \lambda_o [M])\{W_n\} = [M]\{u_{n-1}\}. \qquad (14)$$

3. Calling Sequence: CALL INVFBS (X,Y,BUF)

CØMMØN /INFBSX/L(7),U(7)

L,U - Matrix control blocks for the lower and upper triangular matrices generated by decomposition of $([K] - \lambda_o [M])$.

X - Double precision right hand vector, $[M]\{u_{n-1}\}$.

Y - Double precision solution vector, $\{W_n\}$.

BUF - GINØ buffer.

4. Method: INVFBS is a stripped down version of GFBS. Both vectors are stored in core. Real, double-precision arithmetic is used for INVFBS and real, single-precision arithmetic is used for INVFSP.

4.48.8.15 Subroutine Name: DETM

1. Entry Point: DETM

2. Purpose: To supervise the operations of the Determinant Method.

3. Calling Sequence: CALL DETM

All determinant routines use common blocks /REGEAN/ and /DETMX/.

CØMMØN /REGEAN/IM(7),IK(7),IEV(7),SCR1,SCR2,SCR3,SCR4,SCR5,LCØRE,RMAX,RMIN,MZ,NEV,EPSI, RMINR,NE,NIT,NEVM,SCR6,SCR7,NFØUND,LAMA,IBUCK,NSYM

IM(7) - Matrix control block for MAA.

IK(7) - Matrix control block for KAA.

IEV(7) - Matrix control block for the eigenvectors.

SCR1,...,SCR7 - GINØ file number of 7 scratch files - integer - input.

SCR1 - Contains [KAA] - λ[MAA].

SCR2 - Contains [LLL].

SCR3 - Contains [ULL].

LCØRE - Amount of open core reserved for starting points, determinants, scale factors and accepted eigenvalues - integer - input.

RMAX - Maximum eigenvalue of interest - real - input/output.

RMIN - Minimum eigenvalue of interest - real - input.

MZ - Number of zero eigenvalues - integer - input.

NEV - Number of estimated eigenvalues in the range of interest - integer - input.

EPSI - Convergence criteria - real - input/output. EPSI = 1.0×10^{-11} currently.

RMINR - Lower boundary to search region. (RMINR = -.01*RMIN)
For buckling problems a pole of geometrically increasing order is placed at RMINR each time the search procedure points below RMIN - real - input.

NE - Number of changes in the convergence criteria - integer - input. NE is currently set at 4.

NIT - Number of iterations allowed to converge to an eigenvalue. NIT is currently set to 20 - integer - input.

NEVM - Number of eigenvalues desired - integer - input.

NFØUND - Number of eigenvalues found - integer - output.

LAMA - GINØ file number of eigenvalue storage file - integer - input.

IBUCK - Buckling flag. If IBUCK = 3, the current problem is a Buckling Analysis problem - integer - input.

NSYM - Symmetric determinant flag. If NSYM = 1, symmetric decomposition is used to compute the determinant of A - integer - input.

CØMMØN/DETMX/P(4),DETX(4),PS1(4),DET1(4),N2EV,IPSAV,IPS,IDET,IPDETA,PREC,NSTART,NDCMP,IC,NSMØVE, ITERM,IS,ND,IADD,SML1,IPDETX(4),IPDET1(4),IFAIL,K,FACT1,IFFND,NFAIL,NPØLE,ISNG

P - The 3 trial values of the eigenvalue - double precision - input/output.

DETX - The determinants of the 3 P's above - double precision - input/output.

PS1 - The 3 current starting points - double precision - input/output.

DET1 - The determinants of the 3 starting points - double precision - input/output.

N2EV - The number of starting points - integer - input.

IPSAV - Pointer to the accepted eigenvalues - integer - input.

IPS - Pointer to the starting points - integer - input.

IDET - Pointer to the determinants of the starting points - integer - input.

IPDETA - Pointer to the scale factors of the determinants - integer - input.

PREC - Precision of the calculations - integer - input.

NSTART - Number of passes through the starting points - integer - output.

NDCMP - Total number of decompositions - integer - output.

IC - Total number of convergence criteria changes - integer - output.

NSMØVE - Number of starting point moves - integer - output.

ITERM - Reason for termination - integer - output.

IS - Start set counter - integer - input/output.

ND - Number of new starting points to evaluate - integer - input.

IADD - Pointer to next starting point to evaluate - integer - input/output.

SML1 - Magnitude of smallest diagonal element of [ULL] - real - output.

IPDETX - Scale factors for the determinants in DETX - integer - input/output.

IPDET1 - Scale factors for the determinants in DET1 - integer - input/output.

IFAIL - If this set of starting points produced a failure to iterate to a root, IFAIL = 1 - integer - input/output.

K - Current iteration counter - integer - input.

FACT1 - Constant = EPSI*SQRT(RMAX) - real - input/output.

IFFND - If an eigenvalue is accepted on a given pass through the starting points, IFFND = 1 - integer - input/output.

NFAIL - Number of failures to iterate to a root - integer - output.

NPØLE - Order of the current pole at RMINR - integer - input/output.

ISNG - Number of singular matrices detected during decomposition - integer - input/output.

CØMMØN/DETDX/DZ(1)

DZ(1) - Array of open core for DETM.

4. Method: The general method used for the Determinant Method is described in section 4.88.

5. Design Requirements: DETM needs sufficient open core to hold two double precision a set vectors and one GINØ buffer. Open core at /DETDX/ is used for storage of starting points, determinants, powers and accepted eigenvalues.

4.48.8.16 Subroutine Name: DETM1

1. Entry Point: DETM1

2. Purpose: To compute the locations of the starting points.

3. Calling Sequence: CALL DETM1 ($n)

n - The statement number to which DETM1 will return if the first three starting points yield a singular matrix.

4.48.8.17 Subroutine Name: DETM2

1. Entry Point: DETM2
2. Purpose: To evaluate the determinant of ND starting points.
3. Calling Sequence: CALL DETM2

4.48.8.18 Subroutine Name: DETM3

1. Entry Point: DETM3
2. Purpose: To iterate for an eigenvalue.
3. Calling Sequence: CALL DETM3 (n_1,n_2,n_3)

n_1 - Return for a new starting point.

n_2 - Return for a new pass through the starting points.

n_3 - Return for problem time expired.

4.48.8.19 Subroutine Name: DETM4

1. Entry Point: DETM4
2. Purpose: To move any starting points necessary.
3. Calling Sequence: CALL DETM4

4.48.8.20 Subroutine Name: DETM5

1. Entry Point: DETM5
2. Purpose: To write out the eigenvalue analysis summary for the determinant method.
3. Calling Sequence: CALL DETM5.

4.48.8.21 Subroutine Name: DETM6

1. Entry Point: DETM6

2. Purpose: To rescale any number by powers of 10.

3. Calling Sequence: CALL DETM6 (D,PØWER)

The arguments are both input and output to the routine and are defined by the following equation.

$$D_{out} \times 10^{PØWER_{out}} = D_{in} \times 10^{PØWER_{in}}, \tag{15}$$

$$.1 \leq |D_{out}| \leq 10 . \tag{16}$$

D is double precision and PØWER is integer.

4.48.8.22 Subroutine Name: FDVECT

1. Entry Point: FDVECT

2. Purpose: To build the load vector to solve for an eigenvector.

3. Calling Sequence: CALL FDVECT (SML1,PK)

SML1 - Smallest diagonal term of [ULL] - real - input.

PK - Accepted eigenvalue - double precision - input.

4.48.8.23 Subroutine Name: EADD

1. Entry Point: EADD

2. Purpose: To compute [A] = [KAA] - p[MAA].

3. Calling Sequence: CALL EADD (P,PREC)

P - Trial value for one eigenvalue - double precision - input.

PREC - "2" - integer - input.

4.48.8.24 Subroutine Name: DETDET

1. Entry Point: DETDET

2. Purpose: To compute the swept determinant of [A].

3. Calling Sequence: CALL DETDET (DETA,IPØWR,P,SML1,ØLDD,IPRØLD)

DETA - Swept determinant of [A] - double precision - output.

IPØWR - Scale factor of DETA - integer - output.

P - Value of p used in computing [A] - double precision - input.

SML1 - Value of smallest diagonal term of [ULL] - real - output.

ØLDD - Swept determinant of previous value of p - double precision - input.

IPRØLD - Scale factor of ØLDD - integer - input.

4.48.8.25 Subroutine Name: ARRM

1. Entry Point: ARRM

2. Purpose: To arrange three starting points in order by the magnitude of their scaled determinants.

3. Calling Sequence: CALL ARRM (P,D,ND)

P - Array of 3 starting points - double precision - input/output.

D - Array of 3 determinants at P - double precision - input/output.

ND - Array of 3 scale factors of D - integer - input/output.

4.48.8.26 Subroutine Name: SUMM

1. Entry Point: SUMM

2. Purpose: To add two scaled numbers together.

3. Calling Sequence: CALL SUMM (SUM,ISUM,T1,IT1,T2,IT2,N)

The arguments are defined by the following equation:

$$SUM \times 10^{ISUM} = T1 \times 10^{IT1} \pm T2 \times 10^{IT2} . \qquad (17)$$

If N = 1, the minus sign is used, otherwise the positive sign is used.

SUM, T1, T2 are double precision.

N, IT1, ISUM, IT2 are integers.

4.48.8.27 Subroutine Name: SQRTM

1. Entry Point: SQRTM

2. Purpose: To compute the square root of a scaled number.

3. Calling Sequence: CALL SQRTM (A,IA,B,IB)

The arguments are defined by the following equation:

$$A \times 10^{IA} = \sqrt{B \times 10^{IB}}$$

A and B are double precision.

IA and IB are integers.

4.48.8.28 Subroutine Name: DETFBS

1. Entry Point: DETFBS

2. Purpose: To solve for the eigenvector.

3. Calling Sequence: CALL DETFBS (F,X,BUFFER,FU,NRØW)

F - Array containing the load vector {F} - double precision - input.

X - Array containing the eigenvector - double precision - output.

BUFFER - GINØ buffer.

FU - Matrix control block for [ULL] - integer - input.

NRØW - Order of the problem (length of F and X) - integer - input.

4.48.8.29 Subroutine Name: VALVEC

1. Entry Point: VALVEC

2. Purpose: To extract the eigenvalues and eigenvectors of a symmetric matrix.

3. Calling Sequence: CALL VALVEC

CØMMØN /GIVN/X1,MØ,MD,MR1,M1,M2,M3,M4,X9(3),RSTRT,X18(82),N,LFREQ,ØRDER,Y4,HFREQ,LAMA,NV,
X8(2),NFØUND,ØEIGS,PHIA,NVER,NEVER,MAX,ITERM

CØMMØN /XXVLVC/Z(1)

/GIVN/ is used by all Givens routines.

MØ - GINØ file number of the input matrix - integer - input.

MD, MR1, M1, M2, M3, M4 - GINØ file numbers of scratch files - integer - input.

RSTRT - '0' indicates no restart is being made - integer - input.

N - Order of the problem - integer - output.

LFREQ, HFREQ - Frequency range for computation of eigenvectors - real - input.

ØRDER - Eigenvalue sort order flag - integer - input.

LAMA, ØEIGS, PHIA - GINØ file name of the associated data blocks - integer - input.

NV - Number of eigenvectors to compute - integer - input.

NFØUND - Number of rigid body modes previously found - integer - input.

NVER - Number of fails to converge on eigenvectors - integer - output.

NEVER - Number of fails to converge on eigenvalues - integer - output.

MAX - Maximum number of QR iterations allowed - integer - input.

ITER - Reason for termination - integer - input.

Z - Open core for VALVEC.

X1, X9, X18, YY, X8 are dummy variables and are not currently used.

4.48.8.30 Subroutine Name: SMLEIG

1. Entry Point: SMLEIG

2. Purpose: To compute the eigenvalues for a 1 by 1 and 2 by 2 matrix and the eigenvector for a 1 by 1 matrix.

3. Calling Sequence: CALL SMLEIG (D,Ø,VAL)

D - Array of diagonal values - double precision - output.

Ø - Array of off-diagonal values - double precision - output.

VAL - Array of eigenvalues - double precision - output.

4.48.8.31 Subroutine TRIDI

1. Entry Point: TRIDI

2. Purpose: To tridiagonalize a symmetric matrix.

3. Calling Sequence: CALL TRIDI (D,Ø,C,A,B,AA)

D - Diagonal terms of the tridiagonal matrix - double precision - output.

Ø - Off diagonal terms of the triadiagonal matrix - double precision - output.

C - Scratch array which contains another copy of the diagonal terms at the conclusion of TRIDI - double precision - output.

A - Remainder of core - double precision - scratch.

B - Scratch array which contains the square of the off-diagonal terms - double precision - output.

AA - Remainder of core - single precision - scratch.

4.48.8.32 Subroutine Name: SICØX

1. Entry Point: SICØX

2. Purpose: To initialize the arrays in SICAS. See section 4.48.8.33.

3. Calling Sequence: CALL SICØX (D,Ø,CØS)

D - Array of diagonal values - double precision - input/output.

Ø - Array of off-diagonal values - double precision - input.

CØS - Array of cosine rotation factors - double precision - input/output.

4.48.8.33 Subroutine Name: SICØX (D,Ø,CØS)

1. Entry Point: SINCAS

2. Purpose: To compute the rotation factors for a given row.

3. Calling Sequence: CALL SINCAS (RØW,FLAG)

RØW - The number of the current row to rotate - integer - input.

FLAG - If no rotations are required for this row, FLAG = 0. Otherwise, FLAG = 1 - integer - input.

4.48.8.34 Subroutine Name: RØTAX

1. Entry Point: RØTAX

2. Purpose: To initialize the arrays in RØTATE. See section 4.48.8.35.

3. Calling Sequence: CALL RØTAX (Ø,SIN,CØS)

Ø - Array of off-diagonal values - double precision - input/output.

SIN - Array of sine rotation factors - double precision - input.

CØS - Array of cosine rotation factors - input.

4.48.8.35 Subroutine Name: RØTAX

1. Entry Point: RØTATE

2. Purpose: To rotate as much of the matrix as fits into core.

3. Calling Sequence: CALL RØTATE (A,RØW,RØW1,RØW2)

A - Partition of the matrix held in core - double precision - input.

RØW -- The row number of current rotation row - integer - input.

RØW1 - The row number of the first row of the matrix partition in core - integer - input.

RØW2 - The row number of the last row of the matrix partition in core - integer - input.

4.48.8.36 Subroutine Name: EMPCØR

1. Entry Point: EMPCØR

2. Purpose: To empty core of a triangular matrix partition.

3. Calling Sequence: CALL EMPCØR (MT1,MT2,PT,PC,FRSRØW,MIDRØW,LASRØW,NX,A,Z)

MT1 - GINØ file name of the first output file - integer - input.

MT2 - GINØ file name of the second output file - integer - input.

PT - Precision (1 = single precision, 2 = double precision) of the input matrix - integer - input.

PC - Precision (1 = single precision, 2 = double precision) of the output matrix - integer - input.

FRSRØW - The row number of the first row in core - integer - input.

MIDRØW - When the current row is greater than MIDRØW, write the remainder of the matrix

onto MT2 - integer - input.

LASRØW - The row number of the last row in core - integer - input.

NX - Order of the matrix - integer - input.

A - Storage containing the triangular matrix - double precision - input.

Z - GINØ buffer - input.

4.48.8.37 Integer Function Name: FILCØR

1. Entry Point: FILCØR

2. Purpose: To fill core with a triangular matrix.

3. Calling Sequence: RØW = FILCØR (MT1,MT2,PC,FRSRØW,MIDRØW,NX,A,NZA,Z)

MT1 - GINØ file name of the first part of the matrix (up to MIDRØW) - integer - input.

MT2 - GINØ file name of the rest of the matrix - integer - input.

PC - Precision (1 = single precision, 2 = double precision) of the matrix in core - integer - input.

FRSRØW - The row number of the first row of the matrix to be read - integer - input.

MIDRØW - Breakpoint of the matrix - integer - input.

NX - Order of the matrix - integer - input.

A - Core storage to hold the matrix - integer - input.

NZA - Number of single precision words at A - integer - input.

Z - GINØ buffer - input.

RØW - The row number of the last row read into A - integer - output.

4.48.8.38 Subroutine Name: QRITER

1. Entry Point: QRITER

2. Purpose: To obtain the eigenvalues of a tridiagonal matrix by the Ortega - Kaiser QR iteration technique.

3. Calling Sequence: CALL QRITER (VAL,Ø,LØC,QR)

VAL - Diagonal terms of the tridiagonal matrix on input, reordered eigenvalues on return - double precision - input/output.

Ø -- Squares of the off-diagonal terms of the tridiagonal matrix. These are iteratively reduced to zero - double precision - input/output.

LØC - Array giving the order in which each eigenvalue is found - integer - output.

QR -- QR ≠ 0 implies that the eigenvalues already exit at VAL and this is an ordering call only - integer - input.

4.48.8.39 Subroutine Name: WILVEC

1. Entry Point: WILVEC

2. Purpose: To compute eigenvectors by the Wilkinson method.

3. Calling Sequence: CALL WILVEC (D,Ø,VAL,VLØC,V,F,P,Q,R,VEC,NX,SVEC)

D - Array of diagonal values - double precision - input.

Ø - Array of off-diagonal values - double precision - input.

VAL - Array of eigenvalues - double precision - input.

VLØC - Array of original ordering of eigenvalues - integer - input.

V,F,P,Q,R - Scratch arrays of length equal tc the order of the problem - double precision - input/output.

VEC - Array of core to store vectors - double precision - scratch.

NX - Not used

SVEC - Array of core to store vectors - single precision - scratch.

4.48.8.40 Subroutine Name: INVERT

1. Entry Point: INVERT

2. Purpose: To drive INVTR (see section 4.48.8.41) to compute the inverse of an upper or lower triangular matrix.

3. Calling Sequence: CALL INVERT (IA,IB,SCR1)

CØMMØN /INVTRX/Z(1)

IA - GINØ file name of an upper or lower triangular matrix - integer - input.

IB - GINØ file name of the inverse of the matrix on IA - integer - input.

SCR1 - GINØ file name of a scratch file - integer - input.

Z - Open core for INVERT.

4.48.8.41 Subroutine Name: INVTR

1. Entry Point: INVTR

2. Purpose: To invert a triangular matrix.

3. Calling Sequence: CALL INVTR (X,DX)

CØMMØN /INVTRX/FA(7),FB(7),SCRFIL,NX,PREC

X - Open core for INVTR - single precision - scratch.

DX - Open core for INVTR (same address as X) - double precision - scratch.

FA - Matrix control block for the input matrix - integer - input.

FB - Matrix control block for the output matrix - integer - input.

SCRFIL - GINØ file name of a scratch file - integer - input.

NX - Length in words of X - integer - input.

PREC - Precision (1 = single precision, 2 = double precision) of the computation - integer - input.

4.48.8.42 Subroutine Name: READ6

1. Entry Point: READ6

2. Purpose: To merge the rigid body eigenvectors with vectors computed by GIVENS.

3. Calling Sequence: CALL READ6 (IRBM,IMGIV,NR,IPHIA)

CØMMØN /READ6X/Z(1)

IRBM - GINØ file name for eigenvectors computed by READ1 - integer - input.

IMGIV - GINØ file name for eigenvectors computed by GIVENS - integer - input.

NR - Number of eigenvectors computed by READ1 - integer - input.

IPHIA - GINØ file name for merged eigenvectors - integer - input.

Z - Open core for READ6.

4.48.9 Design Requirements

Design requirements are peculiar to the method chosen. The appropriate subroutines should be consulted. Nine scratch files are used.

4.48.10 Diagnostic Messages

Messages output from READ are peculiar to the individual subroutine.

4.48.11 Mathematical Considerations for the Inverse Power Method

The algorithm for finding the eigenvalues and eigenvectors of

$$([K] - \lambda[M])\,[\Phi] = 0, \tag{19}$$

is given as follows.

1. The iteration algorithm is given by the following equations.

$$([K] - \lambda_o\,[M])\,\{W_n\} = [M]\,\{u_{n-1}\}\,, \tag{20}$$

$$\{\bar{u}_n\} = \frac{1}{C_n}\,\{W_n\}, \tag{21}$$

$$\{u_n\} = \{\bar{u}_n\} - \sum_i \left(\{\Phi_i\}^T\,[M]\,\{\bar{u}_n\}\right)\,\{\Phi_i\}\,, \tag{22}$$

where C_n is the absolute value of the maximum component of $\{W_n\}$. The sum over i extends over all previously extracted eigenvectors.

2. Form

$$\{F_n\} = [M]\,\{u_n\}. \tag{23}$$

3. Compute

$$\alpha_n = \left(\{u_n\}^T\,\{F_n\}\right)^{1/2}. \tag{24}$$

4. Compute

$$\{\delta u_n\} = \frac{\{u_n\}}{\alpha_n} - \frac{\{u_{n-1}\}}{\alpha_{n-1}}. \tag{25}$$

5. Compute

$$\{\delta F_n\} = [M]\,\{\delta u_n\}. \tag{26}$$

6. Compute the approximate eigenvalue

$$\lambda_1 = \frac{1}{C_n}\,\frac{\alpha_{n-1}}{\alpha_n}. \tag{27}$$

7. For the rapid convergence test, compute

$$\eta = (\{\delta u_n\}^T \{\delta F_n\})^{1/2}. \tag{28}$$

8. For normal convergence, compute

$$\frac{\lambda_2}{\lambda_1} = \frac{\{\delta u_n\}^T \{\delta F_{n-1}\}}{\eta^2}, \tag{29}$$

and

$$\delta_n = (\{\delta u_n\}^T \{\delta F_n\}) / (1 - \frac{\lambda_2}{\lambda_1})^2. \tag{30}$$

9. For the shift decision test, compute

$$h_{1,n} = \frac{\lambda_{1,n} - \lambda_{1,n-1}}{R_o}, \tag{31}$$

and

$$k = \frac{\log_{10}\left(\frac{\sqrt{\delta_n}}{A\varepsilon}\right)}{\log_{10}(\lambda_2/\lambda_1)}. \tag{32}$$

10. For the λ_2 reliability test, compute

$$h_{2,n} = \frac{\lambda_{2,n} - \lambda_{2,n-1}}{R_o} \tag{33}$$

The above equations, along with the proper logic given in Figure 1 form the basis for the Inverse Power Method.

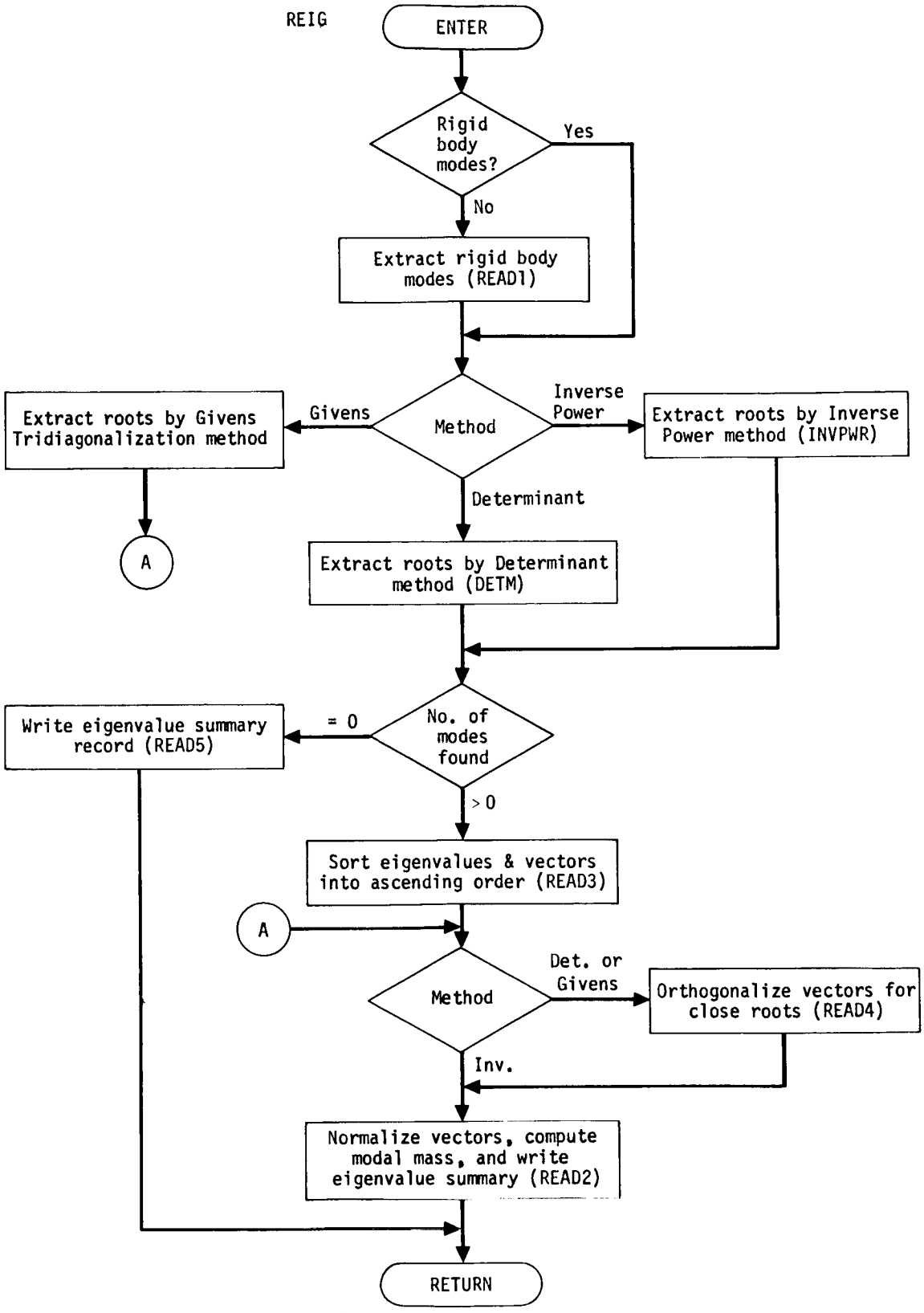


Figure 1.(a) Flowchart for module READ.

FUNCTIONAL MODULE READ (REAL EIGENVALUE ANALYSIS - DISPLACEMENT)

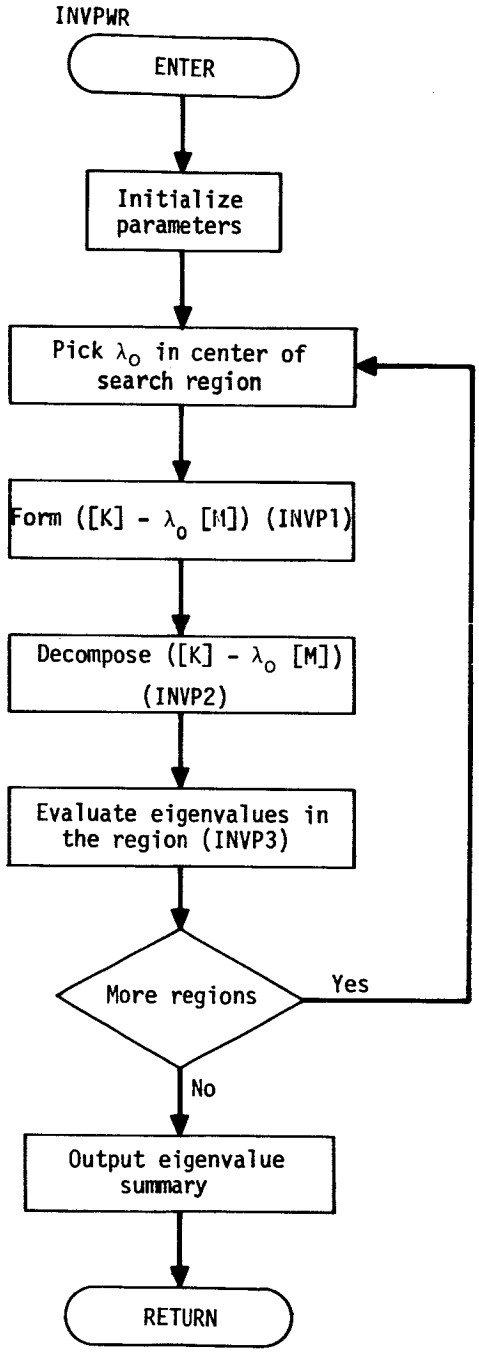


Figure 1.(b) Flowchart for module READ

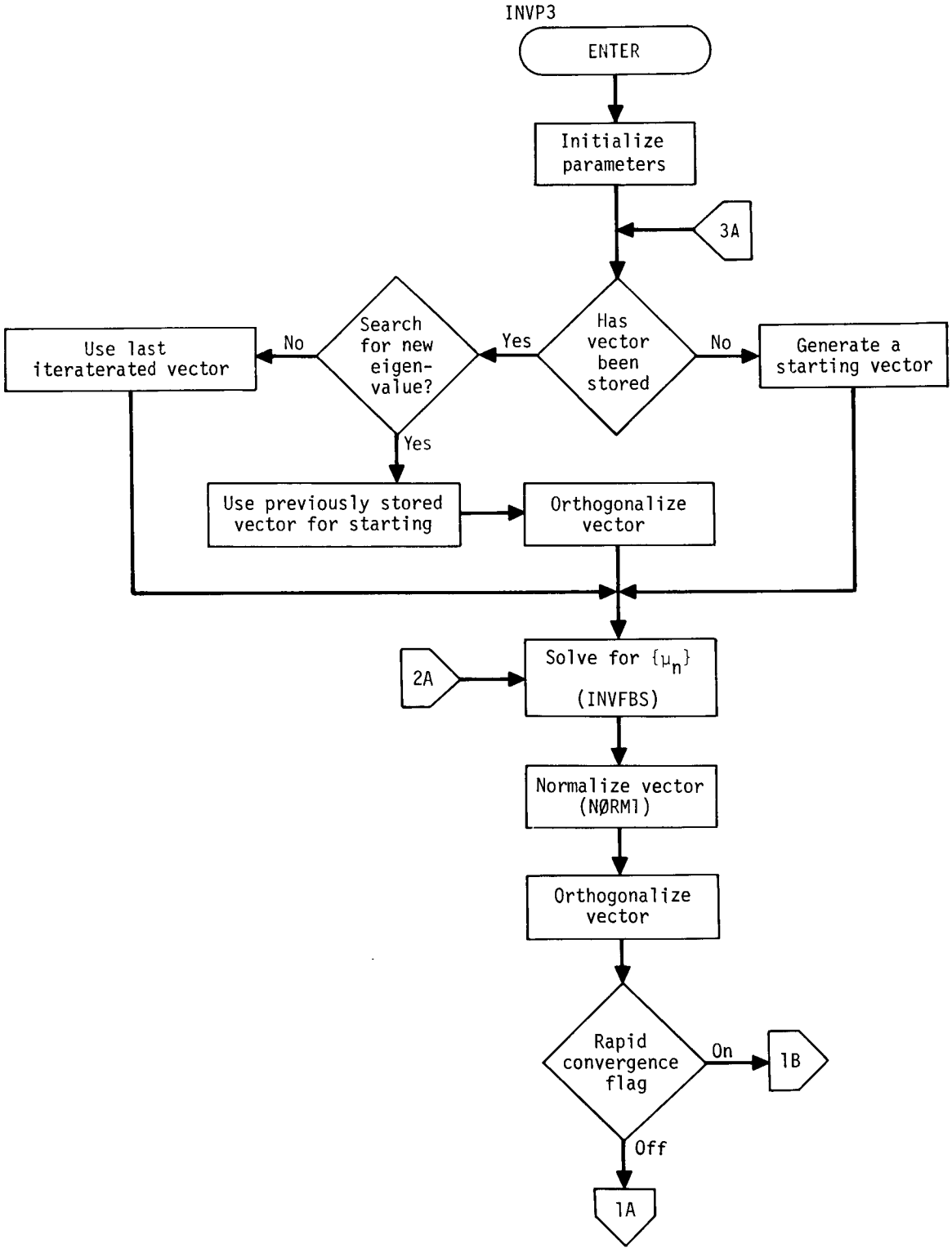


Figure 1.(c) Flowchart for module READ

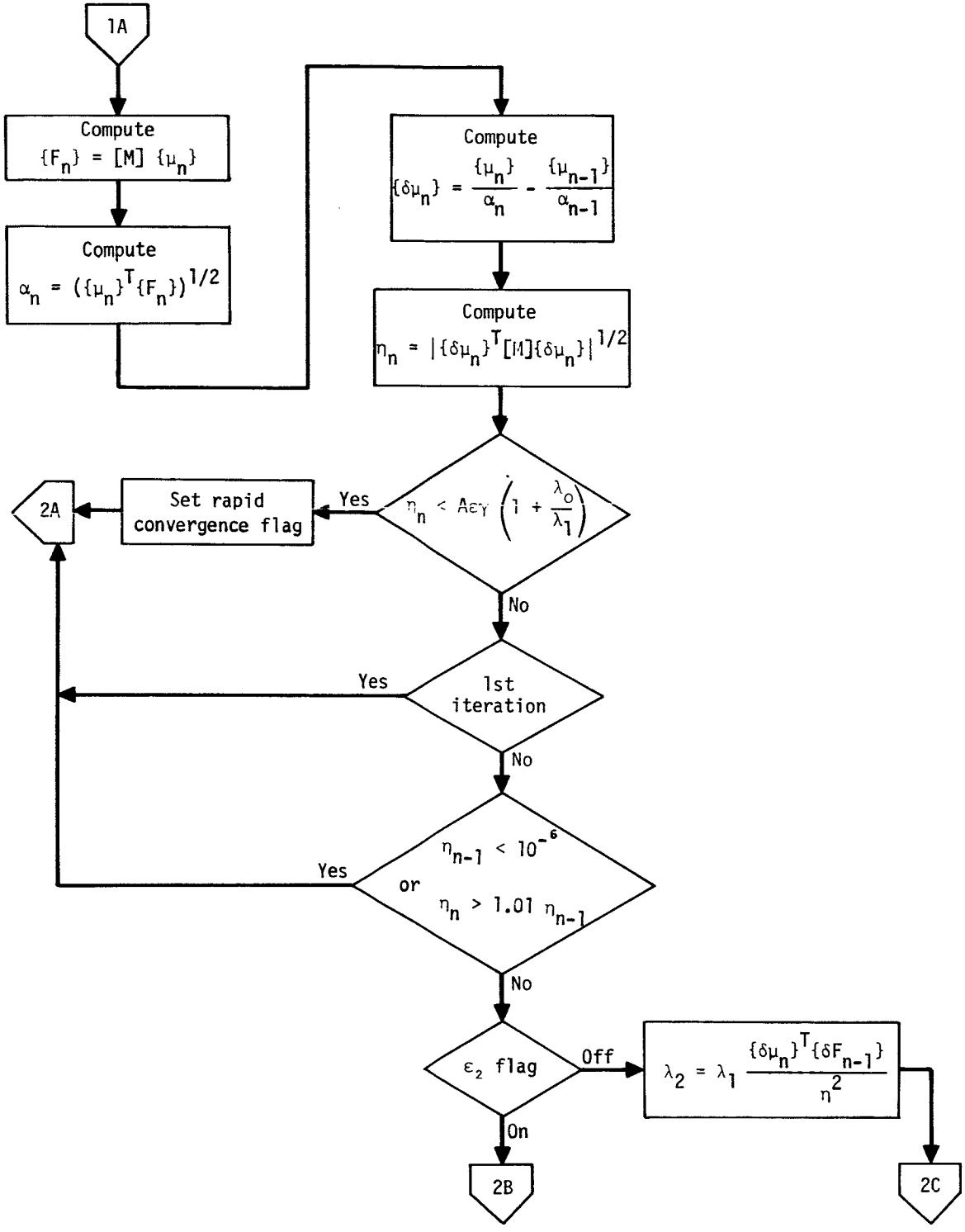


Figure 1.(d) Flowchart for module READ

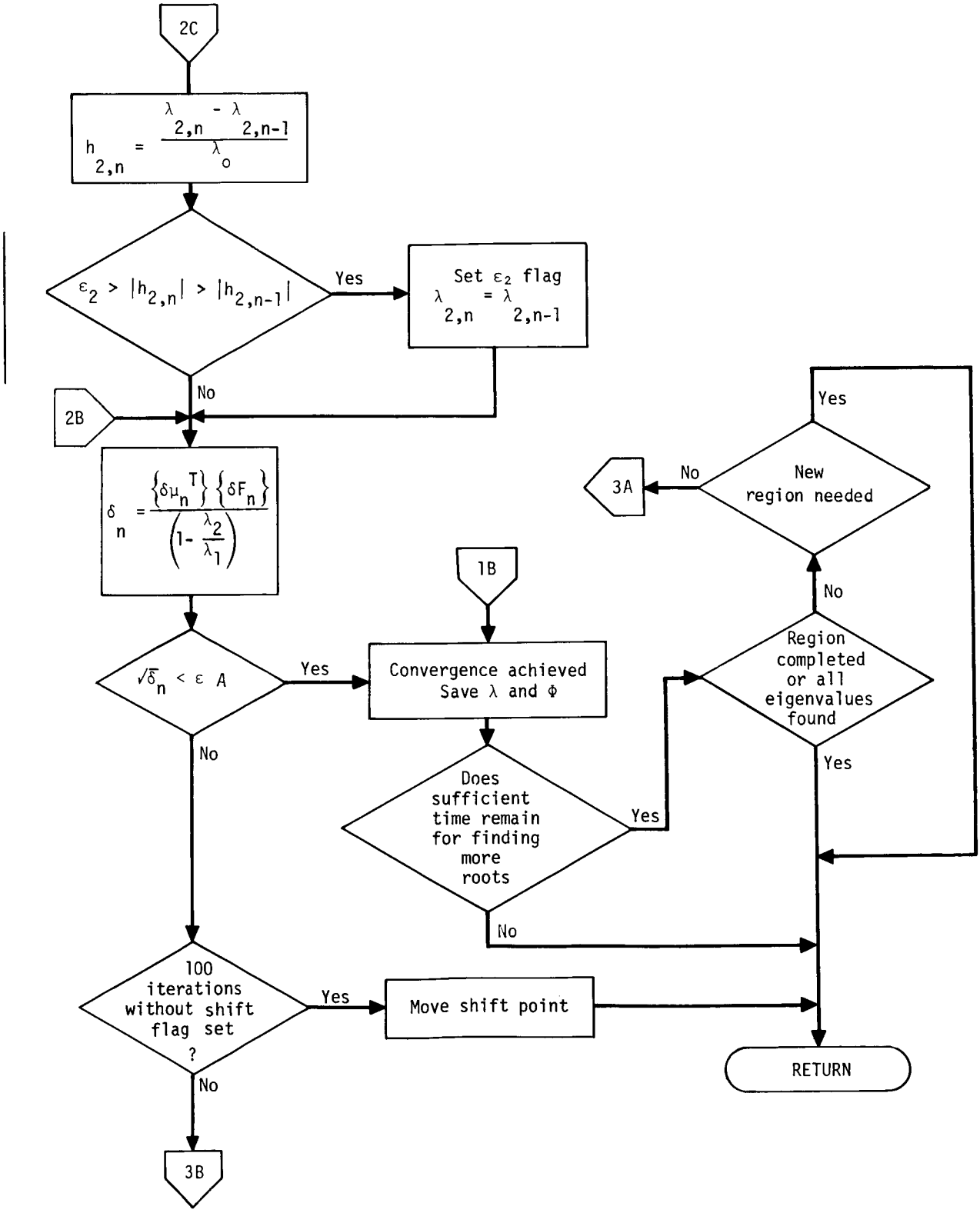


Figure 1.(e) Flowchart for module READ.

FUNCTIONAL MODULE READ (REAL EIGENVALUE ANALYSIS - DISPLACEMENT)

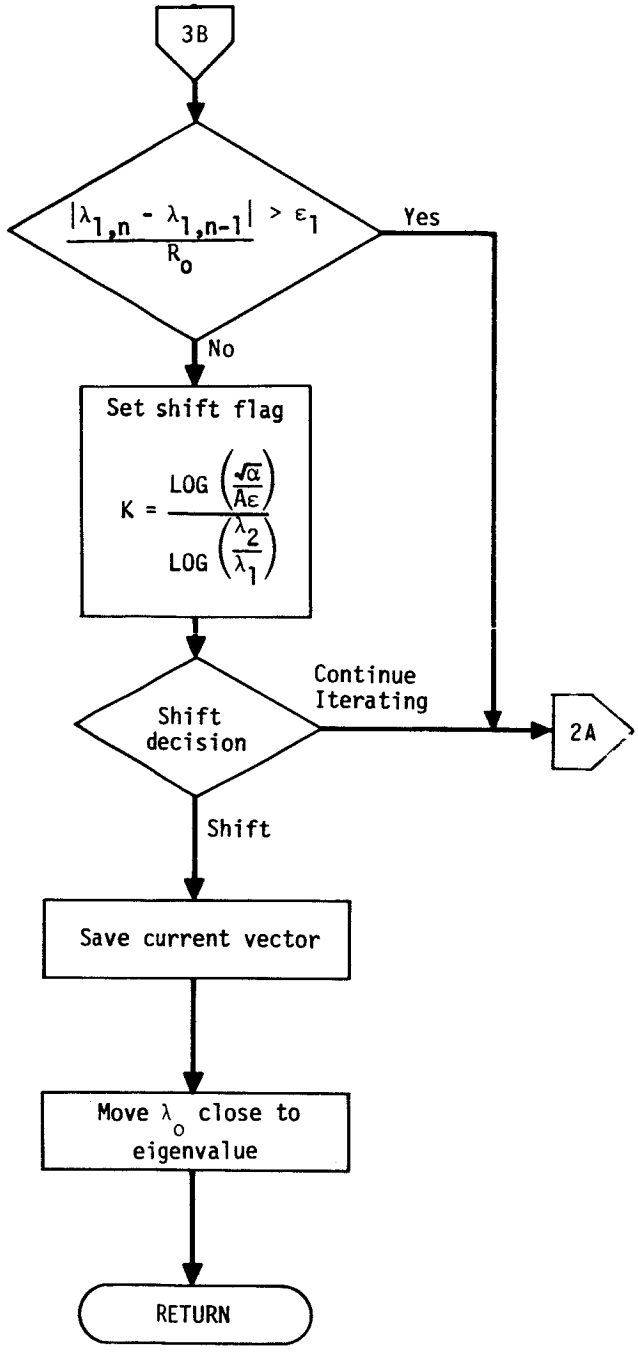


Figure 1.(f) Flowchart for module READ

4.49 FUNCTIONAL MODULE DSMG1 (DIFFERENTIAL STIFFNESS MATRIX GENERATOR - PHASE 1)

4.49.1 Entry Point: DSMG1

4.49.2 Purpose

To generate the differential stiffness matrix, $[K^{d}_{gg}]$, which is used in two Rigid Formats: Static Analysis with Differential Stiffness and Buckling Analysis.

4.49.3 DMAP Calling Sequence

```
DSMG1     CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/V,N,DSCØSET    $
```

4.49.4 Input Data Blocks

CASECC - Case Control Data Table.

GPTT - Grid Point Temperature Table.

SIL - Scalar Index List.

EDT - Element Deformation Table.

UGV - Initial Approximation to the Displacement Vector - g set.

CSTM - Coordinate System Transformation Matrices.

MPT - Material Properties Table.

ECPT - Element Connection and Properties Table.

GPCT - Grid Point Connection Table.

DIT - Direct Input Tables.

Notes:

1. A fatal error exists if CASECC is purged.
2. A fatal error exists if there is a temperature load and the GPTT is purged.
3. A fatal error exists if there is a temperature load and the SIL is purged.
4. A fatal error exists if an element deformation set is requested by the user in case control and EDT is purged.
5. A fatal error exists if UGV is purged.
6. CSTM can be purged. However, if some grid point of the model is not in basic coordinates and the CSTM is purged, a fatal error occurs.

7. If the MPT is purged and some element references a material property, a fatal error occurs.

8. A fatal error occurs if the ECPT is purged.

9. A fatal error occurs if the GPCT is purged.

10. If some material property is temperature dependent, DIT cannot be purged.

4.49.5 Output Data Blocks

KDGG - Partition of differential stiffness matrix - g set.

Note: KDGG cannot be pre-purged. A fatal error occurs if it is.

4.49.6 Parameters

DSCØSET - Output-integer-no default value. The set identification number of a DSFACT bulk data card chosen by the user in his Case Control Deck. If no such set was specified by the user, DSCØSET is set to -1.

4.49.7 Method

The module driver, DSMG1, is a very short routine whose only function is to call the two principal subroutines of the module, DS1 and DS1A, which accomplish the two phases of the module. The first phase of the module is incorporated in subroutine DS1. This routine creates the scratch file ECPTDS (GINØ file number 301) by appending to each element in the ECPT data block for which differential stiffness is defined an element deformation, an average element loading temperature for all elements except the conical shell element (a loading temperature at each grid point is appended for the conical shell element) and the proper components of the displacement vector, UGV. It should be noted that although element deformations are defined only for rods, tubes, beams, and bars, an element deformation is attached to each element written on the ECPTDS scratch data block. The elements admissible to the ECPTDS scratch data block are: rods, beams, tubes, shear (but not twist) panels, triangular and quadrilateral elements (TRMEM's and QDMEM's), the combination membrane and plate triangular and quadrilateral elements (TRIA1, TRIA2, QUAD1, QUAD2) and the conical shell element.

The flow of DS1 is given in the following steps:

1. The length of variable core is determined, buffers are defined at the bottom of open

core, and zero pointers to, and lengths of, subarrays in open core are initialized.

2. The Case Control data block, CASECC, is read to determine the element deformation set number, the loading temperature set number, and the differential stiffness coefficient set number.

3. If there is no temperature load, go to step 4. If there is a temperature load, the Grid Point Temperature Table data block, GPTT, is read such that the proper temperature set is read into open core. The Scalar Index List data block, SIL, is read into open core, and the internal grid point numbers in the GPTT are replaced with the corresponding SIL numbers.

4. If a non-zero element deformation set number was read from CASECC, the element deformation set is read into open core.

5. The first (and only) record of the displacement vector file, UGV, is read into open core, and then the ECPTDS and ECPT files are opened and positioned correctly.

6. The ECPT data block is read record by record, and the ECPTDS scratch data block is generated for use by subroutine DS1A. The procedure for each record is as follows. The pivot point is read. For each element in the current ECPT record, it is determined if the element type is admissible to the ECPTDS data block. If is not admissible, the next element entry is read; if it is admissible, a test is made to determine if the element type is a TRIA1, QUAD1 or conical shell element. If it is a TRIA1, QUAD1 or a conical shell element and if this element has zero membrane thickness (which implies the element has bending properties only) and since differential stiffness is not defined for plate elements, then the next element entry is read from the current ECPT record. When the first element of the ECPT record which belongs to the differential stiffness set is encountered, the pivot point is written on the ECPTDS data block. Note that if the element is a BAR, the ECPT entry is rearranged to conform with the ECPT entry for the BEAM so that the DBAR subroutine may be called in subroutine DS1A. The element type is written on the ECPTDS record. Then an element deformation number, an average element loading temperature (two loading temperatures for a conical shell element), and the displacement vector components are appended in core to the ECPT entry for the element. Finally this appended ECPT entry is written on ECPTDS. It should be noted that the 2nd through the $(n+1)^{st}$ words (n being the number of grid points of the element) of every ECPT entry, since they are scalar index numbers, are direct pointers

into the displacement vector, UGV. Note further that for elements for which differential stiffness is defined (save for the BAR, the BEAM and the conical shell element) only the three translational components of the displacement vector at each grid point are appended. For the BAR and BEAM all six displacement components at each grid point are appended. For the special case of the conical shell element, only the six displacement components at each grid point associated with the zeroth harmonic are appended.

When an end-of-record is sensed for an ECPT record, an indicator is interrogated to determine whether or not any of the elements in the record were written on the ECPTDS data block. If there weren't any, a -1 is written on ECPTDS with an end-of-record mark; if there was at least one element, an end-of-record is written on ECPTDS. In either case, after this step has been done, the next ECPT record is processed identically. When an end-of-file is sensed on the ECPT, the files for ECPT and ECPTDS are closed, and the routine returns to DSMG1.

The module driver, DSMG1, tests the argument of DS1. If it is equal to zero, this implies that no element of the ECPT was a member of the set of elements for which differential stiffness is defined, and hence a fatal error exit occurs. If the argument is greater than zero, subroutine DS1A is called.

In the second phase of the module, subroutine DS1A processes the scratch file ECPTDS to produce the differential stiffness matrix, $[K^{d}_{gg}]$. The logic of this processing is very similar to that used in subroutine SMA1A (of module SMA1, the stiffness matrix generation routine). See the Module Functional Description for SMA1 (section 4.27) for details.

4.49.8 Subroutines

All subroutines defined below except DS1 are necessary to accomplish the second phase of the module, which is the processing of the ECPTDS scratch file in order to generate $[K^d_{gg}]$. The auxiliary routines PRETRD, PREMAT, GMMATD and INVERD are used similarly to module SMA1.

The data (an ECPTDS entry) input to an element differential stiffness matrix generation routine (e.g., DRØD) are communicated to the routine via /DS1AET/, which fact is not expressly stated in the subroutine descriptions given below.

4.49.8.1 Subroutine Name: DS1

1. Entry Point: DS1

2. Purpose: See discussion above.

3. Calling Sequence: CALL DS1 (IARG)

IARG - Initially set to zero in subroutine DS1. This variable is set to 1 in DS1 every time an element in the ECPT is encountered which is in the set of elements for which differential stiffness is defined. If IARG is still zero upon DS1's return to DSMG1, DSMG1 will terminate the job by calling MESAGE and PEXIT.

4.49.8.2 Subroutine Name: DS1A

1. Entry Point: DS1A

2. Purpose: See discussion above.

3. Calling Sequence: CALL DS1A

4.49.8.3 Subroutine Name: DS1B

1. Entry Point: DS1B

2. Purpose: This routine, called by the module's element matrix generation routines such as DRØD, DBEAM, etc., adds a double precision 6 by 6 element differential stiffness matrix to the "submatrix" corresponding to the current pivot point. This same function is performed in module SMA1 by subroutine SMA1B, in SMA2 by SMA2B and in PLA4 by PLA4B.

3. Calling Sequence: CALL DS1B (KE,J)

KE - Row-stored double precision 6 by 6 matrix to be added to the "submatrix" corresponding to the current pivot point. Double precision; input.

J - The column index of the $[K^d_{gg}]$ matrix which corresponds to the first column of the KE matrix. Integer; input.

4.49.8.4 Block Data Subprogram Name: DS1ABD

1. Entry Point: DS1ABD

2. Purpose: This block data program sets 1) GINØ file numbers; 2) GINØ ØPEN, WRITE and CLØSE option parameters; 3) differential stiffness element routine (e.g., DRØD, DBAR) overlay parameters; and 4) an array which defines the number of words to be read for each element from the ECPTDS scratch file. The common block /DS1AAA/ is used for the second phase of the module.

4.49.8.5 Subroutine Name: DRØD

1. Entry Point: DRØD

2. Purpose: To generate the element differential stiffness matrix for a RØD, CØNRØD or TUBE element.

3. Calling Sequence: CALL DRØD

4.49.8.6 Subroutine Name: DBAR

1. Entry Point: DBAR

2. Purpose: To generate the element differential stiffness matrix for a BAR or BEAM element.

3. Calling Sequence: CALL DBAR

4.49.8.7 Subroutine Name: DSHEAR

1. Entry Point: DSHEAR

2. Purpose: To generate the element differential stiffness matrix for a SHEAR (panel) element.

3. Calling Sequence: CALL DSHEAR

4.49.8.8 Subroutine Name: DTRMEM

1. Entry Point: DTRMEM

2. Purpose: To generate the element differential stiffness matrix for a TRMEM element.

3. Calling Sequence: CALL DTRMEM (IARG)

IARG = { 0 = Called from DSGM1
1 = Called from DQDMEM
2 = Called from DTRIA
3 = Called from DQUAD

4.49.8.9 Subroutine Name: DQDMEM

1. Entry Point: DQDMEM

2. Purpose: To generate the element differential stiffness matrix for a QDMEM element.

3. Calling Sequence: CALL DQDMEM

4.49.8.10 Subroutine Name: DCØNE

1. Entry Point: DCØNE

2. Purpose: To generate the element differential stiffness matrix for a conical shell element.

3. Calling Sequence: CALL DCØNE

4.49.8.11 Subroutine Name: DTRIA (IARG)

1. Entry Point: DTRIA

2. Purpose: To generate the element differential stiffness matrix for a TRIA1 and TRIA2 element.

3. Calling Sequence: CALL DTRIA (IARG)

IARG = { 1 = TRIA1 element
2 = TRIA2 element

4.49.8.12 Subroutine Name: DQUAD (IARG)

1. Entry Point: DQUAD

2. Purpose: To generate the element differential stiffness matrix for a QUAD1 and QUAD2 element.

3. Calling Sequence: CALL DQUAD (IARG)

IARG = { 1 = QUAD1 element
       { 2 = QUAD2 element

4.49.8.13 Subroutine Name DTRBSC (IARG, NPIVØT)

1. Entry Point: DTRBSC

2. Purpose: Used by subroutines DTRIA and DQUAD to generate differential stiffness matrices for elementary triangles.

3. Calling Sequence: CALL DTRBSC (IARG, NPIVØT)

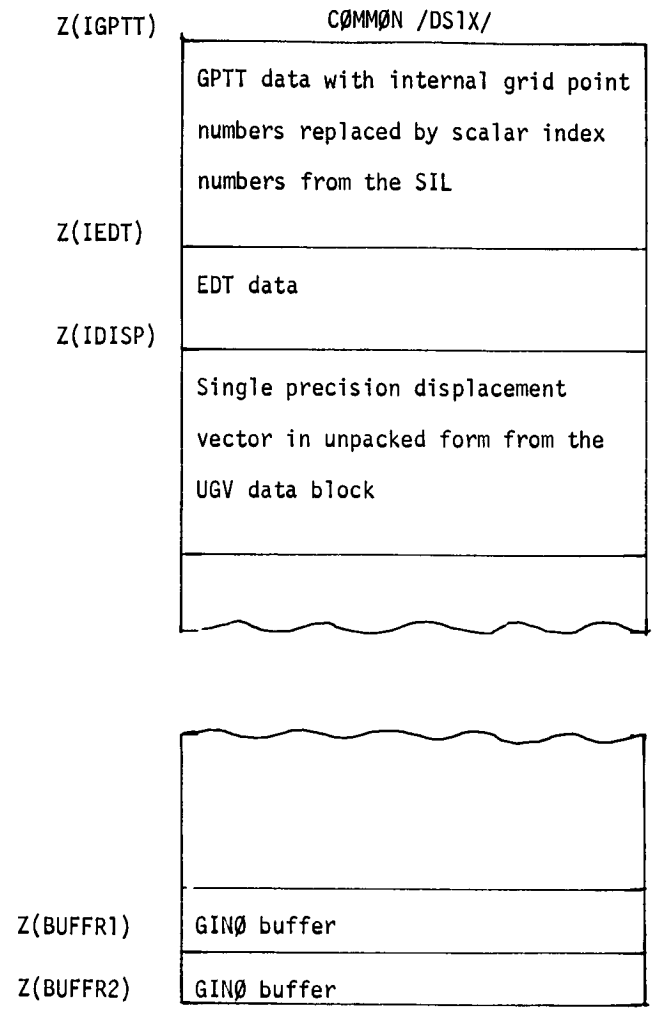
IARG = { 1 = Called from DTRIA
       { 2 = Called from DQUAD

NPIVØT = 0,1,2, or 3 = Point on triangle used as pivot point. (0 = no pivot)

4.49.9 Design Requirements

4.49.9.1 Open Core Design

During phase one of the module's operation, the maximum core storage requirements are given in the following diagram, in which open core, the Z array, is defined at /DS1X/.



During phase two of the module's operation, the open core design is the same as that for module SMA1, except that only 3 GINØ buffers are needed instead of 5, one for ECPTDS, one for GPCT and one for KDGG. Open core for phase two is defined at /DS1AXX/.

4.49.9.2 Common Storage Requirements

During phase one, there are no special common storage requirements.

During phase two, /DS1AAA/ takes the place of /SMA1IØ/, /SMA1BK/ and /SMA1CL/; /DS1AET/ corresponds to /SMA1ET/; and /DS1ADP/ corresponds to /SMA1DP/. See the common storage requirements section of the SMA1 Module Functional Description for details on /SMA1IØ/, /SMA1BK/, /SMA1CL/, /SMA1ET/ and /SMA1DP/ (section 4.27.9.3).

4.49.9.3 Arithmetic Considerations

All floating point arithmetic operations are carried out in double precision. $[K^{d}_{gg}]$ is a real double precision symmetric matrix.

4.49.10 Diagnostic Messages

During phase one the fatal messages 2029 and 2030 can be called if the GPTT is not in the proper format. If a BAR element is encountered whose coupled bending interia property, I_{12}, is non-zero, then it is set to zero and the user is warned of this fact with message 2111. User messages 2081 and 2083 are fatal messages indicating a null differential stiffness matrix and a null displacement vector respectively.

For phase two diagnostics, the reader is referred to the diagnostic message section of the Module Functional Description for SMA1.

4.50 FUNCTIONAL MODULE SMP2 (STRUCTURAL MATRIX PARTITIONER - PHASE 2)

4.50.1 Entry Point: SMP2

4.50.2 Purpose

To perform the following matrix operations:

$$[K^d_{ff}] \Longrightarrow \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline (K^d_{ao})^T & K^d_{oo} \end{array}\right], \tag{1}$$

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{ao}]\,[G_o] + ([K^d_{ao}]\,[G_o])^T + [G_o]^T\,[K^d_{oo}]\,[G_o]. \tag{2}$$

4.50.3 DMAP Calling Sequence

SMP2 USET,GØ,KDFF/KDAA/ $

4.50.4 Input Data Blocks

USET - Displacement set definitions table.

GØ - Structural matrix partitioning transformation matrix.

KDFF - Partition of differential stiffness matrix - f set.

4.50.5 Output Data Blocks

KDAA - Partition of differential stiffness matrix - a set.

4.50.6 Parameters

None

4.50.7 Method

The matrix $[K^d_{ff}]$ is partitioned as in Equation 1 using USET (UF,UA,UØ), and matrix subroutine ELIM (see section 3.5.22 for details) is called to perform the operations in Equation 2.

4.50.8 Subroutines

SMP2 has no auxiliary subroutine.

4.50.9 Design Requirements

See design requirements for subroutine UPART and its entry point MPART which perform the symmetric partition of Equation 1; also see design requirements for subroutine ELIM. These are in sections 3.5.9 and 3.5.22 respectively.

4.51 FUNCTIONAL MODULE DSMG2 (DIFFERENTIAL STIFFNESS MATRIX GENERATOR - PHASE 2).

4.51.1 Entry Point: DSMG2

4.51.2 Purpose

This module performs the following matrix operations:

$$[K^{b}_{\ell\ell}] = [K_{aa}] + \beta[K^{d}_{aa}] , \tag{1}$$

$$[K^{b}_{fs}] = [K_{fs}] + \beta[K^{d}_{fs}], \tag{2}$$

$$[K^{b}_{ss}] = [K_{ss}] + \beta[K^{d}_{ss}] , \tag{3}$$

$$\{P^{b}_{\ell}\} = \beta\{P_{\ell}\} , \tag{4}$$

$$\{P^{b}_{s}\} = \beta\{P_{s}\} , \tag{5}$$

$$\{Y^{b}_{s}\} = \beta\{Y_{s}\} , \tag{6}$$

$$\{u^{ob}_{o}\} = \beta\{u^{o}_{o}\} . \tag{7}$$

The value of β is on a DSFACT bulk data card whose set identification number is specified by the input parameter DSCØSET. The particular value on that card to be used for β on any pass through the DMAP loop in the Static Analysis with Differential Stiffness Rigid Format is controlled by the parameter NDSKIP (see below).

4.51.3 DMAP Calling Sequence

```
DSMG2    MPT,KAA,KDAA,KFS,KDFS,KSS,KDSS,PL,PS,YS,UØØV/KBLL,KBFS,KBSS,PBL,PBS,YBS,UBØØV/
         V,N,NDSKIP/V,N,REPEATD/V,N,DSCØSET  $
```

4.51.4 Input Data Blocks

MPT - Material Property Table.

KAA - Partition of stiffness matrix - a set.

KDAA - Partition of differential stiffness matrix - a set.

KFS - Partition of stiffness matrix after single-point constraints have been removed.

KDFS - Partition of differential stiffness matrix after single-point constraints have been removed.

KSS - Partition of stiffness matrix after single-point constraints have been removed - s set.

KDSS - Partition of differential stiffness matrix after single-point constraints have been removed - s set.

PL - Partition of the load vector matrix giving static loads on ℓ set.

PS - Partition of the load vector matrix giving loads in s set.

YS - Constrained displacement vector - s set.

UØØV - Partition of the displacement vector matrix giving displacements in the o set.

Notes:

1. A fatal error occurs if MPT is purged.
2. KAA and KDAA cannot be purged.
3. KFS and KDFS must be both purged or both non-purged.
4. KSS and KDSS must be both purged or both non-purged.
5. A fatal error occurs if PL is purged.
6. PS, YS and UØØV can be purged.

4.51.5 Output Data Blocks

KBLL - Partition of the stiffness matrix of the first order approximation to large displacements - ℓ set.

KBFS - Partition of the stiffness matrix of the first order approximation to large displacements.

KBSS - Partition of the stiffness matrix of the first order approximation to large displacements - s set.

PBL - Partition of the load vector of the first order approximation to the large displacements - ℓ set.

PBS - Partition of the load vector of the first order approximation to the large displacements - ℓ set.

YBS - Partition of the constrained displacement vector of the first order approximation to the large displacement vector - s set.

UBØØV - Partition of the displacement vector of the first order approximation to the large displacement problem - o set.

Notes:

1. KBLL must not be purged or a fatal error exists.
2. KBFS can be purged if and only if both KFS and KDFS are purged.
3. KBSS can be purged if and only if both KSS and KDSS are purged.
4. PL must not be purged or a fatal error exists.
5. PBS, YBS and UBØØV can be purged if and only if PS, YS and UBØØV respectively are purged.

4.51.6 Parameters

NDSKIP - Input and output-integer - must be set to zero before the DMAP loop for Static Analysis with Differential Stiffness is initiated. This parameter is used as a loop counter for the DMAP loop in the Static Analysis with Differential Stiffness Rigid Format. It enables this module to skip the proper number of words on the proper DSFACT card (see definition of the parameter DSCØSET below) to fetch the value of β for the scalar multiplications defined above.

REPEATD - Output-integer-no default value. This parameter is set to +1 if another pass is to be made through the Static Analysis with Differential Stiffness DMAP loop (and hence through the DSMG2 module). It is set to -1 if the module determines that the current pass through the module will be the final one. This latter condition is met if (1) no differential stiffness coefficient set number was specified by the user in his Case Control Deck (if this condition is true, module DSMG1 sets the parameter DSCØSET (see below) equal to -1 and a value of 1.0 is used for β); or if (2) the current β is the last one on the user specified DSFACT card.

DSCØSET - Input-integer-no default value. DSCØSET is the differential stiffness coefficient

set number of a DSFACT bulk data card chosen by the user in his Case Control Deck. If no such set was specified by the user, DSCØSET = -1 and this module will set $\beta = 1.0$ and set the REPEATD parameter to -1. If DSFACT > 0, DSFACT is used to search the MPT for the DSFACT bulk data card chosen by the user.

4.51.7 Method

REPEATD is set to one and NDSKIP is incremented by one. If DSCØSET = -1, REPEATD is set to -1 and the three matrix additions in Equations 1, 2 and 3 are carried out using the matrix subroutine SSG2C. It should be noted that if DSCØSET = -1, it is assumed that DMAP equivalences have been made between PL and PBL, PS and PBS, YS and YBS, and UØØV and UBØØV and hence Equations 4 through 7 are not calculated.

If DSCØSET $\neq$ -1, the MPT is searched until a match is found between DSCØSET and a DSFACT bulk data card image on the MPT. If a match is found, the parameter NDSKIP is used to find the correct value of β for this pass through the DMAP loop. If a match is not found, a fatal error occurs. A match having been found, the following operations are performed.

1. REPEATD is set to -1 if it is determined that this β is the last one on the DSFACT card.
2. The four scalar multiplications in Equations 4 through 7 are performed using matrix subroutine SSG2C.
3. The three matrix additions in Equations 1 through 3 are performed using matrix subroutine SSG2C.

4.51.8 Subroutines

DSMG2 has no auxiliary subroutines. A description of SSG2C can be found in section 3.5.11.

4.51.9 Design Requirements

If DSCØSET = -1, it is assumed that DMAP equivalences have been made between the data blocks corresponding to the matrices in Equations 4 through 7.

Two GINØ buffers are needed and open core is defined at /DSMG2X/.

4.51.10 Diagnostic Messages

Fatal error message 2084 may occur.

4.52 FUNCTIONAL MODULE PLA1 (PIECEWISE LINEAR ANALYSIS - PHASE 1)

4.52.1 Entry Point: PLA1

4.52.2 Purpose

PLA1 is a pre-processor for the modules unique to the Piecewise Linear Analysis Rigid Format. PLA1 extracts the linear elements from the ECPT data block (an element is defined to be linear if its modulus of elasticity (E on a MAT1 bulk data card) is not referenced as a stress-strain tabular function defined on a TABLES1 bulk data card. PLA1 extracts the nonlinear element entries from the ECPT data block to form ECPTNL, and separates the linear and nonlinear element entries in the EST to form ESTL and ESTNL. The linear elements are used to generate the $[K_{gg}^{x\ell}]$ matrix.

4.52.3 DMAP Calling Sequence

```
PLA1    CSTM,MPT,ECPT,GPCT,DIT,CASECC,EST/KGGXL,ECPTNL,ESTL,ESTNL/V,N,KGGLPG/V,N,NPLALIM/
        V,N,ECPTNLPG/V,N,PLSETNØ/V,N,NØNLSTR/V,N,PLFACT $
```

4.52.4 Input Data Blocks

CSTM - Coordinate System Transformation Matrices.

MPT - Material Properties Table.

ECPT - Element Connection and Properties Table.

GPCT - Grid Point Connection Table.

DIT - Direct Input Tables.

CASECC - Case Control Data Table.

EST - Element Summary Table.

Notes: 1. The CSTM may be purged. However, if it is, and some grid point is not in basic coordinates, then a fatal error exists.

2. If an element references a material property and the MPT is purged, a fatal error exists.

3. If any of the data blocks ECPT, GPCT, DIT, CASECC or EST is purged, a fatal error exists.

4.52.5 Output Data Blocks

KGGXL - Stiffness matrix of linear elements exclusive of general elements - g set.

ECPTNL - Element Connection and Properties Table for Nonlinear Elements.

ESTL - Element Summary Table for Linear Elements.

ESTNL - Element Summary Table for Nonlinear Elements.

Note: None of the output data blocks may be pre-purged.

4.52.6 Parameters

KGGLPG - Output-integer-no default value. Purge flag for the KGGXL matrix. If all elements are nonlinear, the KGGXL matrix is the zero matrix, and the module sets KGGLPG = -1. If a linear element is found, KGGLPG will be set to +1.

NPLALIM - Output-integer-no default value. NPLALIM is the number of load increments on the PLFACT card chosen by the user in his Case Control Deck. This parameter controls the number of steps in the DMAP loop of the Piecewise Linear Analysis (PLA) Rigid Format.

ECPTNLPG - Output-integer-no default value. Purge flag for the ECPTNL data block as well as a fatal error condition flag with respect to the PLA Rigid Format. If the module finds that all elements are linear, ECPTNLPG is set = -1, and, upon completion of the module, a JUMP to an error condition message writer will occur, and then an EXIT will be executed. If at least one element is nonlinear, ECPTNLPG is set to +1, and the flow through DMAP sequence continues.

PLSETNØ - Output-integer-no default value. PLSETNØ is the set number on a PLFACT card which is chosen by the user in his Case Control Deck. It is used in modules PLA3 and PLA4 to find the proper PLFACT card in the MPT data block.

NØNLSTR - Output-integer-no default value. NØNLSTR is a flag used to control the calling of the PLA3 module, which outputs stresses, in ØFP (Output File Processor) format, for nonlinear elements. If either (a) the user does not request the output of element stresses, or (b) the user has requested

element stress output for a set of elements all of whose members are linear, then NØNLSTR is set to -1. If there is a stress output request for some nonlinear element, then NØNLSTR is set = +1 and PLA3 will be called each time through the PLA DAMP loop.

PLFACT - Output-complex-no default value. The first load increment factor to be used the first time through the PLA DAMP loop.

4.52.7 Method

The routine is divided into two phases. Phase 1 processes the ECPT data block in a fashion similar to module SMA1 (see Section 4.27). For each pivot point, every element is examined to determine whether it is linear or non linear. This is accomplished by calling subroutine MAT (see Section 3.4.36) with the second word, INFLAG, of the common block /MATIN/ equal to 5. If the element is linear, the proper element stiffness matrix generator routine such as KRØD, KBAR, etc. is called. The element routine will, in turn, call subroutine SMA1B to add its contribution to the 6 (or fewer, if the pivot point is a scalar point or there is not enough core storage available-see Module Functional Description for SMA1, Section 4.27-) rows of the KGGXL matrix currently being generated. If the MAT routine determines that the element is nonlinear, then the ECPT entry for that element, along with words needed subsequently in module PLA4, is appended (see data block description for ECPTNL in Section 2.3.34.4 for details). The number of words appended depends upon element type. This appended ECPT entry is written onto the ECPTNL data block.

Phase 2 of this routine reads the first record of CASECC into core, and the MPT data block is searched to find the set number on a PLFACT bulk data card (if the default is not used) requested by the user in CASECC. If the default value is specified by the user as described for the PLCØ card of Section 2.3 of the User's Manual, a single value of 1.0 will be generated. Parameters PLFACT and PLASETNØ are set. The EST data block is then processed. The logic here is similar to Phase 1. For each element, it is determined if the element is linear or nonlinear. If the element is linear, its EST entry is copied onto the ESTL data block. If the element is non-linear and stress output is requested, the EST entry along with words needed subsequently in module PLA3 are appended. The number of words appended depends upon element type and is not the same number of words appended to the ECPT entry to create the ECPTNL. If the element nonlinear and stress output is not requested, the EST entry for the element is written onto the ESTL data block.

4.52.8 Subroutines

PLA1 has no auxiliary subroutines as such. However, it uses all the structural element routines of module SMA1 to generate $\left[K_{gg}^{x\ell}\right]$, which in turn use the common blocks of SMA1 as well as the "insertion" routine, SMA1B. See Module Functional Description for SMA1, section 4.27.

4.52.9 Design Requirements

For phase 1 of PLA1, the design requirements are the same as those for SMA1. For phase 2, the first record of CASECC must be held in open core.

4.52.10 Diagnostic Messages

For phase 1, see diagnostic messages for module SMA1, section 4.27.10. For phase 2, a user fatal message, 3032, occurs if the PLFACT bulk data card which was chosen by the user in his Case Control Deck could not be found in the MPT.

4.53 FUNCTIONAL MODULE PLA2 (PIECEWISE LINEAR ANALYSIS - PHASE 2)

4.53.1 Entry Point: PLA2

4.53.2 Purpose

To add the incremental displacement vector, the incremental load vector, and the incremental vector of single-point forces of constraint for the current pass through the Piecewise Linear Analysis Rigid Format DMAP loop to the current running sum of these vectors:

$$\{u_{g_{i+1}}\} = \{u_{g_i}\} + \{\Delta u_{g_i}\} , \tag{1}$$

$$\{P_{g_{i+1}}\} = \{P_{g_i}\} + \{\Delta P_{g_i}\} , \tag{2}$$

$$\{q_{g_{i+1}}\} = \{q_{g_i}\} + \{\Delta q_{g_i}\} . \tag{3}$$

4.53.3 DMAP Calling Sequence

```
PLA2    DELTAUGV,DELTAPG,DELTAQG/UGV1,PGV1,QGL/V,N,PLACØUNT  $
```

4.53.4 Input Data Blocks

DELTAUGV - Incremental displacement vector in Piecewise Linear Analysis - g set.

DELTAPG - Incremental load vector in Piecewise Linear Analysis - g set.

DELTAQG - Incremental vector of single-point forces of constraint in Piecewise Linear Analysis - g set.

Note:

1. DELTAUGV and DELTAPG cannot be pre-purged.
2. DELTAQG may be pre-purged.

4.53.5 Output Data Blocks

UGV1 - Matrix of successive sums of incremental displacement vectors - g set.

PGV1 - Matrix of successive sums of incremental load vectors - g set.

QG1 - Matrix of successive sums of incremental vectors of single-point forces of constraint - g set.

Notes:

1. UGV1 and PGV1 cannot be purged.
2. QG1 may be purged if DELTAQG is purged.

4.53.6 Parameters

PLACØUNT - Input and output-integer - this parameter must be set to 1 outside the Piecewise Linear Analysis Rigid Format DMAP loop. This is done using the PARAM module rather than through the Module Properties List (MPL).

4.53.7 Method

If PLACØUNT = 1, that is, this is the first time PLA2 has been called in the Piecewise Linear Analysis Rigid Format DMAP loop, then the DELTAUGV data block is copied onto the UGV1 data block. If PLACØUNT > 1, then PLACØUNT is used as a counter to determine how many records (running sum displacement vectors) to skip on the file containing UGV1 so that the most recently computed running sum displacement vector can be read into open core for the vector addition. Once this vector is read into open core, the incremental displacement vector is read and interpreted using subroutines INTPK and ZNTPKI, and the vector addition given in Equation 1 is carried out element-by-element.

Equations 2 and 3 are computed using the method described in the above paragraph.

4.53.8 Subroutines

PLA2 has no auxiliary subroutines.

4.53.9 Design Requirements

Open core is defined at /PLA2X/.

4.53.10 Diagnostic Messages

User message 2127 or 2128 is output if either DELTAUGV (DELTAPG) or UGV1 (PGV1) is purged.

4.54 FUNCTIONAL MODULE PLA3 (PIECEWISE LINEAR ANALYSIS - PHASE 3)

4.54.1 Entry Point: PLA3

4.54.2 Purpose

To compute element stresses for nonlinear elements (see definition of linear elements in section 4.52.2) for which the user has requested stress output. It also updates the ESTNL data block so that the output data block, ESTNL1, contains up-to-date element stress information.

4.54.3 DMAP Calling Sequence

```
PLA3    CSTM,MPT,DIT,DELTAUGV,ESTNL,CASECC/ØNLES,ESTNL1/V,N,PLACØUNT/V,N,PLSETNØ  $
```

4.54.4 Input Data Blocks

CSTM - Coordinate System Transformation Matrices.

MPT - Material Properties Table.

DIT - Direct Input Tables.

DELTAUGV - Current incremental displacement vector.

ESTNL - Element Summary Table for Nonlinear Elements.

CASECC - Case Control Data Table.

Notes:

1. CSTM can be purged. However, if some grid point of the model is not in basic coordinates and the CSTM is purged, a fatal error occurs.

2. A fatal error occurs if either MPT, DIT, DELTAUGV, ESTNL or CASECC is purged.

4.54.5 Output Data Blocks

ØNLES - Nonlinear element stresses (to be processed by the Output File Processor).

ESTNL1 - Element Summary Table for Nonlinear Elements - Updated.

Note: Neither output data block may be purged.

4.54.6 Parameters

PLACØUNT - Input-integer-no default value. This is the Piecewise Linear Analysis (PLA)

Rigid Format DMAP loop counter. It is used in this routine to find the proper loading factors on the PLFACT bulk data card specified by the user (see PLSETNØ below).

PLTSETNØ - Input-integer-no default value. PLSETNØ is the set identification number of some PLFACT bulk data card chosen by the user in his Case Control Deck. It is used to find this PLFACT card in the MPT data block.

4.54.7 Method

The module driver, PLA3, is a short routine whose only function is to call subroutines PLA31 and PLA32 which accomplish phase 1 and phase 2 of the task of the module respectively. Subroutine PLA31 reads the incremental displacement vector into core and appends to each element entry of the ESTNL data block the components of the incremental displacement vector corresponding to the grid points of each element. This merged information is written on the scratch data block ESTNLS, GINØ file number 301. In PLA32, the ESTNLS data block is read, and the proper element routine is called to compute element stresses which are prepared in ØFP (Output File Processor) format. Each element routine also updates incremental stress data. The ESTNL data for each element with the updated stress information (but without the components of the displacement vector) are written on ESTNL1.

In PLA31, for TRMEM and QDMEM elements, only the three translational components of the displacement vector at each grid point of the element are appended to the ESTNL entry. Other elements for which Piecewise Linear Analysis is defined use all six components at each grid point.

In PLA32, the difference quotients γ^* and γ, which are the previous and current (with respect to the DMAP loop in the PLA Rigid Format) load increment ratios, are computed as follows. Let $P_1, P_2, P_3, \ldots,$ be the loading factors on a PLFACT bulk data card. Define $P_o = 0$. Define

$$\alpha_i = P_i - P_{i-1} \quad , \tag{1}$$

for $i \geq 1$. Then, define $\gamma_1^* = 0$, and

$$\gamma_i^* = \frac{\alpha_i}{\alpha_{i-1}} \quad , \tag{2}$$

for $i > 1$, and define

$$\gamma_i = \frac{\alpha_{i+1}}{\alpha_i}, \qquad (3)$$

for $i \geq 1$. These difference quotients are stored in /PLA32C/ for communication to the module's element routines so that they can compute the estimated next strain. The details of the element calculation are given in section 4.87. The input parameter PLACØUNT, being the counter for the PLA Rigid Format DMAP loop, controls the computation of γ^* and γ. However, the module's design assumes (1) PLACØUNT is set to one outside the PLA DMAP loop and (2) module PLA2, which increments PLACØUNT by one, will be executed prior to every DMAP call to PLA3. Hence, the proper choice for the subscript i in Equations 1, 2 and 3 is one less than the value of PLACØUNT. The difference PLACØUNT-1 is stored in /PLA32C/ as IPASS.

4.54.8 Subroutines

PLA3 uses, for element routine calculations, the utility routines PRETRS, PREMAT, GMMATS and element drivers. Communication of an appended ESTNL element entry to an element routine during phase 2 of PLA3 is accomplished via /PLA32E/, which is 100 words in length. This fact is not explicitly stated below.

The element drivers PSTRM, PSQDM, PSTRI1, PSTRI2, PSQAD1, and PSQAD2, use a) /PLA3ES/, which is 300 words in length, as a communication link for the element subroutines which they call; and b) /PLA3UV/, which is 25 words in length, as a communication link for displacement vectors between the driver and their subroutines. PLA32 will call the element drivers listed above (plus PSRØD and PSBAR); the other subroutines described below (in sections 4.54.8.11 through 4.54.8.18) are only used (directly or indirectly) by the element drivers.

4.54.8.1 Subroutine Name: PLA31

1. Entry Point: PLA31
2. Purpose: To perform phase 1 of the module's operations as described above.
3. Calling Sequence: CALL PLA31

4.54.8.2 Subroutine Name: PLA32

1. Entry Point: PLA32

2. Purpose: To perform phase 2 of the module's operation as described above.

3. Calling Sequence: CALL PLA32

4.54.8.3 Subroutine Name: PSRØD

1. Entry Point: PSRØD

2. Purpose: To compute element stresses and to update the ESTNL entry for a RØD, CØNRØD or TUBE element. Note that for a TUBE element, the ESTNL entry is rearranged and elementary transformations are performed in PLA32 so that the PSRØD routine may compute element stresses for a TUBE.

3. Calling Sequence: CALL PSRØD

4.54.8.4 Subroutine Name: PSBAR

1. Entry Point: PSBAR

2. Purpose: To compute element stresses and to update the ESTNL entry for a BAR element.

3. Calling Sequence: CALL PSBAR

4.54.8.5 Subroutine Name: PSTRM

1. Entry Point: PSTRM

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the TRMEM element.

3. Calling Sequence: CALL PSTRM

4.54.8.6 Subroutine Name: PSQDM

1. Entry Point: PSQDM

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the QDMEM element.

3. Calling Sequence: CALL PSQDM

4.54.8.7 Subroutine Name: PSTRI1

1. Entry Point: PSTRI1

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the TRIA1 element.

3. Calling Sequence: CALL PSTRI1

4.54.8.8 Subroutine Name: PSTRI2

1. Entry Point: PSTRI2

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the TRIA2 element.

3. Calling Sequence: CALL PSTRI2

4.54.8.9 Subroutine Name: PSQAD1

1. Entry Point: PSQAD1

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the QUAD1 element.

3. Calling Sequence: CALL PSQAD1

4.54.8.10 Subroutine Name: PSQAD2

1. Entry Point: PSAQD2

2. Purpose: To calculate the material properties matrix, arrange the flow of element stress calculations and update the ESTNL entry for the QUAD2 element.

3. Calling Sequence: CALL PSQAD2

4.54.8.11 Subroutine Name: PSTRM1

1. Entry Point: PSTRM1

2. Purpose: To generate element stress matrices for the TRMEM element, and the membrane portion of TRIA1 and TRIA2 elements, and perform subcomputations for the PSQDM1 routine.

3. Calling Sequence: CALL PSTRM1 (NTYPE)

NTYPE { 0 = TRMEM, TRIA1, or TRIA2
      { 1 = Subcomputations for the PSQDM1 subroutine

4.54.8.12 Subroutine Name: PSQDM1

1. Entry Point: PSQDM1

2. Purpose: To generate element stress matrices for the QDMEM element and the membrane portions of QUAD1 and QUAD2 elements.

3. Calling Sequence: CALL PSQDM1

4.54.8.13 Subroutine Name: PSTQ1

1. Entry Point: PSTQ1

2. Purpose: To generate element stress matrices for the TRIA1, TRIA2, QUAD1, and QUAD2 elements.

3. Calling Sequence: CALL PSTQ1 (NTYPE)

NTYPE { 1 = TRIA1
      { 2 = TRIA2
      { 3 = QUAD1
      { 4 = QUAD2

4.54.8.14 Subroutine Name: PSTRB1

1. Entry Point: PSTRB1

2. Purpose: To generate element stress matrices for subcalculations of basic bending triangles for the plate portion of TRIA1, TRIA2, QUAD1 and QUAD2 elements.

3. Calling Sequence: CALL PSTRB1 (IØPT)

IØPT { 1 = Subcalculations for PSQPL1
     { 2 = Subcalculations for PSTPL1

4.54.8.15 Subroutine Name: PSTPL1

1. Entry Point: PSTPL1

2. Purpose: To generate the element stress matrices for the plate portion of TRIA1 and

TRIA2 elements.

3. Calling Sequence: CALL PSTPL1

4.54.8.16 Subroutine Name: PSQPL1

1. Entry Point: PSQPL1

2. Purpose: To generate element stress matrices for the QUAD1 and QUAD2 elements.

3. Calling Sequence: PSQPL1

4.54.8.17 Subroutine Name: PSTRQ2

1. Entry Point; PSTRQ2

2. Purpose: To perform final stress computations for TRMEM and QDMEM elements.

3. Calling Sequence: CALL PSTRQ2 (NTYPE)

NTYPE { 1 = TRMEM element
      { 2 = QDMEM element

4.54.8.18 Subroutine Name: PSTQ2

1. Entry Point: PSTQ2

2. Purpose: To perform final stress computations for the TRIA1, TRIA2, QUAD1, and QUAD2 elements.

3. Calling Sequence: CALL PSTQ2 (NPTS)

NPTS { 3 = TRIA1 and TRIA2 elements
     { 4 = QUAD1 and QUAD2 elements

4.54.9 Design Requirements

1. The module was designed so that phase 1 and phase 2 can be executed in separate overlay segments.

2. Open core for phase 1 is defined at /PLA31X/ and for phase 2 at /PLA32X/. Open core requirements for both phases are minimal. In phase 1, the single precision incremental displacement vector in unpacked form must be able to be contained in open core. In phase 2, the CSTM and MPT data blocks, tables in the DIT referenced on MATS1 bulk data cards, and

the first record (and only record since a PLA problem allows only one CASECC record) of CASECC must be able to be contained in open core.

3. In addition to the common blocks mentioned above, PLA32 uses /PLA32S/, which is 325 words in length, as scratch storage for the module's element routines, and /SØUT/, which is 30 words in length, as a storage buffer for computed element stresses.

4. One scratch file is used, and all arithmetic operations are performed in single precision.

4.54.10 Diagnostic Messages

During phase 1, the following diagnostic messages may appear. If the incremental displacement vector is null, user fatal error 3005 will be given. Two system fatal "fail-safe" error messages, 2091 and 2092, may be implemented if the ESTNL input data block was incorrectly constructed in PLA1 or was incorrectly updated during the previous execution of the PLA3 module.

During phase 2, error messages 3001, 3002 or 3003 may occur if the proper loading factors P_j cannot be found on the PLFACT bulk data card image in the MPT. If the ECPTDS scratch file is not in the prescribed format, system fatal message 2091 will occur.

If the minimal core storage requirements in either phase 1 or phase 2 are not met, the usual fatal error 3008 will occur.

4.55 FUNCTIONAL MODULE PLA4 (PIECEWISE LINEAR ANALYSIS - PHASE 4)

4.55.1 Entry Point: PLA4

4.55.2 Purpose

To generate the stiffness matrix for nonlinear elements, $[K_{gg}^{n\ell}]$, and to update the Element Connection and Properties Table for Nonlinear Elements, ECPTNL, so that it contains up-to-date element stress information.

4.55.3 DMAP Calling Sequence

```
PLA4     CSTM,MPT,ECPTNL,GPCT,DIT,DELTAUGV/KGGNL,ECPTNL1/V,N,PLACØUNT/V,N,PLSETNØ/
         V,N,PLFACT   $
```

4.55.4 Input Data Blocks

CSTM - Coordinate System Transformation Matrices.

MPT - Material Properties Table.

ECPTNL - Element Connection and Properties Table for Nonlinear Elements.

GPCT - Grid Point Connection Table.

DIT - Direct Input Tables.

DELTAUGV - Current incremental displacement vector.

Notes:

1. CSTM may be purged. However, if some grid point of the model is not in basic coordinates and the CSTM has been purged, a fatal error will occur.
2. A fatal error occurs if either MPT, ECPTNL, GPCT, DIT or DELTAUGV is purged.

4.55.5 Output Data Blocks

KGGNL - Stiffness matrix of nonlinear elements - g set.

ECPTNL1 - Element Connection and Properties Table for Nonlinear Elements - updated.

Note: Neither KGGNL or ECPTNL1 may be purged.

4.55.6 Parameters

PLACØUNT - Input-integer-no default value. Loop counter for the Piecewise Linear Analysis (PLA) Rigid Format DMAP loop. The module uses this parameter to find the correct loading factors on the PLFACT bulk data card chosen by the user.

PLSETNØ - Input-integer-no default value. Set identification number of a PLFACT bulk data card chosen by the user in his Case Control Deck. The module uses this parameter to search the MPT for this card.

PLFACT - Output-complex-no default value. The difference of loading factors to be used during the next pass of the PLA Rigid Format DMAP loop.

4.55.7 Method

The module driver PLA4 is a short routine whose only function is to call subroutines PLA41 and PLA42 which accomplish phase 1 and phase 2 of the task of the module respectively. Subroutine PLA41 reads the incremental displacement vector into core and appends to each element entry of the ECPTNL data block the components of the incremental displacement vector corresponding to the grid points of each element. This merged information is written on the scratch data block ECPTS, GINØ file number 301. In PLA42, the ECPTS data block is processed in a fashion similar to the processing of the ECPT data block in module SMA1 (see the Module Functional Description for SMA1, section 4.27).

In PLA41, for all elements except the BAR element, only the three translational components of the displacement vector at each grid point of an element are appended to the ECPTNL element entry. For a BAR element, all six components of the displacement vector at each grid point are appended.

The logic of the processing of the scratch data block, ECPTS, in PLA42 is very similar to that used in subroutine SMA1A (of SMA1, the stiffness matrix generation module - see the Module Functional Description for SMA1, section 4.27). The similarities are not enumerated here, but notable differences are the following.

1. Before PREMAT is called to read into open core the MPT data block and tables from the DIT data block referenced on MATS1 bulk data cards, the MPT is read in subroutine

PLA42 to compute γ^* and γ as in Equations 1, 2 and 3 in section 4.54, and the real part of the output DMAP parameter PLFACT is set to the value of α_{i+1} in Equation 3 in section 4.54. The imaginary part of PLFACT is set to zero. The reason for PLFACT being complex is that it is an input parameter to the DMAP module ADD during the next pass of the PLA Rigid Format DMAP loop, and ADD (see section 4.78) requires its parameters to be complex.

2. When PREMAT is called, the last argument is set negative to signal PREMAT that this is a PLA problem and hence that special processing will be required.

3. Subsequent to the call of an element routine, the element type and the updated ECPT entry are written onto the ECPTNL1 data block.

4.55.8 Subroutines

PLA4 uses PRETRD, PRETRS, PREMAT, INVERS, INVERD, GMMATS, and GMMATD as utility routines. The common block /PLA42E/ is the means of communicating a) the element entry of the ECPTS from PLA42 to an element stiffness matrix generation routine and b) the ECPTS element entry with updated stress information from the element routine back to PLA42 upon completion of element matrix generation. This fact is not explicitly stated in the descriptions of the element routines (e.g., PKRØD) given below.

The element drivers PKTRM, PKQDM, PKTRI1, PKTRI2, PKQAD1, and PKQAD2 use a) /PLA4ES/, which is 300 words in length, and b) /PLA4UV/, which is 25 words in length, as communication links with the subroutines that they call. PLA42 will call the drivers listed above which will use (directly and indirectly) the subroutines described below in sections 4.55.8.12 through 4.55.8.22.

4.55.8.1 Subroutine Name: PLA41

1. Entry Point: PLA41

2. Purpose: See discussion above.

3. Calling Sequence: CALL PLA41

4.55.8.2 Subroutine Name: PLA42

1. Entry Point: PLA42

2. Purpose: See discussion above.

3. Calling Sequence: CALL PLA42

4.55.8.3 Subroutine Name: PLA4B

1. Entry Point: PLA4B

2. Purpose: To add a double precision 6 by 6 element stiffness matrix to the "submatrix" corresponding to the current pivot point. This routine performs the same function as, and is modeled after, subroutine SMA1B of module SMA1.

3. Calling Sequence: CALL PLA4B (KE,J)

KE - Row-stored double precision 6 by 6 matrix to be added to the submatrix in core - input.

J - The column index of the KGGNL matrix which corresponds to first column of the KE matrix - integer - input.

4.55.8.4 Subroutine Name: PKRØD

1. Entry Point: PKRØD

2. Purpose: To generate the element stiffness matrix for a RØD element and to update the ECPTNL element entry for a RØD element.

3. Calling Sequence: CALL PKRØD

4.55.8.5 Subroutine Name: PKBAR

1. Entry Point: PKBAR

2. Purpose: To generate the element stiffness matrix for a BAR element and to update the ECPTNL element entry for a BAR element.

3. Calling Sequence: CALL PKBAR

4.55.8.6 Subroutine Name: PKTRM

1. Entry Point: PKTRM

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the TRMEM element.

3. Calling Sequence: PKTRM

4.55.8.7 Subroutine Name: PKQDM

1. EEntry Point: PKQDM

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the QDMEM element.

3. Calling Sequence: CALL PKQDM

4.55.8.8 Subroutine Name: PKTRI1

1. Entry Point: PKTRI1

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the TRIA1 element.

3. Calling Sequence: CALL PKTRI1

4.55.8.9 Subroutine Name: PKTRI2

1. Entry Point: PKTRI2

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the TRIA2 element.

3. Calling Sequence: CALL PKTRI2

4.55.8.10 Subroutine Name: PKQAD1

1. Entry Point: PKQAD1

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the QUAD1 element.

3. Calling Sequence: CALL PKQAD1

4.55.8.11 Subroutine Name: PKQAD2

1. Entry Point: PKQAD2

2. Purpose: To calculate the material properties matrix, update the ECPTNL entry, and arrange the flow of element stiffness calculations for the QUAD2 element.

3. Calling Sequence: CALL PKQAD2

4.55.8.12 Subroutine Name: PKTRM1

1. Entry Point: PKTRM1

2. Purpose: To generate element stress matrices for the TRMEM, TRIA1 and TRIA2 elements, and perform subcomputations for the PKQDM1 routine.

3. Calling Sequence: CALL PKTRM1 (NTYPE)

NTYPE { 0 = TRMEM, TRIA1 or TRIA2
      { 1 = Subcomputations for the PKQDM1 routine

4.55.8.13 Subroutine Name: PKQDM1

1. Entry Point: PKQDM1

2. Purpose: To generate element stress matrices for the QDMEM, QUAD1 and QUAD2 elements.

3. Calling Sequence: CALL PKQDM1

4.55.8.14 Subroutine Name: PKTQ1

1. Entry Point: PKTQ1

2. Purpose: To generate element stress matrices for the TRIA1, TRIA2, QUAD1, and QUAD2 elements.

3. Calling Sequence: CALL PKTQ1 (NTYPE)

NTYPE { 1 = TRIA1
      { 2 = TRIA2
      { 3 = QUAD1
      { 4 = QUAD2

4.55.8.15 Subroutine Name: PKTRQ2

1. Entry Point: PKTRQ2

2. Purpose: To perform final stress computations for the TRMEM and QDMEM elements.

3. Calling Sequence: CALL PKTRQ2 (NTYPE)

NTYPE { 1 = TRMEM element
      { 2 = QDMEM element

4.55.8.16 Subroutine Name: PKTQ2

1. Entry Point: PKTQ2

2. Purpose: To perform final stress computations for the TRIA1, TRIA2, QUAD1, and QUAD2 elements.

3. Calling Sequence: CALL PKTQ2 (NPTS)

NPTS { 3 = TRIA1 or TRIA2 elements
     { 4 = QUAD1 or QUAD2 elements

4.55.8.17 Subroutine Name: PKTRMS

1. Entry Point: PKTRMS

2. Purpose: To generate the element stiffness matrix for the TRMEM element and sub-computations for the PKQDMS routine.

3. Calling Sequence: CALL PKTRMS (NTYPE)

NTYPE { 0 = TRMEM
      { 1 = Sub-computations for PKQDMS

4.55.8.18 Subroutine Name: PKQDMS

1. Entry Point: PKQDMS

2. Purpose: To generate the element stiffness matrix for the QDMEM element.

3. Calling Sequence: CALL PKQDMS

4.55.8.19 Subroutine Name: PKTRQD

1. Entry Point: PKTRQD

2. Purpose: To generate the element stiffness matrix for the TRIA1, TRIA2, QUAD1, or QUAD2 elements.

3. Calling Sequence: CALL PKTRQD (NTYPE)

NTYPE
- 1 = TRIA1
- 2 = TRIA2
- 3 = QUAD1
- 4 = QUAD2

4.55.8.20 Subroutine Name: PKTRBS

1. Entry Point: PKTRBS

2. Purpose: To generate the element stiffness matrix subcalculations for the PKTRPL and PKQDPL routines.

3. Calling Sequence: CALL PKTRBS (IØPT)

IØPT
- 1 = Subcomputations for PKQDPL
- 2 = Subcomputations for PKTRPL

4.55.8.21 Subroutine Name: PKTRPL

1. Entry Point: PKTRPL

2. Purpose: To generate the element stiffness matrix for the TRIA1 and TRIA2 elements.

3. Calling Sequence: CALL PKTRPL

4.55.8.22 Subroutine Name: PKQDPL

1. Entry Point: PKQDPL

2. Purpose: To generate the element stiffness matrix for the QUAD1 and QUAD2 elements.

3. Calling Sequence: CALL PKQDPL

4.55.9 Design Requirements

The module was designed so that phase 1 and phase 2 can be executed in separate overlay segments.

Open core for phase 1 is defined at /PLA41X/ and for phase 2 at /PLA42X/. In phase 1 the single precision incremental displacement vector in unpacked form must be able to be contained in core. In phase 2, the open core requirements are the same as those for module SMA1 (see section 4.27.9.1) except that only four GINØ buffers are required during the principal loop of phase 2,

which processes the ECPTS and GPCT in a complementary manner. One GINØ buffer is defined for each of KGGNL, ECPTNL1, ECPTS and GPCT.

In addition to /PLA42E/, which is 100 words in length, subroutine PLA42 uses the following common blocks: a) /PLA42D/, which is 300 double precision words in length, and is used as a scratch storage for the module's element routines; b) /PLA425/, which is 325 single precision words in length, and is used as scratch storage for the module element routines; and c) /PLA42C/, which is a communication region for phase 2 of the task of the module. /PLA42C/ is defined as follows:

CØMMØN/PLA42C/NPVT,GAMMA,GAMMAS,IPASS,ICSTM,NCSTM,IGPCT,NGPCT,IPØINT,NPØINT,I6X6K,N6X6K,CSTM,MPT, ECPTS,GPCT,DIT,KGGNL,ECPTØ,INRW,ØUTRW,EØR,NEØR,CLSRW,JMAX,FRØWIC,LRØWIC,NRØWSC,NLINKS,NWØRDS(40), IØVRLY(40),LINK(40),NØGØ

GAMMA,GAMMAS	-	The load increment ratios as defined in Equations 2 and 3 in section 4.54.
IPASS	-	Number of the current pass through the PLA DMAP loop.
NPVT,ICSTM,NCSTM,IGPCT, NGPCT,IPØINT,NPØINT, I6X6K,N6X6K	-	As defined in section 4.27.9.
CSTM,MPT,ECTPS,GPCT, DIT,KGGNL	-	GINØ file numbers for their corresponding data blocks.
ECPTØ	-	GINØ file number for the ECTPNL1 data block.
INRW,ØUTRW,..., IØVRLY(40),LINK(40),NØGØ	-	As defined in section 4.27.9.

The variables a) corresponding to GINØ file numbers, b) GINØ parameter options (e.g., INRW, ØUTRW), and c) NLINKS, IØVRLY, and NWØRDS, and NØGØ are set in the block data subprogram PLA4BD.

One scratch file is used, and all operations associated with stiffness matrix calculations are performed in double precision.

4.55.10 Diagnostic Messages

During phase 1, if the incremental displacement vector is null, user fatal error 2083 will occur.

During phase 2, error messages 3001, 3002, or 3003 may occur if the proper loading factors cannot be found on the PLFACT bulk data card image in the MPT. Other diagnostic messages for phase 2 are the same as those for module SMA1 (see section 4.27.10).

4.56 FUNCTIONAL MODULE CASE (SIMPLIFY CASE CONTROL)

4.56.1 Entry Point: CASE

4.56.2 Purpose

To remove looping considerations from later dynamics modules.

4.56.3 DMAP Calling Sequence

```
CASE    CASECC,PSDL/CASEXX/C,N,APPRØACH/V,N,REPEAT/V,N,LØØP  $
```

4.56.4 Input Data Blocks

CASECC - Case Control Data Table.

PSDL - Power Spectral Density List.

Note: PSDL is used only if APPRØACH = FREQRESP and Random Analysis is selected in CASECC.

4.56.5 Output Data Blocks

CASEXX - Case Control data table for dynamics problems.

Note: CASEXX cannot be purged.

4.56.6 Parameters

APPRØACH - Input-BCD-no default. Defines the approach to be used for looping criteria.

BCD Value	LØØP
STATICS	NØNE
REIGEN	NØNE
DSO	NØNE
DS1	NØNE
FREQRESP	DIRECT INPUT MATRICES OR TRANSFER FUNCTIONS
TRANRESP	LØADS
BLKO	NØNE
BLK1	NØNE
CEIGEN	DIRECT INPUT MATRICES OR TRANSFER FUNCTIONS

BCD Value	LØØP
PLA	NØNE

REPEAT - Input and output-integer-set equal to zero outside of the DMAP loop by the PARAM module. -1 if no additional loops; + loop count if loops.

LØØP - Output-integer-default = -1. -1 if this is not a looping problem, 0 if this is a looping problem.

4.56.7 Method

The method of operation depends upon the input parameter APPRØACH.

4.56.7.1 Transient Response

If APPRØACH = TRANRESP, CASECC is skipped over REPEAT records. If REPEAT = 0, REPEAT is set to 1. One record of CASECC is read and copied onto CASEXX. An attempt is made to read another record. If no more records exist, REPEAT is set to -1. Also, if this is the first entry to CASE (i.e., REPEAT = 1), LØØP is set to -1. If additional records exist, REPEAT and LØØP are set to 1.

4.56.7.2 Complex Eigenvalue Analysis

If APPRØACH = CEIGEN, REPEAT records are skipped in CASECC. If REPEAT = 0, REPEAT is set to 1. One record of CASECC is read and copied onto CASEXX. The names of the Direct Input Matrices and Transfer Functions sets are saved. An attempt is made to read another record. If no more exist, REPEAT is set to -1. Also if this is the first entry (i.e., REPEAT = 1) LØØP is set to -1. If additional records exist, their Direct Input Matrices and Transfer Functions sets are compared to those saved. If they all agree, this record is copied onto CASEXX and the process is repeated. If they do not agree, REPEAT is incremented by 1, LØØP is set to 1, and CASE returns.

4.56.7.3 Frequency Response

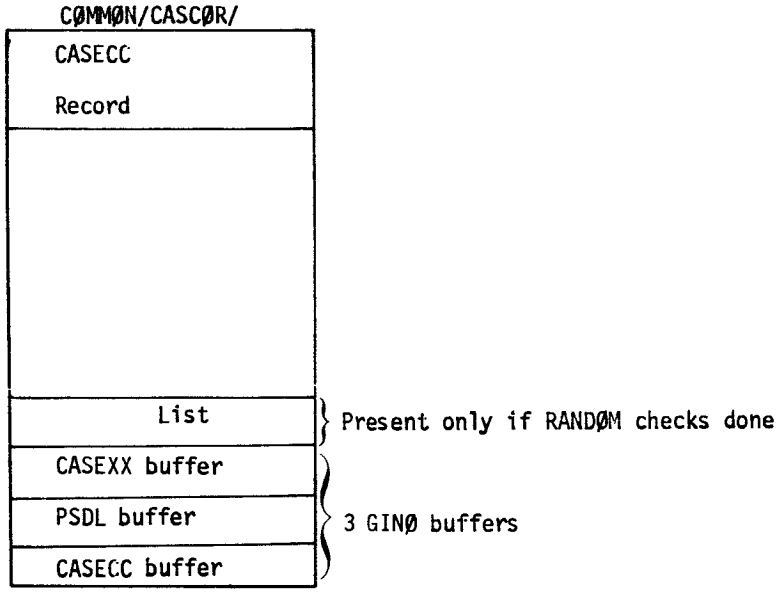
If APPRØACH = FREQRESP, the method used is the same as Complex Eigenvalue Analysis except a test is also made for frequency set selection changes. In addition, if RANDPS cards are selected, the selected set is read from PSDL and the unique subcase "id's" referenced are stored. Each subcase id copied onto CASEXX is compared to this list, and the entry is marked as found. If at the completion of CASE unmarked entries exist, the routine terminates with message 3033.

4.56.8 Subroutines

No auxiliary subroutines are used by CASE.

4.56.9 Design Requirements

Open core is defined at /CASCØR/.



4.56.10 Diagnostic Messages

If a case control record cannot be held in core, CASE will issue error message 3008. Message 3033 may be issued by CASE as outlined above.

4.57 FUNCTIONAL MODULE MTRXIN (MATRIX INPUT)

4.57.1 Entry Point: MTRXIN

4.57.2 Purpose

MTRXIN has two purposes: (1) to provide a capability for direct input matrices as may occur in control systems in the dynamics Rigid Formats and, (2) to provide the DMAP user a capability of converting matrices input on DMIG bulk data cards to NASTRAN matrix format.

4.57.3 DMAP Calling Sequences

1. Dynamics Rigid Formats:

```
MTRXIN    CASECC,MATPØØL,EQDYN,SILD,TFPØØL/K2PP,M2PP,B2PP/V,N,LUSETD/V,N,NØMAT1/V,N,NØMAT2/
          V,N,NØMAT3  $
```

2. DMAP Approach:

```
MTRXIN,   ,MATPØØL,EQEXIN,SIL,/NAME1,NAME2,NAME3/V,N,LUSET/V,N,NØMAT1/V,N,NØMAT2/V,N,NØMAT3   $
```

4.57.4 Input Data Blocks

CASECC - Case Control.

MATPØØL - Data block containing matrices input on DMIG bulk data cards.

EQDYN - Equivalence between external numbers and internal numbers, dynamics.

SILD - Scalar Index List - dynamics.

TFPØØL - Transfer Function Pool.

EQEXIN - Equivalence between external numbers and internal numbers.

SIL - Scalar Index List.

Notes:

1. If CASECC is purged, the second purpose is assumed by MTRXIN.
2. EQDYN, EQEXIN, SIL and SILD may not be purged.

4.57.5 Output Data Blocks

K2PP - Direct input stiffness matrix - p set.

M2PP - Direct input mass matrix - p set.

B2PP - Direct input damping matrix - p set.

NAME1, NAME2, NAME3 - The same names that appear on the DMIG cards, i.e., the DMIG matrix called NAME1 will be output on data block NAME1.

Note: Any output data block may be purged.

4.57.6 Parameters

LUSET - Input-integer-no default. Degrees of freedom in the g set. Used with EQEXIN and SIL.

LUSETD - Input-integer-no default. Degrees of freedom in the p set. Used with EQDYN and SILD.

NØMATi - Output-integer-no default. +1 if the i^{th} output data block is generated, -1 otherwise.

4.57.7 DMAP Example

Assume the bulk data contain two DMIG matrices named M1 and M2 which reference grid and/or scalar points only. The following set of DMAP instructions will generate these two matrices in NASTRAN matrix format, multiply them together and print the result.

```
BEGIN
GP1       GEØM1,GEØM2/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/C,N,0/C,N,0  $
SAVE      LUSET $
MTRXIN,   ,MATPØØL,EQEXIN,SIL,/M1,M2,/V,N,LUSET/V,N,NØM1/V,N,NØM2/C,N,0 $
SAVE      NØM1,NØM2 $
CØND      EXIT,NØM1 $
CØND      EXIT,NØM2 $
MPYAD     M1,M2,/PRØDUCT/C,N,0/C,N,1/C,N,1/C,N,1 $
MATPRN    PRØDUCT,,,,// $
LABEL     EXIT $
END
```

4.57.8 Method

The first logical record in the Case Control data block is read into core, and the names of the requested DMIG matrices are fetched. If the Case Control data block is purged, FNAME is called to determine the names of the DMIG matrices from the names of the output data blocks. If the Case Control record was read, the transfer function set selection is fetched. If transfer matrices are requested, the TFPØØL data block is opened, and the file is positioned to the requested set. Each transfer function matrix for which a corresponding direct input matrix exists is written on a scratch file. If no direct input matrix exists corresponding to a transfer function matrix, the transfer function matrix is written directly on the appropriate output data block. The transfer function matrices are written in NASTRAN matrix format by decoding the row and column numbers and calling BLDPK.

Upon completion of the writing of the transfer function matrices (if any), the second record of EQEXIN or EQDYN is read into core. The second word of each entry is converted into a scalar index number by dividing by 10. The MATPØØL data block is opened. The following processing occurs:

1. The header information for the DMIG matrix is read. If an end-of-file is encountered, step (5) is executed. If the matrix is not requested, the remainder of the record is skipped and step (1) is repeated. Otherwise, step (2) is executed.

2. Each term in the matrix is read. The grid identification and component code are converted to a scalar index value by performing a binary search in EQEXIN or EQDYN in core. The scalar index forms a row position of the matrix. The row and column number (packed in one word) and the value for the term are stored in core. If core storage is exceeded, the terms are written on a scratch file.

3. When all terms have been read, converted and stored, the matrix is sorted by SØRT. The matrix is now written in NASTRAN format by BLDPK.

4. If a transfer function is to be added to the DMIG matrix, the ADD routine is called to accomplish the matrix addition.

5. A test is made to determine if all requested matrices have been processed. If not, an error message is queued, and PEXIT is called. Otherwise, the module makes a normal exit.

4.57.9 Design Requirements

4.57.9.1 Allocation of Core Storage

Storage is required to hold the EQDYN or EQEXIN table (2 words per point in the problem) plus five GINØ buffers. Complete spill logic is provided for processing the DMIG matrices.

4.57.9.2 Environment

The module MTRXIN consists of one subroutine, MTRXIN. Calls are made to the utility routine SØRT and matrix operation ADD. Open core is defined by /MTRXXX/. Seven scratch files are used.

4.57.10 Diagnostic Messages

The following messages may be issued by MTRXIN:

2065, 2070, 2074.

4.58 FUNCTIONAL MODULE GKAD (GENERAL K ASSEMBLER DIRECT)

4.58.1 Entry Point: GKAD

4.58.2 Purpose

To assemble the dynamic stiffness, damping and mass matrices.

4.58.3 DMAP Calling Sequence

```
GKAD  USETD,GM,GØ,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,GØD,K2DD,M2DD,B2DD/
      V,N,TYPE/V,N,APP/V,N,FØRM/V,Y,G/V,Y,W3/V,Y,W4/V,N,NØK2PP/V,N,NØM2PP/V,N,NØB2PP/
      V,N,MPCF1/V,N,SINGLE/V,N,ØMIT/V,N,NØUE/V,N,NØK4GG/V,N,NØBGG/V,N,KDEKA/V,Y,MØDACC   $
```

4.58.4 Input Data Blocks

USETD - Displacement set definitions table dynamics.

GM - Multipoint constraint transformation matrix - m set.

GØ - Structural matrix partitioning transformation matrix.

KAA - Partition of stiffness matrix - a set.

BAA - Partition of damping matrix - a set.

MAA - Partition of mass matrix - a set.

K4AA - Partition of structural damping matrix - a set.

K2PP - Direct input stiffness matrix - p set.

M2PP - Direct input mass matrix - p set.

B2PP - Direct input damping matrix - p set.

Notes:
1. USETD cannot be purged.
2. GM cannot be purged if MPCF1 ≥ 0.
3. GØ cannot be purged if ØMIT ≥ 0.
4. KAA cannot be purged if KDEKA ≥ 0.
5. BAA cannot be purged if NØBGG ≥ 0.
6. MAA may be purged.
7. K4AA cannot be purged if NØK4GG ≥ 0.
8. K2PP cannot be purged if NØK2PP ≥ 0.
9. M2PP cannot be purged if NØM2PP ≥ 0.

10. B2PP cannot be purged if NØB2PP ≥ 0.

4.58.5 Output Data Blocks

KDD - Dynamic stiffness matrix - d set.

BDD - Dynamic damping matrix - d set.

MDD - Dynamic mass matrix - d set.

GMD - Multipoint constraint transformation matrix - dynamics.

GØD - Omitted coordinate transformation matrix - dynamics.

K2DD - Direct input stiffness matrix - d set.

M2DD - Direct input mass matrix - d set.

B2DD - Direct input damping matrix - d set.

Notes: 1. GMD cannot be purged if MPCF1 ≥ 0.

2. GØD cannot be purged if ØMIT ≥ 0.

3. K2DD cannot be purged if NØK2PP ≥ 0.

4. M2DD cannot be purged if NØM2PP ≥ 0.

5. B2DD cannot be purged if NØB2PP ≥ 0.

4.58.6 Parameters

TYPE - Input-BCD-no default. If TYPE = TRANSIENT the transient equations are used; otherwise the frequency response equations are used.

APP - Input-BCD-no default. If APP = FØRCE the p set = d set; otherwise p's are reduced to d's by removing m's, s's, and o's.

FØRM - Input-BCD-no default. If FØRM = MØDAL, KDD and BDD are not computed. MDD is not computed unless MØDACC ≥ 0.

G - Input-real-default = 0.0. G is the coefficient of K4DD if TYPE ≠ TRANSIENT. G/W3 is coefficient of K1DD if TYPE = TRANSIENT.

W3 - Input-real-default = 0.0. If TYPE = TRANSIENT G/W3 is the coefficient of K1DD. If W3 = 0.0 K1DD is not used.

W4 - Input-real-default = 0.0. 1.0/W4 is the coefficient of K4DD if TYPE = TRANSIENT. If W4 = 0.0 K4DD is not used.

NØK2PP - Input-integer-no default. NØK2PP ≥ 0 indicates presence of K2PP.

NØM2PP - Input-integer-no default. NØM2PP ≥ 0 indicates presence of M2PP.

NØB2PP - Input-integer-no default. NØB2PP ≥ 0 indicates presence of B2PP.

MPCF1 - Input-integer-no default. MPCF1 ≥ 0 indicates presence of GM.

SINGLE - Input-integer-no default. SINGLE ≥ 0 indicates presence of single-point constraints.

ØMIT - Input-integer-no default. ØMIT ≥ 0 indicates presence of GØ.

NØUE - Input-integer-no default. NØUE ≥ 0 indicates presence of extra points.

NØK4GG - Input-integer-no default. NØK4GG ≥ 0 indicates presence of K4AA.

NØBGG - Input-integer-no default. NØBGG ≥ 0 indicates presence of BAA.

KDEKA - Input-integer-no default. KDEKA ≥ 0 indicates presence of MAA and KAA.

MØDACC - Input-integer-default = -1. MØDACC ≥ 0 requests computation of MDD (meaningful only if FØRM = MØDAL)

4.58.7 Method

If extra points are present (NØUE≥0) and multipoint constraints or omitted coordinates are present (MPCF1≥0 or ØMIT≥0), then

$$GM \Rightarrow GMD, \tag{1}$$

and

$$G\emptyset \Rightarrow G\emptyset D. \tag{2}$$

Subroutine GKAD1A performs these tasks.

If direct input matrices are present and m's, s's or o's are present, the direct input matrices are reduced from the p set to the d set. Let $[D^2_{pp}]$ be a direct input matrix,

$$[D^2_{pp}] = [K^2_{pp}], [M^2_{pp}] \text{ or } [B^2_{pp}]$$

1. If m's are present,

$$[D^2_{pp}] \Longrightarrow \left[\begin{array}{c|c} \bar{D}^2_{nn} & \bar{D}^2_{nm} \\ \hline \bar{D}^2_{mn} & \bar{D}^2_{mm} \end{array}\right] . \qquad (3)$$

(The e coordinates are included with the n coordinates). Then compute:

$$[D^2_{nn}] = [\bar{D}^2_{nn}] + [\bar{D}^2_{nm}]\,[G^d_m] + [G^d_m]^T\,[\bar{D}^2_{mn}] + [G^d_m]^T\,[\bar{D}^2_{mn}]\,[G^d_m] .$$

2. If s's are present,

$$[D^2_{ff}] \Longrightarrow \left[\begin{array}{c|c} D^2_{ff} & D^2_{fs} \\ \hline D^2_{sf} & D^2_{ss} \end{array}\right] , \qquad (5)$$

where only $[D^2_{ff}]$ is saved. The e coordinates are included with the f coordinates.

3. If o's are present, first partition $[D^2_{ff}]$

$$[D^2_{ff}] \Longrightarrow \left[\begin{array}{c|c} \bar{D}^2_{dd} & \bar{D}^2_{do} \\ \hline \bar{D}^2_{od} & \bar{D}^2_{oo} \end{array}\right] , \qquad (6)$$

then:

$$[D^2_{dd}] = [\bar{D}^2_{dd}] + [\bar{D}^2_{do}]\,[G^d_o] + [G^d_o]^T\,[D_{od}] + [G^d_o]^T\,[\bar{D}^2_{oo}]\,[G^d_o]. \qquad (7)$$

Steps 1 through 3 are done for K2PP, M2PP and B2PP, using subroutines GKAD1C and GKAD1D.

If FØRM = MØDAL and MØDACC < 0, GKAD is done. If not, the a set matrices are expanded to the d set by adding zeros at extra points. Let $[D_{aa}]$ be an a set matrix. Then,

$$\left[\begin{array}{c|c} D_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Longrightarrow \quad [D^{1}_{dd}] \ . \tag{8}$$

The above step is done for KAA, BAA, MAA, and K4AA and is performed in subroutine GKAD1B.

Compute KDD, BDD and MDD.

1. For Frequency Response or Complex Eigenvalue Analysis (TYPE ≠ TRAN),

$$[K_{dd}] = (1+iG)\,[K^{1}_{dd}] + [K^{2}_{dd}] + i\,[K^{14}_{dd}] \ , \tag{9}$$

$$[B_{dd}] = [B^{1}_{dd}] + [B^{2}_{dd}] \ , \tag{10}$$

$$[M_{dd}] = [M^{1}_{dd}] + [M^{2}_{dd}] \ . \tag{11}$$

2. For Transient Analysis (TYPE = TRAN),

$$[K_{dd}] = [K^{1}_{dd}] + [K^{2}_{dd}] \ , \tag{12}$$

$$[B_{dd}] = [B^{1}_{dd}] + [B^{2}_{dd}] + \frac{G}{W3}\,[K^{1}_{dd}] + \frac{1.0}{W4}\,[K^{14}_{dd}] \ , \tag{13}$$

$$[M_{dd}] = [M^{1}_{dd}] + [M^{2}_{dd}] \ . \tag{14}$$

If W3 or W4 is zero, the corresponding matrices are ignored.

4.58.8 Subroutines

GKAD uses matrix utility routines SSG2C, CALCV, MERGE, UPART, MPART and ELIM. Descriptions for these routines can be found in section 3.

4.58.8.1 Subroutine Name: GKAD1A

1. Entry Point: GKAD1A

2. Purpose: To expand GM or GØ to d size matrices:

$$[G_m \vdots o] \Rightarrow [G_m^d] \tag{15}$$

3. Calling Sequence: CALL GKAD1A (USETD,GØ,GØD,SCR1,UE,UA,UNE)

   USETD - GINØ file number of USETD - integer - input.

   GØ - GINØ file number of GØ - integer - input.

   GØD - GINØ file number of GØD - integer - input.

   SCR1 - GINØ file number of scratch file - integer - input.

   UE - Pointer to UE bit in USETD word - integer - input.

   UA - Pointer to UA bit in USETD word - integer - input.

   UNE - Pointer to UNE bit in USETD word - integer - input.

4.58.8.2 Subroutine Name: GKAD1B

1. Entry Point: GKAD1B

2. Purpose: To expand a set matrices to d set size.

3. Calling Sequence: CALL GKAD1B (USETD,KAA,MAA,BAA,K4AA,K1DD,M1DD,B1DD,K41DD,UA, UE,UD,SCR1)

   USETD - GINØ file number of USETD - integer - input.

   KAA - GINØ file number of KAA - integer - input.

   MAA - GINØ file number of MAA - integer - input.

   BAA - GINØ file number of BAA - integer - input.

   K4AA - GINØ file number of K4AA - integer - input.

K1DD - GINØ file number of K1DD - integer - input.

M1DD - GINØ file number of M1DD - integer - input.

B1DD - GINØ file number of B1DD - integer - input.

K41DD - GINØ file number of K41DD - integer - input.

SCR1 - GINØ file number of scratch file - integer - input.

UA - Pointer to UA bit in USETD word - integer - input.

UE - Pointer to UE bit in USETD word - integer - input.

UD - Pointer to UD bit in USETD word - integer - input.

4.58.8.3 Subroutine Name: GKAD1C

1. Entry Point: GKAD1C
2. Purpose: To initialize GKAD1D.
3. Calling Sequence: CALL GKAD1C (GMD,GØD,SCR1,SCR2,SCR3,SCR4,SCR5,SCR6,USETD)
   GMD,GØD,USETD are GINØ file numbers of their respective data blocks - integer - input.
   SCR1,...,SCR6 are GINØ file numbers of six scratch files - integer - input.

4.58.8.4 Subroutine Name: GKAD1D

1. Entry Point: GKAD1D
2. Purpose: To reduce "2PP" matrices to "2DD" matrices.
3. Calling Sequence: CALL GKAD1D (K2PP,K2DD)
   K2PP - GINØ file number of input matrix - integer - input.
   K2DD - GINØ file number of reduced matrix - integer - input.

4.58.9 Design Requirements

Six scratch files are necessary. Open core for GKAD1A and GKAD1B is defined at /GKADA1/. Open core for GKAD1C and GKAD1D is defined at /GKADC1/.

4.58.10 Diagnostic Messages

None

4.59 FUNCTIONAL MODULE CEAD (COMPLEX EIGENVALUE ANALYSIS - DISPLACEMENT)

4.59.1 Entry Point: CEAD

4.59.2 Purpose

To solve the equation

$$\left([M]p^2 + [B]p + [K]\right)\{u\} = \{0\} \qquad (1)$$

for the eigenvalues p and the associated eigenvectors {u} where [M], [B] and [K] are mass, damping and stiffness matrices respectively.

4.59.3 DMAP Calling Sequence

```
CEAD     KDD,BDD,MDD,EED,CASECC/PHID,CLAMA,ØCEIGS/V,N,NFØUND   $
```

4.59.4 Input Data Blocks

KDD - Dynamic stiffness matrix - d set.

BDD - Dynamic damping matrix - d set.

MDD - Dynamic mass matrix - d set.

EED - Eigenvalue Extraction Data.

CASECC - Case Control Data Table.

Notes:

1. EED must be present.
2. CASECC must be present.
3. At least one of KDD, BDD and MDD must be present.

4.59.5 Output Data Blocks

PHID - Complex eigenvectors in the d set.

CLAMA - Complex eigenvalue table.

ØCEIGS - Complex eigenvalue summary table.

Note: No output data block can be purged.

4.59.6 Parameters

NFØUND - Output-integer-no default. NFØUND indicates the number of eigenvalues found. If none were found, NFØUND is set to -1.

4.59.7 Method

The Complex Eigenvalue Analysis Module calculates the eigenvalues and eigenvectors for a general system which may have complex terms in the mass, damping, and stiffness matrices. The eigenvectors are scaled according to the user-requested normalization scheme. Modal masses are not calculated since they will, in general, be complex, and their value is rather dubious. The form of the problem solved by the Complex Eigenvalue Analysis Module is given in Equation 1.

The eigenvalues p and the eigenvectors {u} are always treated as complex. These data are related to the u_d displacements if a direct formulation is used or are related to the u_h displacements if a modal formulation is used. The method to be used and the necessary data are selected by calling for one ID number in the EED data block. A set of EED data which defines either the Determinant Method or the Inverse Power Method must be used. Subroutine CINVPR or CDETM is called to solve the eigenvalue problem (see subroutine descriptions below for method details). The eigenvalues and associated vectors are sorted by the magnitude of the imaginary part of the eigenvalue with all positives listed ahead of all negatives. (Subroutine CEAD1A).

4.59.8 Subroutines

The subroutines used by CEAD can be divided into four groups: 1) those used by CEAD; 2) those used for the Inverse Power Method; 3) those used by the Determinant Method; and, 4) general utility routines. The descriptions of the utility routines can be found in section 3.

CEAD	Inverse Power		Determinant	General
CEAD1A	CINVPR	CINFBS	CDETM	CDCØMP
	CINVP1	CMTIMU	CDETM2	ADD
	CINVP2	CXTRNY	CSUMM	PRELØC
	CINVP3	CSUB	CSQRT	
	CNØRM	ØRTHØ	CDTFBS	
	CNØRM1	CDIFBS	CDETM3	
	CDIVID	CSQRTX		

4.59.8.1 Subroutine Name: CEAD1A

1. Entry Point: CEAD1A

2. Purpose: To sort the eigenvectors and eigenvalues.

3. Calling Sequence: CALL CEAD1A (LAMAI,PHII,LAMAØ,PHIØ,NFØUND)

LAMAI - GINØ file number of unsorted eigenvalues - integer - input.

PHII - GINØ file number of unsorted eigenvectors - integer - input.

LAMAØ - GINØ file number of data block CLAMA - integer - input.

PHIØ - GINØ file number of data block PHID - integer - output.

NFØUND - Number of eigenvalues found - integer - input.

4.59.8.2 Subroutine Name: CINVPR

1. Entry Point: CINVPR

2. Purpose: CINVPR is the main driver for the Complex Inverse Power Method of eigenvalue extraction.

3. Calling Sequence: CALL CINVPR (EED,METHØD,NFØUND)

CØMMØN /CINVPX/K(7),M(7),B(7),LAM(7),PHI(7),EIGSUM,SCRFIL(11),NØREG,EPS,REG(7,10)

CØMMØN /CINVX/Z(1)

K,M,B - Input matrix control blocks for the stiffness, mass, and damping matrices [K], [M], and [B].

LAM,PHI - Matrix control blocks for the output eigenvalue and eigenvector files.

EIGSUM - The output eigenvalue summary file.

SCRFIL(11) - Eleven scratch files available to Inverse Power.

NØREG - Number of regions input to CINVPR.

EPS - Convergence criterion.

REG(7,10) - Storage space for up to 10 region parameters.

Z(1) - Open core for CINVPR.

EED - GINØ file number for this input data block.

METHØD - ID of an EIGC card for the Inverse Power Method.

NFØUND - Number of eigenvalues found.

4. Method: Complex Inverse Power was, in general, designed identically to Real Inverse Power. The notable exceptions are in the iteration equation and the orthogonalization with respect to previously extracted eigenvectors. With these points in mind, the basic flow can be taken from READ in section 4.48. Theoretical development is given in the Theoretical Manual.

4.59.8.3 Subroutine Name: CINVP1

1. Entry Point: CINVP1

2. Purpose: To generate calling sequences to ADD to form

$$[A] = [K] + \lambda[B] + \lambda^2[M]. \qquad (2)$$

3. Calling Sequence: CALL CINVP1

CØMMØN /CINVPX/ K(7),M(7),B(7),DUM(15),A

CØMMØN /CINV1X/Z(1)

CØMMØN /CINVXX/ LAMBDA

K,M,B - Matrix control blocks for the input matrices.

A - GINØ file number for the output matrix.

Z(1) - Area of open core available to ADD.

LAMBDA - Complex double precision scalar multiplier.

4.59.8.4 Subroutine Name: CINVP2

1. Entry Point: CINVP2

2. Purpose: To initialize and call CDCØMP for subroutine CINVPR.

3. Calling Sequence: CALL CINVP2

```
CØMMØN /CINVPX/ DUM(36),A,XX,L,U,SCR1,SCR2,SCR3,LL,UU
CØMMØN /CINVXX/DUMM(4),SWITCH
CØMMØN /CINV2X/Z(1)
```

A	-	GINØ file number for the input matrix.
L,U	-	GINØ file number for the lower and upper triangular factors output from CDCØMP.
SCR1,SCR2,SCR3	-	Three scratch files used by CDCØMP.
LL,UU	-	GINØ file numbers for alternate storage of L and U.
SWITCH	-	0, store factors on L and U. 1, store factors on LL and UU.
Z(1)	-	Area of open core used by CDCØMP.

4.59.8.5 Subroutine Name: CINVP3

1. Entry Point: CINVP3

2. Purpose: To solve for a complex eigenvalue and eigenvector using the Inverse Power Method.

3. Calling Sequence: CALL CINVP3

CØMMØN /CINVPX/K(7),M(7),B(7),LAM(7),PHI(7),XXX,SCRFIL(11)

CØMMØN /CINV3X/Z(1)

See section 4.59.8.2 above for details on /CINVPX/.

Z(1) - Area of open core available in CINVP3.

4. Method: The logic flow and the mathematical equations are essentially identical to INVP3, with the following exceptions. The eigenvalues and eigenvectors are found corresponding to the matrix equation

$$(\lambda^2[M] + \lambda[B] + [K])\ [\Phi] = [0] \tag{3}$$

where the iteration equation is given by

$$(\lambda_o^2[M] + \lambda_o[B] + [K])\ \{W_n\} = -([B] + \lambda_o[M])\ \{u_{n-1}\} - [M]\ \{v_{n-1}\} \tag{4}$$

with

$$\{\bar{u}_n\} = \frac{1}{C_n}\{W_n\}\ , \tag{5}$$

$$\{\bar{v}_n\} = \lambda_o\{\bar{u}_n\} + \frac{1}{C_n}\ \{u_{n-1}\}\ , \tag{6}$$

$$\{u_n\} = \{\bar{u}_n\} - \sum_i \alpha_i\{\Phi_i\}, \tag{7}$$

$$\{v_n\} = \{\bar{v}_n\} - \sum_i \alpha_i\ \lambda_i\{\Phi_i\}, \tag{8}$$

and

$$\alpha_i = \frac{\{\Phi_i\}^T\ [\lambda_i[M]\{\bar{u}_n\} + [M]\ \{\bar{v}_n\} + [B]\ \{\bar{u}_n\}]}{\{\Phi_i\}^T\ (2\lambda_i\ [M] + [B])\ \{\Phi_i\}}\ . \tag{9}$$

where

Φ_i = Previously extracted right-hand vector,

$\bar{\Phi}_i$ = Previously extracted left-hand vector,

C_n = Largest element (in magnitude) of $\{W_n\}$, and

λ_i = Previously extracted eigenvalue.

The above equations replace Equations 19 through 22 in section 4.48. The calculation of the remaining equations remains the same except for the use of complex arithmetic. The left eigenvector is obtained by decomposing Equation 3 with $\lambda_o - \lambda_i$ and using CDIFBS to make the appropriate substitution using the factors from CDCØMP.

5. Design Requirements: CINVPS requires fourteen complex double precision vectors in core plus four GINØ buffers.

4.59.8.6 Subroutine Name: CNØRM

1. Entry Point: CNØRM

2. Purpose: To normalize successive iterated vectors such that the maximum element is equal to unity, and to return the normalizing divisor.

3. Calling Sequence: CALL CNØRM (X,DIV)

X - Input vector to be normalized.

DIV - Divisor which was used to normalize the vector corresponding to the argument X.

4.59.8.7 Subroutine Name: CNØRM1

1. Entry Point: CNØRM1

2. Purpose: To normalize a complex vector such that the largest magnitude of an element is equal to one.

3. Calling Sequence: CALL CNØRM (X,N)

X - Vector to be normalized.

N - Length of the vector (complex terms).

4.59.8.8 Subroutine Name: CINFBS

1. Entry Point: CINFBS

2. Purpose: To perform the forward-backward substitution necessary to solve an iteration of the Inverse Power Method.

3. Calling Sequence: CALL CINFBS (X,Y,BUF)

CØMMØN /CINFBX/L(7),U(7)

L,U - Matrix control blocks for the factors output from CDCØMP.

X - Complex double precision input vector.

Y - Complex double precision solution vector.

BUF - GINØ buffer.

4. Method: CINFBS is a stripped down version of GFBS. Both vectors reside in core, and only complex double precision arithmetic is used.

4.59.8.9 Subroutine Name: CDIFBS

1. Entry Point: CDIFBS

2. Purpose: To perform the forward-backward substitution necessary to solve for the left eigenvector.

3. Calling Sequence: CALL CDIFBS (X,BUF)

CØMMØN /CINVPX/DUM(41),UPRTRI,XXX,LØWTRI

UPRTRI,LØWTRI - Files containing the upper and lower triangular factors output from CDCØMP.

X - The output complex double precision left eigenvector.

BUF- GINØ buffer used by CDIFBS.

4. Method: CDIFBS actually solves the system of equations

$$[A]^T \{x\} = \{y\}, \qquad (10)$$

where [A] has been decomposed into [A] = [L] [U]. To solve the transpose problem we have that

$$[A]^T = ([L][U])^T = [U]^T [L]^T \tag{11}$$

so that

$$[U]^T [L]^T \{x\} = \{y\}. \tag{12}$$

CDIFBS is a modified form of GFBS which does the forward pass on [U] and the backward pass on [L]. All arithmetic operations are complex double precision.

4.59.8.10 Subroutine Name: CMTIMU

1. Entry Point: CMTIMU

2. Purpose: To pre-multiply a vector {y} by a matrix to obtain a vector {x}.

3. Calling Sequence: CALL CMTIMU (Y,X,FILE,BUF)

CØMMØN /CINVPX/DUM(7),M(7)

FILE - If FILE = 0, form {x} = [M]{y}.
FILE ≠ 0, form {x} = [A] {y}, where [A] is the matrix on FILE.

X,Y - Complex double precision vectors.

BUF - GINØ buffer.

4.59.8.11 Subroutine Name: CXTRNY

1. Entry Point: CXTRNY

2. Purpose: To form the inner product of two complex vectors, {x} and {y}

$$a = \{x\}^T \{\bar{y}\}, \tag{13}$$

where $\{\bar{y}\}$ denotes a vector all of whose components are the complex conjugates of {y}.

3. Calling Sequence: CALL CXTRNY (X,Y,A)

CØMMØN /CINVPX/XX,N

N - Length of the vectors.

X,Y - Complex double precision vectors.

A - Complex double precision value of the inner product of {x} and {y}.

4.59.8.12 Subroutine Name: CSUB

1. Entry Point: CSUB

2. Purpose: To evaluate the vector equation

$$\{z\} = a\{x\} - b\{y\}, \tag{14}$$

where {x}, {y}, a and b may be complex.

3. Calling Sequence: CALL CSUB (X,Y,Z,A,B)

CØMMØN /CINVPX/XXX,N

N - Length of the vectors {x} and {y}.

X,Y,Z - Complex double precision vectors.

A,B - Complex double precision scalar multipliers.

4.59.8.13 Subroutine Name: ØRTHØ

1. Entry Point: ØRTHØ

2. Purpose: To orthogonalize a vector with respect to all previously extracted vectors.

3. Calling Sequence: CALL ØRTHØ (U,V,X1,X2,X3,X4,X5,NZ,BUF1,BUF2,BUF3,BUF4)

CØMMØN /CINVPX/K(7),M(7),B(7),LAMBDA(7),PHI(7),XXX,SCRFIL(10)

CØMMØN /CINVXX/DUM(19),NRØØTS

See section 4.59.8.2 for /CINVPX/ details.

NRØØTS - Number of eigenvectors already extracted.

U,V - Input-current vectors - Output - orthogonalized vectors.

X1,...,X5- Storage space for five complex double precision vectors.

NZ - The number of words of core available to ØRTHØ.

BUF1, ..., BUF4 - Four GINØ buffers.

4. Method: ØRTHØ solves the equations

$$\{u_n\} = \{u_n\} - \sum_i \alpha_i \lambda_i \{\Phi_i\}, \tag{15}$$

$$\{v_n\} = \{v_n\} - \sum_i \alpha_i \lambda_i \{\Phi_i\}, \tag{16}$$

where

$$\alpha_i = \frac{\{\bar{\Phi}_i\}^T[\lambda_i[M] \{u_n\} + [M] \{v_n\} + [B] \{u_n\}]}{\{\bar{\Phi}_i\}^T[2 \lambda_i[M] + [B]] \{\Phi_i\}} \tag{17}$$

and

$\{\bar{\Phi}_i\}$ = Previously found left eigenvectors.

$\{\Phi_i\}$ = Previously found right eigenvectors.

λ_i = Previously found eigenvalues.

Note that the demoninator of equation 17 is constant with respect to the current iterate u_n and v_n. Thus it is computed once for each vector and saved on the left vector scratch file in place of the left vector.

4.59.8.14 Subroutine Name: CDETM

1. Entry Point: CDETM

2. Purpose: To solve the complex eigenvalue problem by the Determinant Method.

3. Calling Sequence: CALL CDETM (METHØD,EED,M,B,K,LAMA,PHID,ØCEIGS,NFØUND,SCR1,SCR2, SCR3,SCR4,SCR5,SCR6,SCR7,SCR8)

METHØD - ID of an EIGC card for the Determinant Method - integer - input.

EED,ØCEIGS, M,B,K - GINØ file numbers of their respective data blocks - integer - input.

LAMA - GINØ file number of temporary eigenvalue storage file - integer - input.

PHID - GINØ file number of temporary eigenvector storage file - integer - input.

NFØUND - Number of eigenvalues found - integer - output.

SCR1,SCR2, ...,SCR8 - GINØ file numbers of 8 scratch files - integer - input.

4. Method: The overall flow and theoretical considerations of the Determinant Method are explained in section 4.88. Two refinements are made in CDETM. The first is the handling of multiple search regions, which allows the user to control the distribution of starting points in the complex plane. See the EIGC bulk data card description in section 2 of the User's Manual for further details. The second is the use of the EIGP card to define poles which will be swept from the determinant as if they were previously accepted eigenvalues. This allows the user to prevent convergence to known or already extracted eigenvalues.

5. Design Requirements: CDETM requires two complex double precision d set vectors plus one GINØ buffer in core.

4.59.8.15 Subroutine Name: CDETM2

1. Entry Point: CDETM2

2. Purpose: To arrange 3 starting points in order of the magnitude of the determinant.

3. Calling Sequence: CALL CDETM2(P,D,IP,PR,PI,DR,DI,IPS)

P - Three starting point values - input-complex double precision.

D - Scaled determinants at P - input-complex double precision.

IP - Scale factors for D - input - integer.

PR - Real parts of the reordered starting points - output-double precision.

PI - Imaginary parts of the reordered starting points - output-double precision.

DR - Real parts of the reordered determinants - output-double precision.

DI - Imaginary parts of the reordered determinants - output-double precision.

IPS - Scale factors of the reordered determinants - output - integer.

4.59.8.16 Subroutine Name: CSUMM

1. Entry Point: CSUMM

2. Purpose: To add two scaled complex numbers together.

3. Calling Sequence: CALL CSUMM (D1,D2,ID1,D3,D4,ID2,D5,D6,ID3)

The arguments are defined in the following equation:

$$(D1,D2) \times 10^{ID1} + (D3,D4) \times 10^{ID2} = (D5,D6) \times 10^{ID3}, \qquad (18)$$

where all Di's are double precision.

4.59.8.17 Subroutine Name: CSQRT

1. Entry Point: CSQRT

2. Purpose: To compute the positive principal square root of a scaled complex number.

3. Calling Sequence: CALL CSQRT (D1,D2,ID1,D3,D4,ID2)

The arguments are defined in the following equation:

$$(D3,D4) \times 10^{ID2} = \sqrt{(D1,D2) \times 10^{ID1}} \qquad (19)$$

where all Di's are double precision.

4.59.8.18 Subroutine Name: CDTFBS

1. Entry Point: CDTFBS

2. Purpose: To solve for the eigenvector given the decomposed impedance matrix.

3. Calling Sequence: CALL CDTFBS (F,EV,BUFFER(1),FU,NRØW)

F - Applied complex load vector - input-complex double precision.

EV - Eigenvector - output- complex double precision.

BUFFER(1) - GINØ buffer.

FU - Matrix control block for [U] - integer - input.

NRØW - Order of problem - integer - input.

4.59.8.19 Subroutine Name: CDETM3

1. Entry Point: CDETM3

2. Purpose: To rescale a scaled complex number.

3. Calling Sequence: CALL CDETM3(D1,D2,ID1)

Let $\overline{D1}$, $\overline{D2}$, $\overline{ID1}$ be the input values of D1, D2, ID1. On return from CDETM3

$$(D1,D2) \times 10^{ID1} = (\overline{D1},\overline{D2}) \times 10^{\overline{ID1}} , \tag{20}$$

and

$$1.0 \leq |(D1,D2)| \leq 10.0 , \tag{21}$$

where all Di's are double precision.

4.59.8.20 Subroutine Name: CDIVID

1. Entry Point: CDIVID

2. Purpose: To divide a complex vector by a complex number.

3. Calling Sequence: CALL CDIVID (DIV,V,V1,NV)

where V is a complex D.P. vector of length NV to be divided by DIV and the answer put in V1.

4.59.9 Design Requirements

Open core is defined at /CEAD1X/ to process EED. Open core is defined at /CEADA1/ for use by CEAD1A.

4.60 FUNCTIONAL MODULE VDR (VECTOR DATA RECOVERY)

4.60.1 Entry Point: VDR

4.60.2 Purpose

VDR formats data blocks for input to the Output File Processor (ØFP) and XY plot (XYPLØT) modules to provide a capability for output of vectors in the solution set.

4.60.3 DMAP Calling Sequence

```
VDR     CASECC,EQDYN,USETD,UDV,PP,XYCDB,PNL/ØUDV1,ØPNL1/
        C,N,{TRANRESP / FREQRESP / CEIGN} /C,N,{DIRECT / MØDAL} /V,N,SØRT2/V,N,ØUTPUT/V,N,SDR2/V,N,FMØDE   $
```

4.60.4 Input Data Blocks

CASECC - Case Control Data Table.

EQDYN - Equivalence between external and internal number - Dynamics.

USETD - Displacement set definitions table - Dynamics.

UDV - Partition of Displacement Vector.

PP - Dynamic Load Vector.

XYCDB - XY Control Data Block.

PNL - Non-Linear Load Vector.

Notes:

1. CASECC, EQDYN and USETD may not be purged.
2. PP may be purged only if UDV is purged.
3. PNL and XYCDB may be purged.

4.60.5 Output Data Blocks

ØUDV1 - Output Displacement Requests - Solution set.

ØPNL1 - Output Non-Linear Load Requests - Solution set.

Note: Output data blocks may be purged.

4.60.6 Parameters

The first parameter indicates a Rigid Format and must be one of the three names shown above. The second parameter indicates a direct or modal formulation and must be one of the two names shown above.

SØRT2 - Output-integer-no default. +1 if any SØRT2 output is requested, -1 otherwise.

ØUTPUT - Output-integer-no default. +1 if any output in the solution set is requested, -1 otherwise.

SDR2 - Output-integer-no default. +1 if any requests for output in the physical set are found in CASECC or XYCDB, -1 otherwise.

FMØDE - Input-integer-no default. If a modal formulation, FMØDE = mode number of the first mode. FMØDE is not used in a direct formulation.

4.60.7 Method

4.60.7.1 General

VDR is the main control program for the module. VDRA is called to analyze the Case Control (CASECC) and XYCDB data blocks. If any requests for solution set output are found, VDRB is called to assemble the ØUDV1 output data block for processing by the ØFP. If the problem is a transient response problem, VDRB is called a second time to process any requests for non-linear load output.

4.60.7.2 Analysis of the Case Control and XYCDB Data Blocks

VDRA attempts to open the XYCDB data block. If it is purged, a return is given to VDR. Otherwise, the header record and first data record of XYCDB are skipped, and data applying to all subcases are read from the second data record. If no such data exist, a dummy master is created. Otherwise, the master data are reduced to a list of unique pairs. If only master data exist, flags are set appropriately.

For each record in the Case Control data block the following processing occurs:

1. The record is read into core. If no XYCDB subcase corresponds to the Case Control subcase, pointers are set to the master data. Otherwise, the master data and appropriate XYCDB subcase data are merged and reduced to unique pairs.

2. For each request for solution set output in XYCDB, the corresponding request in Case Control is examined. If no request is present in Case Control, the XYCDB request is reduced to a set in Case Control format, and a request for the set is turned on in Case Control. If the Case Control set is "ALL", no further action is taken. If the Case Control request is a set, the set is merged with the XYCDB set, and the request altered to reflect the new set (unless all points in the XYCDB set were already in the Case Control set). A flag is set if any new requests are formed.

3. When all requests for the current Case Control record have been analyzed, the record (as modified) is written on a scratch file.

4. When all Case Control records have been read, the GINØ file name for the Case Control data block is switched to the scratch file (unless no modifications were made to Case Control).

4.60.7.3 Preparation of Solution Set Output

The operations of VDRB are dependent on the Rigid Format being executed. VDRB operates in all six of the dynamics Rigid Formats. The initial operations in VDRB proceed as follows:

1. For a direct solution, or a modal solution with extra points, the second record of EQDYN is read into core. USETD is read into core.

2. If the problem is a direct solution, each entry in EQDYN is processed. The scalar index value (the 2nd word of each entry) is replaced by the scalar index value in the solution set plus a code indicating which components of the point are in the solution set.

3. If the problem is a modal solution with extra points, the scalar index of each extra point in EQDYN is replaced with a scalar index in the solution set. The scalar indices of all other points are replaced with zero.

4. If the problem is a complex eigenvalue problem, a list of mode numbers and complex eigenvalues is read into core from the CLAMA data block.

5. If the problem is a transient response problem, a list of times is read into core from the PP data block.

6. If the problem is a frequency response problem, a list of frequencies is read into core from the PP data block.

7. The header record on the input file is skipped, and various parameters are initialized for the overall processing.

A record on the Case Control data block is read. The output request is examined. If the output is defined in terms of a set, pointers to the set definition are computed. The vector is unpacked in core (unless the vector is already in core in the case of velocities and accelerations for frequency problems).

Information is assembled to write the identification record on the output data block as follows.

1. For complex eigenvalues, the mode number and eigenvalue are picked up from the list in core.

2. For frequency response, the frequency is picked up from the list in core. A comparison with the ØFREQ selection in Case Control is made. If the current frequency is not marked for output, the remainder of the calculations for the current vector are skipped.

3. For a transient problem, the time is picked up.

The identification record is written. Entries are written in the data record according to the request. The modified EQDYN table in core is used to pick up points in the vector to be output. Conversion to magnitude and phase is made if requested.

When all points in the current request have been processed, post processing occurs depending on the problem type as follows:

1. For complex eigenvalues, a pointer is updated to the next mode number and eigenvalue. If all eigenvectors have not been processed, the steps above are repeated. Otherwise, terminal processing is initiated.

2. For frequency response, if the vector just processed was a displacement vector, the corresponding velocity vector is determined by differentiating with respect to time.

$$\{v\} = iw\ \{u\}. \tag{1}$$

Similarly, if the vector just processed was a velocity vector, the corresponding acceleration vector is formed by differentiating with respect to time:

$$\{a\} = iw\ \{v\}. \tag{2}$$

If all vectors have not been processed, the steps above are repeated. Otherwise, terminal processing is initiated.

3. For transient response, pointers are updated so that the vectors will be processed in the order a) displacement, b) velocity, and c) acceleration. If all vectors have not been processed, the steps above are repeated. Otherwise, terminal processing is initiated.

The terminal processing consists of closing all files, writing a trailer on the output file and exiting.

4.60.8 Subroutines

4.60.8.1 Subroutine Name: VDR

1. Entry Point: VDR

2. Purpose: Main control program for the module.

3. Calling Sequence: CALL VDR

4.60.8.2 Subroutine Name: VDRA

1. Entry Point: VDRA

2. Purpose: To analyze the output requests in the Case Control and XYCDB data blocks.

3. Calling Sequence: CALL VDRA

4.60.8.3 Subroutine Name: VDRB

1. Entry Point: VDRB

2. Purpose: To process requests for solution set output and assemble the output data block.

3. Calling Sequence: CALL VDRB (INFIL,ØUTFL,IREQ)

INFIL - GINØ file name of the data block containing vectors to be output in the solution set.

ØUTFL - GINØ file name of the data block where solution set output will be written.

IREQ - Word position in the Case Control record where solution set output request is defined.

4.60.9 Design Requirements

4.60.9.1 Allocation of Core Storage

The maximum storage requirements for the module are in VDRB. A general picture of core storage is as follows:

CØMMØN/VDRCØR/Z(1)

1	EQDYN Table	2 words per entry, one entry for each point in the problem.
ILIST	List of eigenvalues, frequencies or times	1, 2 or 3 words per entry, one entry for each eigenvalue, frequency or time.
ICC+1	Case Control record	
IVEC	Unpacked Vector	One word for each degree of freedom in the solution set. (two words if complex).
BUF3	Buffer for input file	
BUF2	Buffer for output file	
BUF1	Buffer for Case Control	

4.60.9.2 Environment

The Block Data program VDRBD initializes /VDRCØM/ with GINØ file names, data defining position of parameters in a Case Control record, data defining rigid formats and problem types, and miscellaneous data. It must be in core when VDR is executed.

The module VDR is designed to be executed as one overlay segment. Open core is defined by /VDRCØR/. Two scratch files are used.

4.61 FUNCTIONAL MODULE FRRD (FREQUENCY RESPONSE - DISPLACEMENT APPROACH)

4.61.1 Entry Point: FRRD

4.61.2 Purpose

To solve the matrix equation

$$[-\omega_i^2 [M] + i\omega [B] + [K]] [X] = [P(\omega_i)] \quad (1)$$

at a given set of frequencies ω_i and loads P (which may be functions of ω_i).

4.61.3 DMAP Calling Sequence

```
FRRD    CASECC,USETD,DLT,FRL,GMD,GØD,KHH,BHH,MHH,PHIDH,DIT/UHV,PS,PD,PP/V,N,APP/V,N,FØRM/
        V,N,LUSETD/V,N,MPCF1/V,N,SINGLE/V,N,ØMIT/V,N,NØNCUP/V,N,FRQSET/C,Y,DECØMØPT=1 $
```

4.61.4 Input Data Blocks

CASECC - Case Control Data table.

USETD - Displacement set definitions table dynamics.

DLT - Dynamic Loads Table.

FRL - Frequency Response List.

GMD - Multipoint constraint transformation matrix - dynamics.

GØD - Omitted coordinate transformation matrix - dynamics.

KHH - Modal stiffness matrix - h set.

BHH - Modal damping matrix - h set.

MHH - Modal mass matrix - h set.

PHIDH - Transformation matrix from d set to modal coordinates.

DIT - Direct Input Tables.

Notes:
1. CASECC cannot be purged.
2. USETD cannot be purged.
3. DLT cannot be purged.
4. FRL cannot be purged.
5. GMD cannot be purged if MPCF1 $\geq$ 0.
6. GØD cannot be purged if ØMIT $\geq$ 0.

7. PHIDH cannot be purged if FØRM = MØDAL.

8. DIT cannot be purged if a load uses tables.

4.61.5 Output Data Blocks

UHV - Displacement vectors.

PS - Partition of load vector matrix giving loads in s set.

PD - Load vectors - d set.

PP - Load vectors - p set.

Notes: 1. UHV, PD, and PP cannot be purged.

2. PS cannot be purged if SINGLE $\geq$ 0.

4.61.6 Parameters

APP - Input-BCD-no default. APP should be set equal to DISP.

FØRM - Input-BCD-no default. FØRM = MØDAL implies a modal solution should be used.

LUSETD - Input-integer-no default. LUSETD indicates length of p set.

MPCF1 - Input-integer-no default. MPCF1 $\geq$ 0 implies multipoint constraints present.

SINGLE - Input-integer-no default. SINGLE $\geq$ 0 implies single-point constraints present.

ØMIT - Input-integer-no default. ØMIT $\geq$ 0 implies omitted coordinates present.

NØNCUP - Input-integer-no default. NØNCUP = -1 implies noncoupled solution if FØRM = MØDAL

FRQSET - Output-integer-no default. FRQSET is the set id of the selected frequency list from CASECC.

DECØMØPT - Input-integer-default = 1. Selects type of arithmetic for equation solution.

1. Indicates double precision with pivoting.
2. Indicates double precision without pivoting.
3. Not used at present.
4. Indicates single precision without pivoting.

4.61.7 Method

4.61.7.1 Overview of the Method

The Frequency Response module for the displacement approach assembles a frequency-dependent load vector and solves for the steady-state, frequency response, displacement vectors. Various

load sets are defined as functions of frequency. Combinations of these sets are used with the various specified frequencies. Load vectors for each frequency are formed and reduced to loads on the proper degree of freedom. The solutions for both direct formulation and coupled modal formulation are identical except that different matrices are used. The solution involves a triangular decomposition and back substitution using the type of arithmetic selected by the parameter DECØMØPT for each frequency. The solutions for the uncoupled modal formulation are analytic equations.

4.61.7.2 Logical Phases

1. The load vectors for each desired frequency are assembled from the DLT data block. The DLØAD section of the DLT tells which load sets to use and what scale factors to use in combining the load sets. The data for each load set are given in the RLØAD section of the DLT. This work is done in subroutine FRRD1A.

2. The total load vectors are partitioned and manipulated to produce load vectors on the solution coordinates. This work is done in subroutine FRRD1B.

3. The matrix equation for displacements is now solved for each load combination and each frequency. The overall dynamic matrix is formed. The matrix is decomposed, and the displacements are formed by back substitution using the various loads. If the formulation is an uncoupled modal system, the displacements are calculated directly. This work is done by subroutines FRRD1C and FRRD1D or FRRD1F.

4. The solution vectors are then resorted into load-frequency order. This work is done by subroutine FRRD1E.

4.61.7.3 Algorithms

1. Assembly of Load Vectors:

The frequency set id is extracted from CASECC. This frequency set is placed in core from the FRL and converted from radians to frequency. These frequencies are output into the header of PP for later output identification. The load id is read from CASECC, found in DLT, and a table is constructed giving a simple id and a scale factor for each component. The DLT data are read for each simple id, and a list of the required tables is extracted. Core is allocated to hold as many load vectors as possible up to the number of

frequencies. If tables are present, they are initialized and evaluated for all frequencies in core. The DLT is read, and two types of loads are constructed:

1) RLØAD1

$$P(f) = A\,[C\,(f) + iD(f)]\,e^{\,i(\Theta-2\pi f\tau)}, \qquad (2)$$

2) RLØAD2

$$P(f) = A\, B(f)\, e^{i(\phi(f) + \Theta - 2\pi f\tau)} \tag{3}$$

where A, B, C, D, Θ, τ and ϕ are user input constants or tables.

If all frequencies cannot be evaluated at once, additional passes through the DLT are made until all are evaluated. If additional subcases exist in CASECC, the above steps are repeated for each load.

2. Manipulation of Load Vectors:

The vectors produced in the previous sections are related to the p set. They are reduced by the following steps using data blocks USETD, GMD and GØD.

If MPCF1 $\geq$ 0:

$$\{P_p\} \Longrightarrow \begin{Bmatrix} \bar{P}_{ne} \\ P_m \end{Bmatrix}, \tag{4}$$

$$\{P_{ne}\} = \{\bar{P}_{ne}\} + [G_m^d]^T \{P_m\}. \tag{5}$$

If SINGLE $\geq$ 0:

$$\{P_{ne}\} \Longrightarrow \begin{Bmatrix} P_{fe} \\ P_s \end{Bmatrix}. \tag{6}$$

$\{P_s\}$ is output on data block PS.

If ØMIT $\geq$ 0:

$$\{P_{fe}\} \Longrightarrow \begin{Bmatrix} \bar{P}_d \\ P_o \end{Bmatrix}, \tag{7}$$

$$\{P_d\} = \{\bar{P}_d\} + [G_o^d]^T \{P_o\}, \tag{8}$$

$\{P_d\}$ is output on PD.

If FØRM = MØDAL:

$$\{P_h\} = [\Phi_{dh}]^T \{P_d\}. \tag{9}$$

3. Solution Phase:

For a direct formulation the equation to be solved is:

$$[-\omega^2 [M_{dd}] + i\omega [B_{dd}] + [K_{dd}]] \{u_d\} = \{P_d(\omega)\}. \tag{10}$$

For a coupled modal formulation the equation to be solved is:

$$[-\omega^2 [M_{hh}] + i\omega[B_{hh}] + [K_{hh}]] \{u_h\} = \{P_n(\omega)\}. \quad (11)$$

The left hand matrix is generated by two calls to ADD and decomposed. The normal matrix decomposition checks are relaxed in these solutions. It is expected that the matrices will not pass the triangular decomposition at certain frequencies. The solution will proceed, and only a warning will be issued. The loads at the given frequency are collected from the load file and fed to GFBS for a forward backward substitution solution. If the decomposition failed, a zero vector will result.

For one uncoupled modal formulation the equations to be solved are:

$$\{\varepsilon_i\} = \left\{ \frac{P_i(\omega)}{-m_i\omega^2 + ib_i\omega + k_i} \right\}. \quad (12)$$

With zero damping the uncoupled modal formulation may produce division by small numbers. This fact is noted and the solution proceeds.

4. Order Phase:

Except for the uncoupled modal approach it may be necessary to reorder the solutions from a frequency / load sort to a load / frequency sort.

4.61.8 Subroutines

Utility subroutines PRETAB,TAB,CALCV,SSG2B,SSG2A,SSG2C,CDCØMP,SCDCMP,CSPSDC,CXFBS and GFBS are used. See subroutine descriptions, Section 3 for details.

4.61.8.1 Subroutine Name: FRRD1A

1. Entry Point: FRRD1A

2. Purpose: To assemble the user selected loads.

3. Calling Sequence: CALL FRRD1A (DLT,FRL,CASECC,DIT,PP,LUSETD,NFREQ,NLØAD,FRQSET)

DLT,FRL,CASECC,DIT,PP are GINØ file numbers of their respective data blocks - integer - input.

LUSETD - Length of p set - integer - input.

NFREQ - Number of frequencies in selected frequency set - integer - output.

NLØAD - Number of loads (records in CASECC) selected - integer - output.

FRQSET - Set id of selected frequency set - integer - output.

4.61.8.2 Subroutine Name: FRRD1B

1. Entry Point: FRRD1B

2. Purpose: To reduce loads from the p to the d (or h) set.

3. Calling Sequence: CALL FRRD1B (PP,USETD,GMD,GØD,MULTI,SINGLE,ØMIT,MØDAL,PHIDH, PD,PS,PH,SCR1,SCR2,SCR3,SCR4)

PP,USETD,GMD,GØD,PHIDH,PD,PS,PH are GINØ file numbers of their respective data blocks - integer - input.

MULTI - MULTI $\geq$ 0 implies m's are present - integer - input.

SINGLE - SINGLE $\geq$ 0 implies s's are present - integer - input.

ØMIT - ØMIT $\geq$ 0 implies o's are present - integer - input.

MØDAL - MØDAL = MØDA implies a modal formulation - BCD - input.

SCR1,...,SCR4 - GINØ file numbers of 4 scratch files - integer - input.

4.61.8.3 Subroutine Name: FRRD1C

1. Entry Point: FRRD1C

2. Purpose: To form and decompose "left" hand side of the frequency equation.

3. Calling Sequence: CALL FRRD1C (FRL,FRQSET,MDD,BDD,KDD,I,ULL,LLL,SCR1,SCR2,SCR3, SCR4,IGØØD)

FRL,MDD,BDD,KDD,ULL,LLL,SCR1-4 are GINØ file numbers of their respective data blocks - integer - input.

FRQSET - Set id of selected frequency set - integer - output.

I - Current frequency counter - integer - input.

IGØØD - IGØØD = 1 implies a singular matrix - integer - output.

4.61.8.4 Subroutine Name: FRRD1D

1. Entry Point: FRRD1D

2. Purpose: To solve for displacements given decomposition factors and loads.

3. Calling Sequence: CALL FRRD1D (PD,ULL,LLL,SCR1,SCR2,UDVP,I,NLØAD,IGØØD,NFREQ)

PD,ULL,LLL,UDVP,SCR1,SCR2 are GINØ file numbers of their respective data blocks - integer - input.

I - Current frequency count - integer - input.

NLØAD - Number of loads - integer - input.

IGØØD - IGØØD = 1 implies a singular matrix - integer - input.

NFREQ - Total number of frequencies - integer - input.

4.61.8.5 Subroutine Name: FRRD1E

1. Entry Point: FRRD1E

2. Purpose: To reorder displacements if necessary.

3. Calling Sequence: CALL FRRD1E (UDVP,UDV,NLØAD,I)

UDVP - GINØ file number of displacements sorted by frequency/load - integer - input.

UDV - GINØ file number of displacements sorted by load/frequency - integer - input.

NLØAD - Number of loads - integer - input.

I - Number of frequencies solved.

4.61.8.6 Subroutine Name: FRRD1F

1. Entry Point: FRRD1F

2. Purpose: To solve the uncoupled modal equations.

3. Calling Sequence: CALL FRRD1F (MHH,BHH,KHH,FRL,FRQSET,NLØAD,NFREQ,PH,UHV)

MHH,BHH,KHH,FRL,PH,UHV are GINØ file numbers of their respective data blocks. - integer - input.

FRQSET - Selected frequency set id-integer - input.

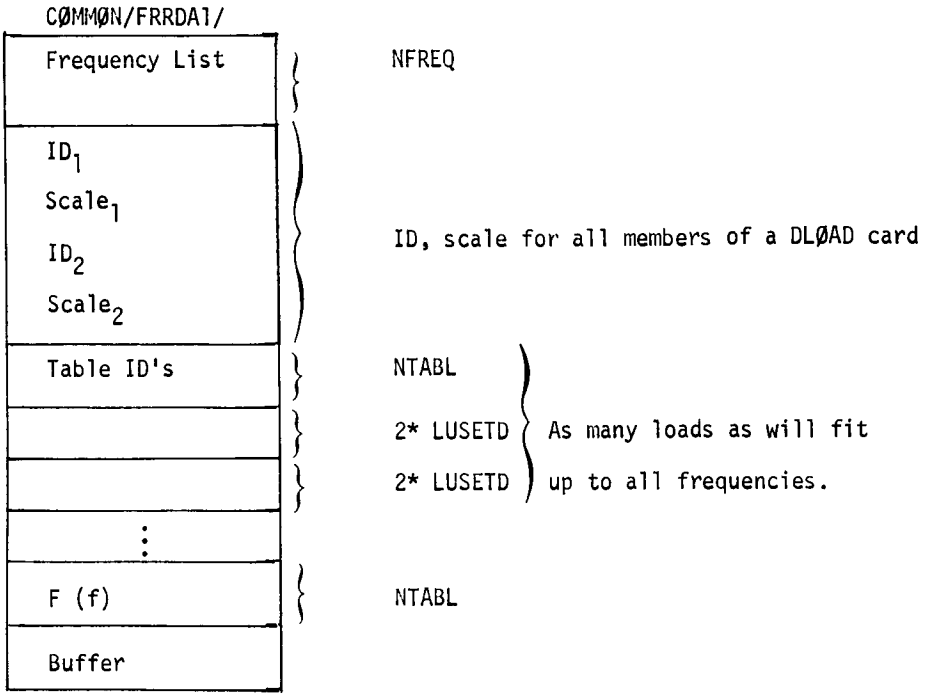
NFREQ - Number of frequencies in FRQSET - integer - input.

NLØAD - Number of loads (Subcases in current execution) - integer - input.

4.61.9 Design Requirements

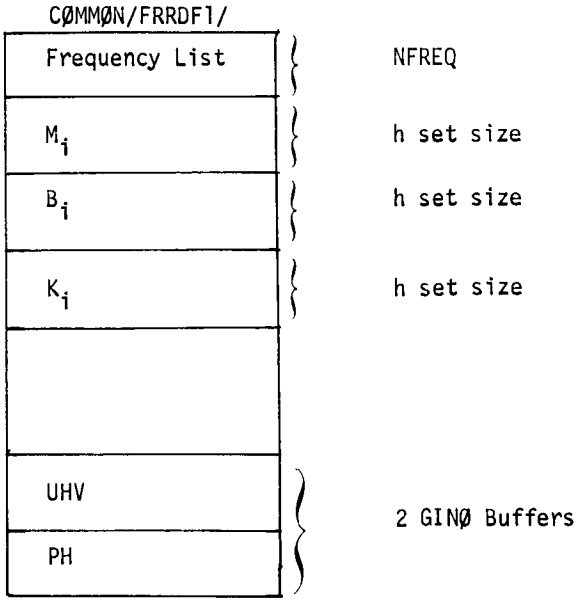
Eight scratch files are used by FRRD.

Open core at /FRRDA1/ is used as follows:



Open core at /FRRDB1/, /FRRDC1/, /FRRDD1/ are used by the matrix routines.

Open core at /FRRDF1/ is used as follows:



4.61.10 Diagnostic Messages

Module FRRD may issue the following diagnostic messages:

3005, 3008 and 3045.

4.62 FUNCTIONAL MODULE SDR3 (STRESS DATA RECOVERY - PHASE 3 - SØRT1 to SØRT2 PROCESSOR)

4.62.1 Entry Point: SDR3

4.62.2 Purpose

To transpose (perform SØRT2) data blocks containing data prepared for output in the form of ELEMENT-ID-SETS or PØINT-ID-SETS versus TIME-STEP or FREQUENCY-STEP to data prepared for output in the form of TIME-STEP-SETS or FREQUENCY-STEP-SETS versus ELEMENT-ID or PØINT-ID.

4.62.2.1 Example of SØRT1 and SØRT2 Output

Below is a table of ØFP printed output of SDR3 input (SØRT1) and output (SØRT2) data blocks.

SDR3 Input Data Block Printed (SØRT1)

TIME = 1.0		D I S P L A C E M E N T S				
POINT-ID	T1	T2	T3	R1	R2	R3
1	0.0	4.53	0.0	0.0	0.0	0.0
2	0.0	5.12	0.0	0.0	0.0	0.0
TIME = 2.0		D I S P L A C E M E N T S				
POINT-ID	T1	T2	T3	R1	R2	R3
1	0.0	4.83	0.0	0.0	0.0	0.0
2	0.0	5.53	0.0	0.0	0.0	0.0
TIME = 3.0		D I S P L A C E M E N T S				
POINT-ID	T1	T2	T3	R1	R2	R3
1	0.0	6.84	0.0	0.0	0.0	0.0
2	0.0	7.96	0.0	0.0	0.0	0.0

SDR3 Output Data Block Printed (SØRT2)

POINT-ID = 1		D I S P L A C E M E N T S				
TIME	T1	T2	T3	R1	R2	R3
1.0	0.0	4.53	0.0	0.0	0.0	0.0
2.0	0.0	4.83	0.0	0.0	0.0	0.0
3.0	0.0	6.84	0.0	0.0	0.0	0.0
POINT-ID = 2		D I S P L A C E M E N T S				
TIME	T1	T2	T3	R1	R2	R3
1.0	0.0	5.12	0.0	0.0	0.0	0.0
2.0	0.0	5.53	0.0	0.0	0.0	0.0
3.0	0.0	7.96	0.0	0.0	0.0	0.0

4.62.3 DMAP Calling Sequence

SDR3 IN1,IN2,IN3,IN4,IN5,IN6/ØUT1,ØUT2,ØUT3,ØUT4,ØUT5,ØUT6/ $

4.62.4 Input Data Blocks

One to six data blocks in any order desired. Input data blocks to SDR3 which are purged are ignored.

4.62.5 Output Data Blocks

One to six data blocks in corresponding order to that of the input data blocks. If SØRT2 is to be performed, there must be an available output data block for the corresponding input data block (Non-Fatal Error if this condition is not met).

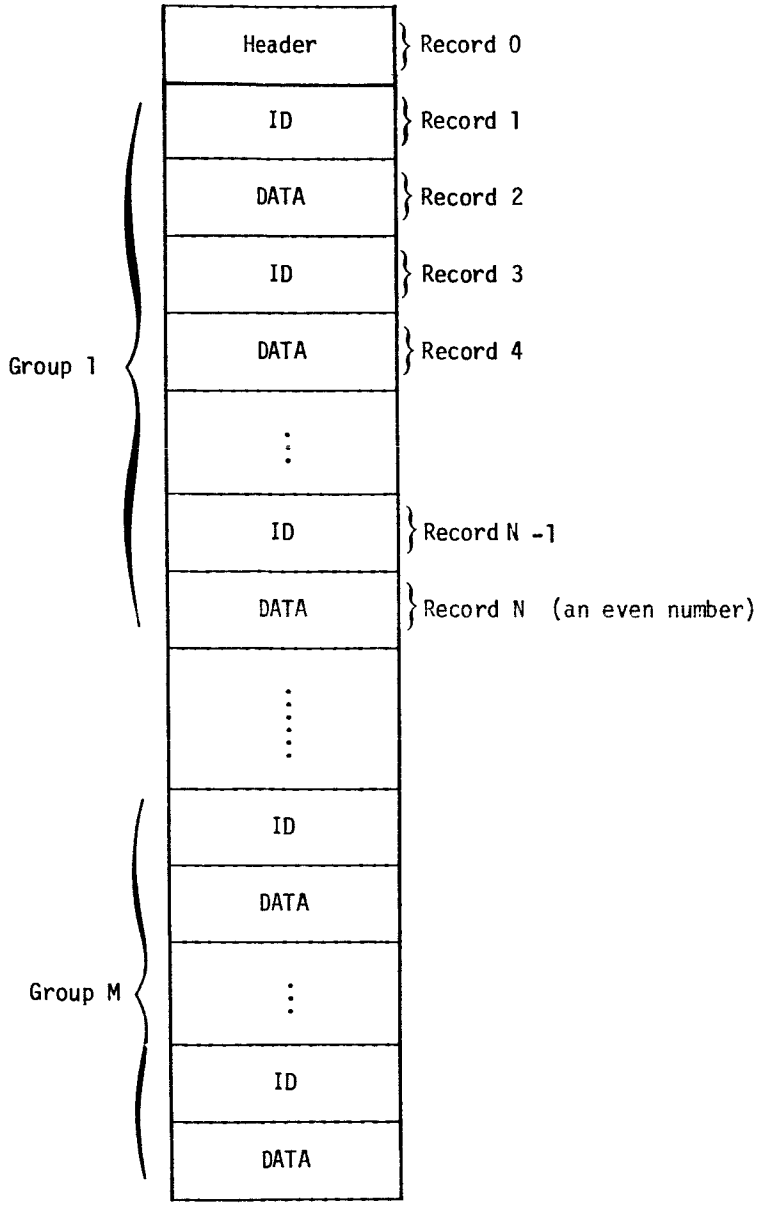
4.62.6 Parameters

None

4.62.7 Method

4.62.7.1 Input and Output Data Block Record Arrangements

Both the input and output data blocks of SDR3 have the following format:

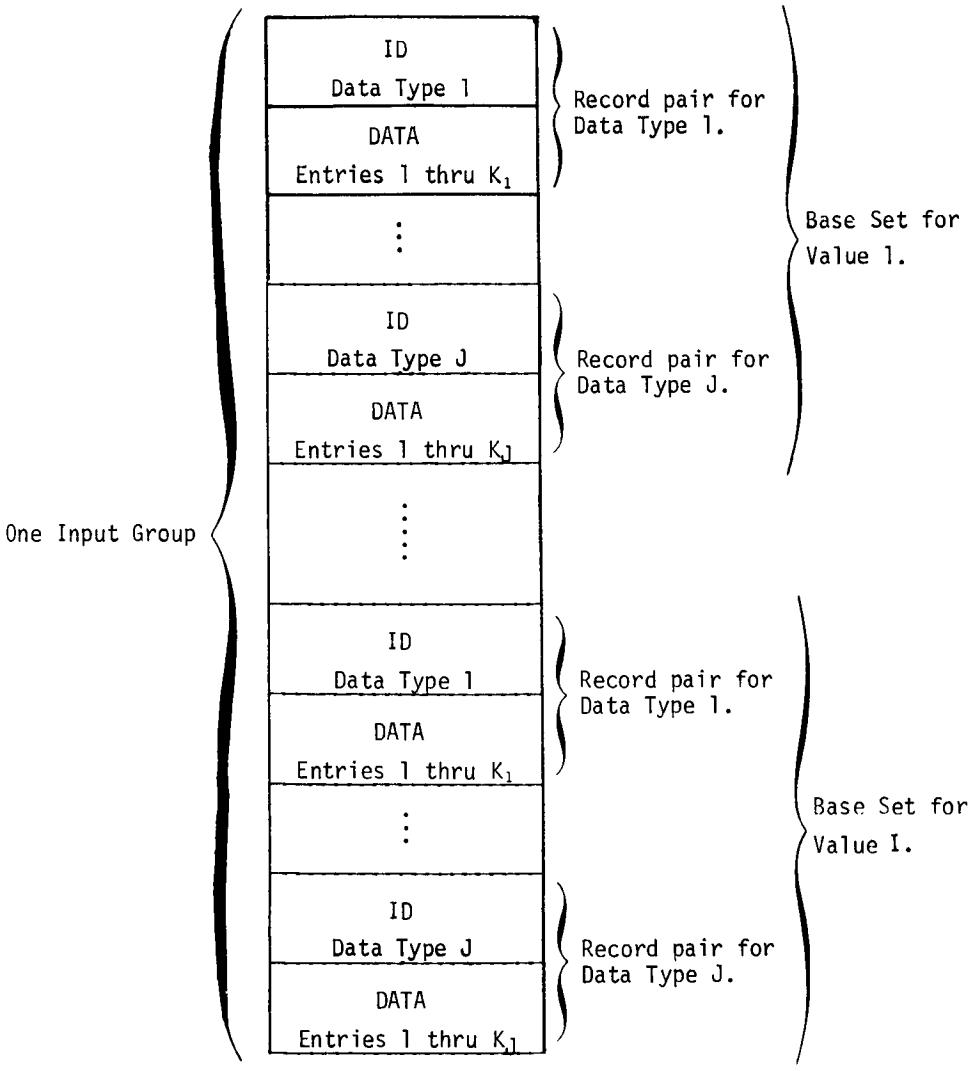

Header
Record 0
ID
Record 1
DATA
Record 2
ID
Record 3
DATA
Record 4
Group 1
ID
Record N -1
DATA
Record N (an even number)
ID
DATA
Group M
ID
DATA

4.62.7.2 Description of a Group

1. An input (SØRT1) data block Group and an output (SØRT2) data block Group are given in the following figures:

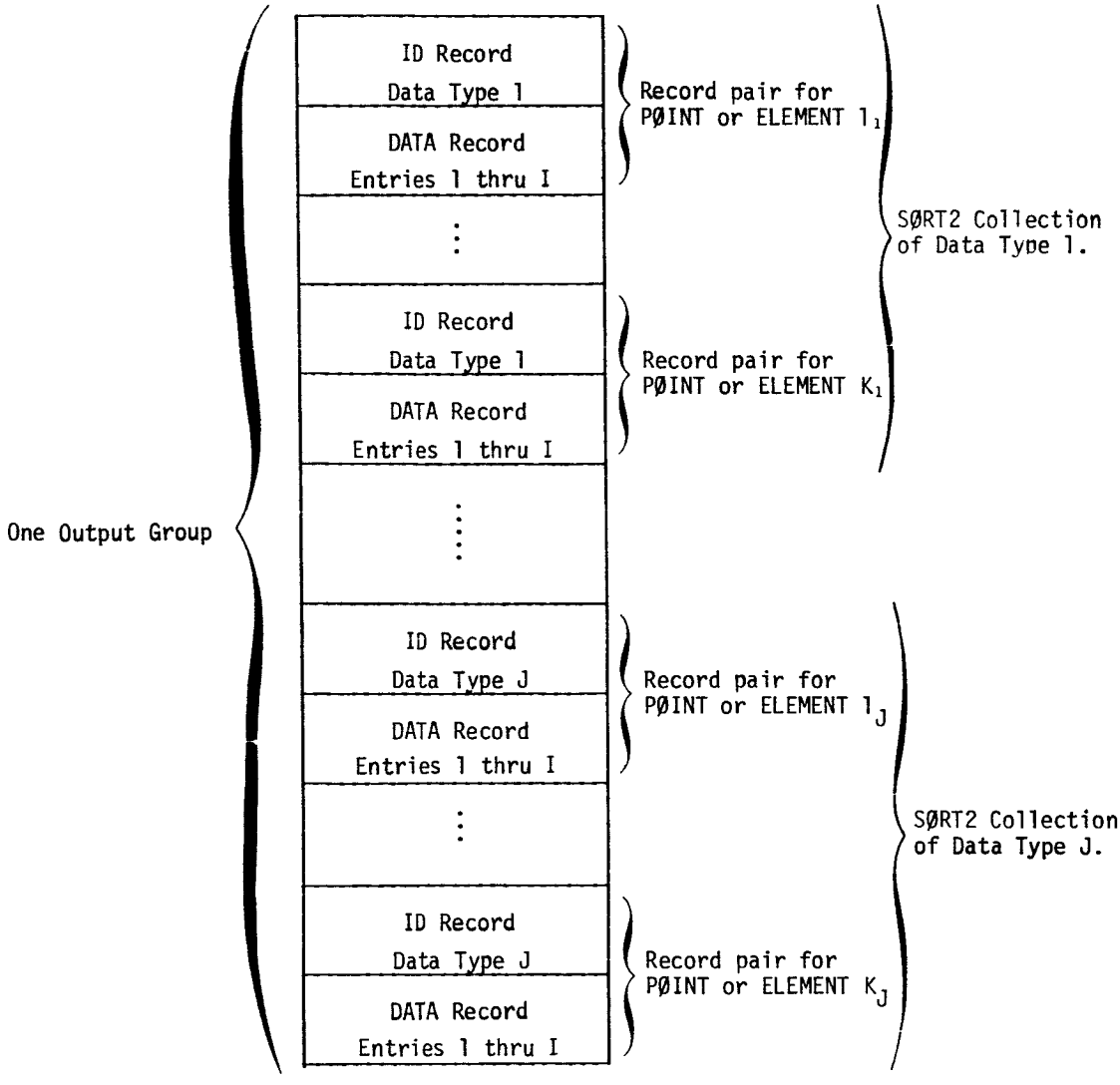
Theoretical Input Group

(SØRT1)



Theoretical Output Group

(SØRT2)



2. In the above figures each Group is independent of any other Group so far as SDR3 need be concerned.

3. A Group is defined as a collection of successive records belonging to the same subcase.

4. An ID-Record is of a fixed size equal to 146 words.

5. A DATA-Record contains multiple Entries with each Entry being of a length in words specified within the immediately preceding ID-Record.

6. I = The number of Values (FREQUENCIES or TIMES) present in the Group.

7. A Base Set is a sub-Group of the Group containing data records for one particular Value.

8. J = The number of different Data Types (DISPLACEMENTS, VELOCITIES, etc.) within a Base Set.

9. K_j = The number of Entries for Data Type j.

10. Respective records of any two Base Sets within an input data block Group are of the same size.

11. Respective Entries within respective DATA Records of all Base Sets of an input data block Group begin with the same ELEMENT-ID or PØINT-ID.

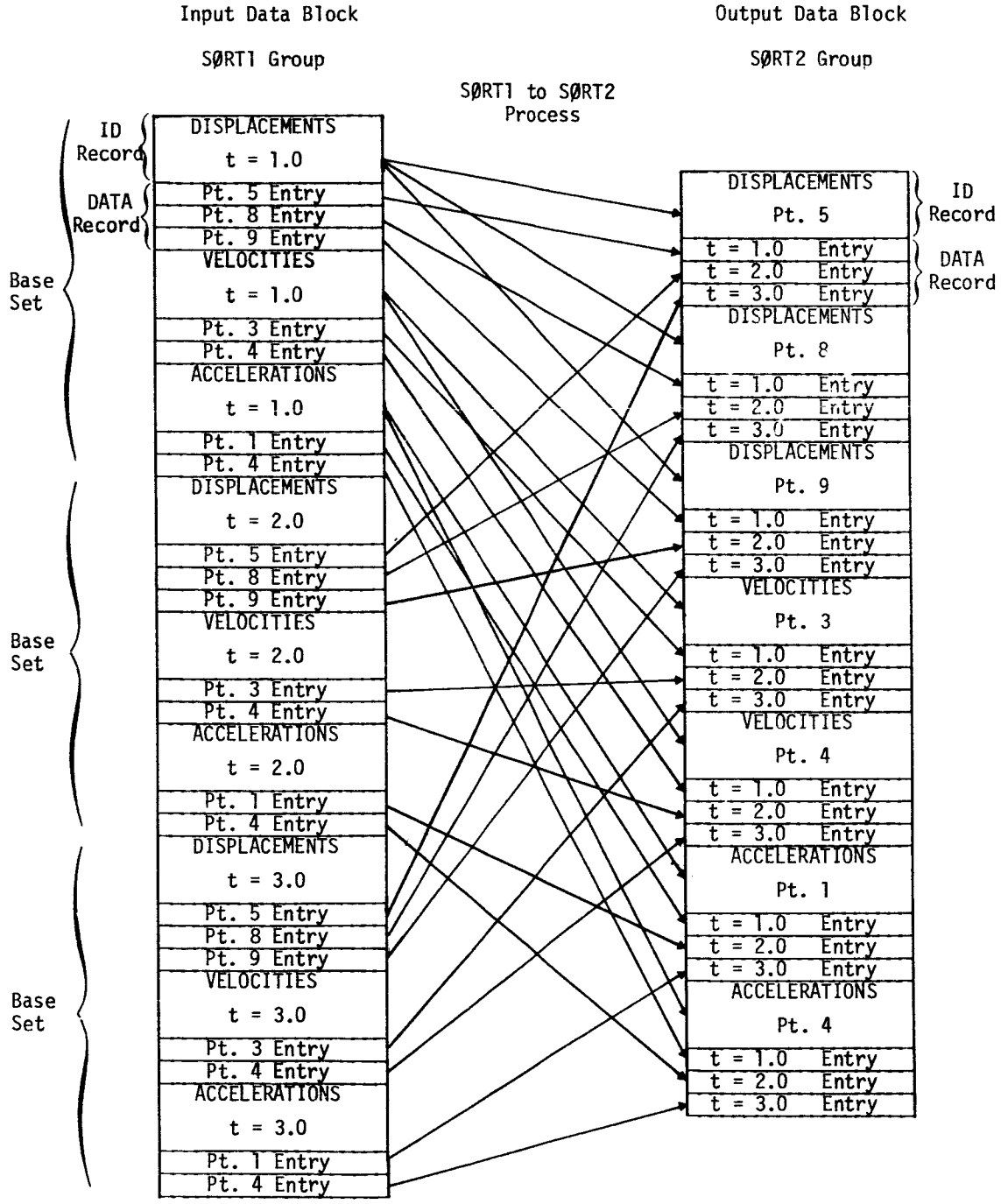
12. Most input data blocks will contain only one Group having but one Data Type. There is normally more than one Base Set within any Group.

13. A pictoral representation of a SØRT1 to SØRT2 process is given on the next page using the following data:

Values = 3 time steps (1.0, 2.0, 3.0)

Data Types = {1 - Displacements (3 Entries/Value - points 5, 8 and 9)
2 - Velocities (2 Entries/Value - points 3 and 4)
3 - Accelerations (2 Entries/Value - points 1 and 4)

FUNCTIONAL MODULE SDR3 (STRESS DATA RECOVERY - PHASE 3 - SØRT1 TO SØRT2 PROCESSOR)



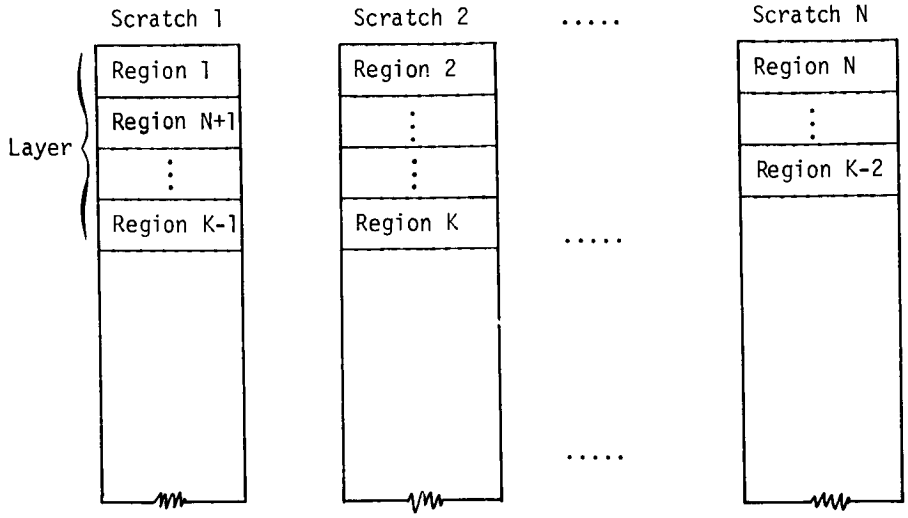
4.62.7.3 Physical Data Processing (SØRT1 to SØRT2)

All emphasis is placed on the Group, and thus in performing SØRT2 a Group pointer always points to the first record of the current Group being processed.

Each Group is processed and completed successively until all Groups have been processed. For each Group a loop of J passes is executed. During the j^{th} pass of this loop, the j^{th} Data Type (note 4.62.7.2) present of the Base Sets will be collected and transposed. The transpose consists of determining how many Entries are present for the current Data Type and then dividing the available core into that many Regions. The Entries of each DATA record for the j^{th} Data Type are distributed in Entry order, one each, to the Regions. At the time each Entry is distributed to a Region, the Entry's first word (PØINT-ID or ELEMENT-ID) is replaced by the Value (FREQUENCY or TIME) in the ID-Record associated with the DATA-Record from which the Entry has come. At the conclusion of each pass of this loop, output to the data block can proceed. For each Region an ID-Record is written. This ID-Record is a copy of the input data block ID-Record in the first Base Set for the j^{th} Data Type, having had the Value (FREQUENCY or TIME) replaced with the PØINT-ID or ELEMENT-ID of the respective Region. The filled portion of the Region is then output as the DATA-Record.

4.62.7.4 Spill Logic

If during the Entry distribution the Regions can hold no more Entries, spill to scratch files is performed. A Layer of records is written, one record for each Region, each time spill is required.



At the output stage, if spill to the scratch files has occurred, the Regions in the scratch files are output before the in-core Regions.

4.62.8 Subroutines

4.62.8.1 Subroutine Name: SDR3A

1. Entry Point: SDR3A

2. Purpose: To perform all SØRT2 operations when called by the driver routine SDR3.

3. Calling Sequence: CALL SDR3A (ØFPFIL)

   ØFPFIL - An array of six words, one for each input data block, each of which is set to zero before the CALL and then reset by SDR3A with a traceback positive integer in the event an error for its respective data block occurred.

4.62.9 Design Requirements

1. The design requires that the largest DATA-Record fit in core. If a problem is outputting so many ELEMENT-ID or PØINT-ID Entries for a particular FREQUENCY or TIME that core is insufficient, then more subcases in conjunction with output request sets are recommended.

2. CØMMØN/SDR3ZZ/Z(1)

This common block defines open core for the SDR3 module.

3. SDR3 will open all its scratch files (8).

4.62.10 Diagnostic Messages

All errors within SDR3 are considered non-fatal-User Warning type errors. Any error resulting in termination of the SØRT2 process results in the setting of an SDR3 traceback number, an appropriate message, and a call to the ØFP (Output File Processor) which in turn will output the data block in SØRT1 format. If ØFP is unable to output the data block it in turn will call the TABPRT routine, and the data block will be printed.

4.63 FUNCTIONAL MODULE XYTRAN (XY - OUTPUT DATA TRANSLATOR)

4.63.1 Entry Point: XYTRAN

4.63.2 Purpose

To read the first record of the XYCDB data block (prepared by subroutine IFP1XY of Executive module IFP1); to set xy-output parameters from the serial specifications of this record; to interpret the user curve requests; to locate in the XYTRAN input data blocks (2 thru 6) the data sets containing the requested curve data; to prepare summary and xy-coordinate data for the requested curves and output them to the system output printer and punch units; and to prepare xy-coordinate data and output them to the XYTRAN output data block for direct plotting by the XYPLØT module of those curve requests specified to be plotted.

4.63.3 DMAP Calling Sequences

4.63.3.1 Frequency Response - Direct Formulation. (Rigid Format 8)

1. Vector data recovery output.

```
XYTRAN  XYCDB,ØUDVC2,,,, /XYPLTFA/C,N,FREQ/C,N,DSET/V,N,PFILE/V,N,CARDNØ  $
```

2. Stress data recovery output.

```
XYTRAN  XYCDB,ØPPC2,ØQPC2,ØUPVC2,ØESC2,ØEFC2/XYPLTF/C,N,FREQ/C,N,PSET/V,N,PFILE/V,N,CARDNØ $
```

3. Random response output.

```
XYTRAN   XYCDB,PSDF,AUTØ,,,/XYPLTR/C,N,RAND/C,N,PSET/V,N,PFILE/V,N,CARDNØ  $
```

4.63.3.2 Transient Response - Direct Formulation. (Rigid Format 9)

1. Vector data recovery output.

```
XYTRAN  XYCDB,ØUDV2,ØPNL2,,,/XYPLTTA/C,N,TRAN/C,N,DSET/V,N,PFILE/V,N,CARDNØ  $
```

2. Stress data recovery output.

```
XYTRAN  XYCDB,ØPP2,ØQP2,ØUPV2,ØES2,ØEF2/XYPLTT/C,N,TRAN/C,N,PSET/V,N,PFILE/V,N,CARDNØ  $
```

4.63.3.3 Frequency Response - Modal Formulation. (Rigid Format 11)

1. Vector data recovery output.

```
XYTRAN  XYCDB,ØUHVC2,,,,/XYPLTFA/C,N,FREQ/C,N,HSET/V,N,PFILE/V,N,CARDNØ $
```

2. Stress data recovery output.

```
XYTRAN  XYCDB,ØPPC2,ØQPC2,ØUPVC2,ØESC2,ØEFC2/XYPLTF/C,N,FREQ/C,N,PSET/V,N,PFILE/
V,N,CARDNØ  $
```

3. Random response output.

```
XYTRAN  XYCDB,PSDF,AUTØ,,,/XYPLTR/C,N,RAND/C,N,PSET/V,N,PFILE/V,N,CARDNØ  $
```

4.63.3.4 Transient Response - Modal Formulation. (Rigid Format 12)

1. Vector data recovery output.

```
XYTRAN  XYCDB,ØUHV2,ØPNL2,,,/XYPLTTA/C,N,TRAN/C,N,HSET/V,N,PFILE/V,N,CARDNØ  $
```

2. Stress data recovery output.

```
XYTRAN  XYCDB,ØPP2,ØQP2,ØUPV2,ØES2,ØEF2/XYPLTT/C,N,TRAN/C,N,PSET/V,N,PFILE/V,N,CARDNØ  $
```

4.63.4 Input Data Blocks

XYCDB - XY Output Control Data Block.

ØUDVC2 - Output displacement vector requests (solution set, SØRT2, complex).

ØPPC2 - Output load vector requests (solution set, SØRT2, complex).

ØQPC2 - Output forces of single-point constraint requests (solution set, SØRT2, complex).

ØUPVC2 - Output displacement vector requests (p set, SØRT2, complex).

ØESC2 - Output element stress requests (SØRT2, complex).

ØEFC2 - Output element force requests (SØRT2, complex).

PSDF - Power Spectral Density Table.

AUTØ - Autocorrelation function table.

ØUDV2 - Output displacement vector requests (solution set, SØRT2, real).

ØPNL2 - Output nonlinear load requests (solution set, SØRT2, real).

ØPP2 - Output load vector requests (p set, SØRT2, real).

ØQP2 - Output forces of single-point constraint (p set, SØRT2, real).

ØUPV2 - Output displacement vector requests (p set, SØRT2, real).

ØES2 - Output element stress requests (SØRT2, real).

ØEF2 - Output element force requests (SØRT2, real).

ØUHVC2 - Output displacement vector requests (solution set, SØRT2, complex).

ØUHV2 - Output displacement vector requests (solution set, SØRT2, real).

4.63.5 Output Data Blocks

XYPLTFA -
XYPLTF -
XYPLTR -
XYPLTTA -
XYPLTT -

} XY-Plot output requests prepared by XYTRAN for direct plotting by XYPLØT.

4.63.6 Parameters

CARDNØ - Input and output-integer-default value = 0. CARDNØ is incremented by one and punched in columns 73-80 of each card punched by XYTRAN.

PFILE - Input and output-integer-default value = 0. PFILE is incremented by one for each frame XYTRAN defines for output by XYPLØT.

FREQ - Input-BCD-2-word-constant distinguishes the problem as frequency response.

TRAN - Input-BCD 2-word-constant distinguishes the problem as transient response.

RAND - Input-BCD 2-word-constant distinguishes the problem as random response.

DSET - Input-BCD 2-word-constant distinguishes the input vector as the d set.

PSET - Input-BCD 2-word-constant distinguishes the input vector as the p set.

HSET - Input-BCD 2-word-constant distinguishes the input vector as the h set.

4.63.7 Method

4.63.7.1 The following diagram illustrates the process of serially reading through the XYCDB data block's first record and performing the XYTRAN data processing.

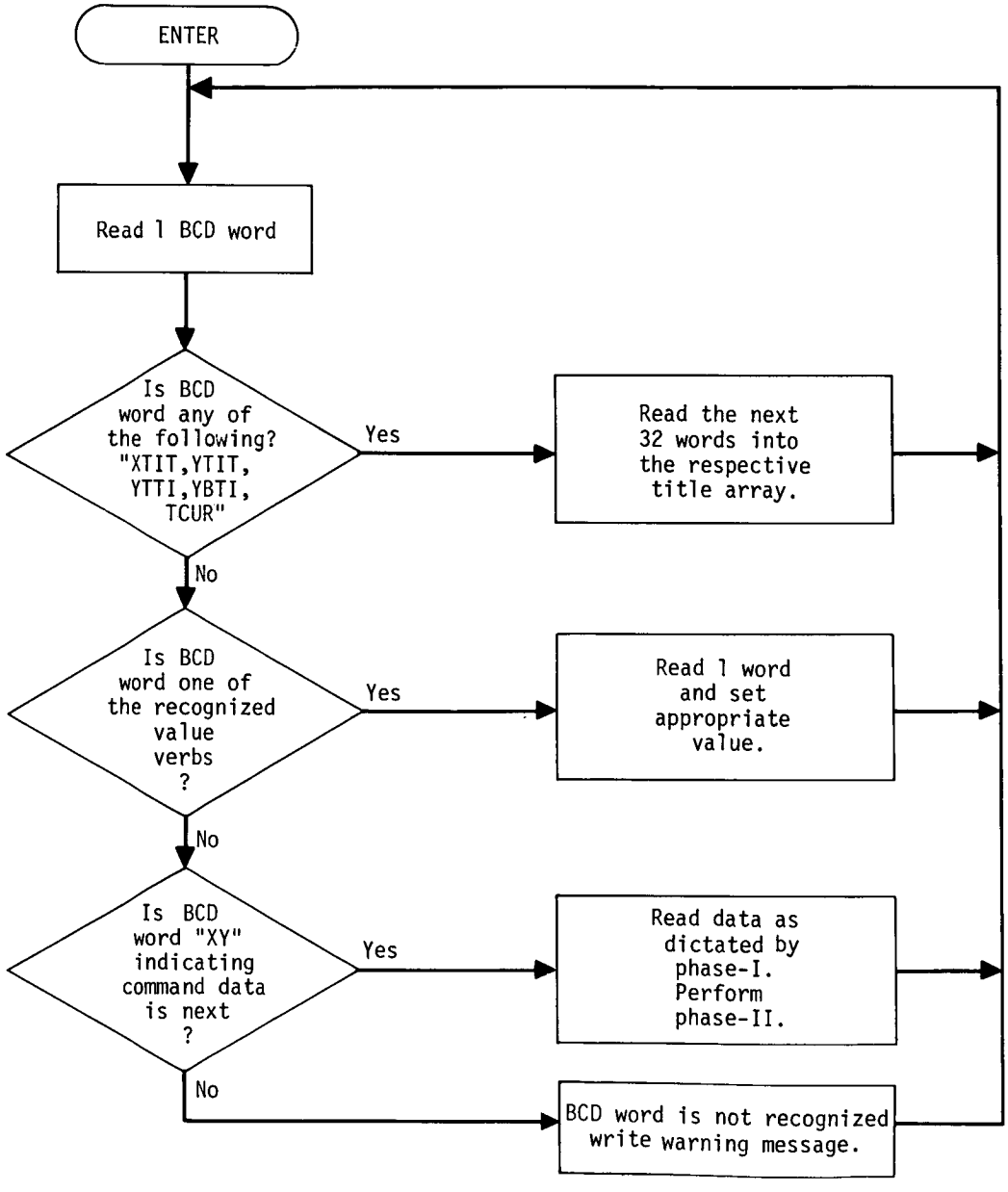


Figure 1. Flowchart for reading the first record of XYCDB

4.63.7.2 Phase I

In Phase I the XYCDB data block is further read to:

1. Determine the type of XY-output curves desired. (Response, Autocorrelation, or Power Spectral Density Function);
2. Determine the type of data (displacements, stresses, etc.,) and subcases desired;
3. Determine which types of XY-output are requested of XYPUNCH, XYPEAK, XYPRINT, XYPAPLØT, and XYPLØT (XY-output requests are described in section 4 of the User's Manual).
4. Determine the point-component curve relationships for a frame.

The data for all curves of a given frame (upper and lower, or whole) are then collected and stored in core.

4.63.7.3 Phase II

The operations of Phase II involve the analysis of the curve data in conjunction with the XY-output specifications stored to this point as a set of values, and the computation and setting of dynamic curve limits. When all processing is complete, output to the printer, the punch, and the XYTRAN output data block is accomplished.

4.63.8 Subroutines

4.63.8.1 Subroutine Name: XYDUMP

1. Entry Point: XYDUMP
2. Purpose: To perform phase II as described above.
3. Calling Sequence: CALL XYDUMP (IARG,ITYPE).

   IARG - 201, GINØ output data block number.

   ITYPE - 1 for RESPØNSE, 2 for PSDF, 3 for AUTØ.

4.63.8.2 Subroutine Name: XYFIND

1. Entry Point: XYFIND
2. Purpose: To position one of the XYTRAN input data blocks (2 thru 6) to the beginning of a data set record for a particular ELEMENT-ID or POINT-ID of a specific

data type.

3. Calling Sequence: CALL XYFIND (n_1,n_2,n_3,MAJID,IDZ)

n_1 = Return taken in the event an end-of-file is sensed when an EØF should not be hit.

n_2 = Return taken in the event an end-of-record is sensed when an end-of-record. should not be hit.

n_3 = Return taken if the data requested could not be found.

MAJID = An array of the eleven data type major-IDs.

IDZ = Pointer into the Z array of open core to an ELEMENT-ID or POINT-ID.

4.63.8.3 Subroutine Name: XYØUT

1. Entry Point: XYØUT

2. Purpose: To output to the system printer unit an xy-output summary or to output to the system printer and/or punch unit(s) an xy-output coordinate pair.

3. Calling Sequence: CALL XYØUT (IARG,BUFF)

IARG = { <0 implies print summary.
       { ≥0 implies print and/or punch coordinate pair.

BUFF = Array containing data to be output.

4.63.8.4 Subroutine Name: XYLØG

1. Entry Point: XYLØG

2. Purpose: To analyze the input arguments V1 and V2 and to reset these arguments to powers of ten bracketing the original values. An example follows.

V1	= 0.5	Input arguments.
V2	= 5.6	
IARG	= Undefined	
V1	= 0.1	Output arguments.
V2	= 10.0	
IARG	= 2	

3. Calling Sequence: CALL XYLØG(V1,V2,IARG)

V1 = Smaller input real variable.

V2 = Larger input real variable.

IARG = Number of logrithmic cycles needed to bracket V1 and V2. (Set by XYLØG before return)

4.63.8.5 Subroutine Name: XYTICS

1. Entry Point: XYTICS

2. Purpose: To accept user-specified xy-plot edge-tic specifications and compute actual edge-tic beginning and ending values, their increments to the successive edge-tics, and their scientific values with powers of ten.

3. Calling Sequence: CALL XYTICS (IØUT,ØUT,IARG1,R1,R2,ISKIP)

IØUT = Integer output array
ØUT = Real output array
} One and the same array.

IARG1 = Number of edge-tic divisions desired by user.

R1 = Minimum coordinate value of edge.

R2 = Maximum coordinate value of edge.

ISKIP = Edge-tic skip count indicating which edge-tics are to have a value printed along with the tic-mark.

4.63.8.6 Subroutine Name: XYPRPL

1. Entry Point: XYPRPL

2. Purpose: To process the XYPAPLØT request. The XYTRAN output data block is read and a proper plot is generated for each XYPAPLØT request. Frame numbers are printed as well as titles, and the data are scaled to the size of the page width.

3. Calling Sequence: CALL XYPRPL

4.63.8.7 Subroutine Name: XYCHAR

1. Entry Point: XYCHAR

2. Purpose: To store the points to be plotted into the appropriate line of the output buffer.

3. Calling Sequence: CALL XYCHAR(IRØW,ICØL,CURVCH)

IRØW = Y coordinate of the point to be plotted

ICØL = X coordinate of the point to be plotted

CURVCH = Symbol to be used for the point

4.63.8.8 Subroutine Name: XYGRAF

1. Entry Point: XYGRAF

2. Purpose: To print the proper plot for a frame.

3. Calling Sequence: CALL XYGRAF(GRAPH)

GRAPH = Frame border data for the plot

4.63.9 Design Requirements

1. The XYTRAN design requires that for a particular frame all of the curve data for the curves of that frame fit in core. If this condition is not possible, one curve at a time will be cancelled, with a warning message output, until the condition is met for the frame in question.

2. The following CØMMØN blocks are used in the subroutines of module XYTRAN.

a. CØMMØN/XYWØRK/

This common block contains variables required in the processing of the user output requests.

b. CØMMØN/XYTRZZ/

Defines open core for the module

4.63.10 Diagnostic Messages

All XYTRAN diagnostic messages are of a USER-WARNING nature. There are no FATAL type error diagnostics. XYTRAN is in all cases expected to make a normal return.

4.64 FUNCTIONAL MODULE RANDØM (RANDOM ANALYSIS MODULE)

4.64.1 Entry Point: RANDØM

4.64.2 Purpose

To compute power spectral density functions and autocorrelation functions from frequency response data.

4.64.3 DMAP Calling Sequence

```
RANDØM     XYCDB,DIT,PSDL,ØUPVC2,ØPP2,ØQP2,ØESC2,ØEFC2,CASECC/PSDF,AUTØ/V,N,NØRAND   $
```

4.64.4 Input Data Blocks

XYCDB - XY Plotter Control Data Block.

DIT - Direct Input Tables.

PSDL - Power Spectral Density List.

ØUPVC2 - Output displacement vector requests (p set, SØRT2, complex).

ØPP2 - Output load vector requests (p set, SØRT2, complex).

ØQP2 - Output forces of single-point constraint (p set, SØRT2, complex).

ØESC2 - Output element stress requests (SØRT2, complex).

ØEFC2 - Output element force requests (SØRT2, complex).

CASECC - Case Control Data Table.

Notes: 1. If XYCDB is purged, RANDØM returns.

2. DIT cannot be purged if PSDL points to tables in DIT.

3. If PSDL is purged, RANDØM returns.

4. ØUPVC2, ØPP2, ØQP2, ØESC2, ØEFC2 must contain the requested outputs.

5. CASECC cannot be purged.

4.64.5 Output Data Blocks

PSDF - Power Spectral Density Table.

AUTØ - Autocorrelation function table.

Notes: PSDF and AUTØ cannot be purged.

4.64.6 Parameters

NØRAND - Output-integer-no default. NØRAND = -1, if no random analysis is requested; 0, otherwise.

4.64.7 Method

4.64.7.1 Overview of the Method

The Random Analysis Module calculates power spectral density functions, autocorrelation functions and mean deviations for selected displacements, loads, forces of single-point constraint, and element forces and stresses.

4.64.7.2 Module Initialization

The following 4 steps of subroutine RAND7 comprise module initialization.

1. The XYCDB must be present or RANDØM returns.
2. A set of RANDPS Bulk Data cards from PSDL must be selected in CASECC or RANDØM returns.
3. The frequency list is extracted from the first non-empty data file.
4. The selected RANDPS cards are read in and stored. The tables referenced are prepared by subroutine PRETAB. The RANDPS (see section 2.4 of the User's Manual) card defines the functions

$$S_{ab}(f) = (x + iy)\, F_K(f) \qquad (1)$$

where a is the subcase id of the excited load set; b is the subcase id of the applied load set ($a \leq b$); (x,y) is a complex number such that if a = b, then y must be 0.0; and K is the table identification number of a TABRND1 Bulk Data card which defines $F_k(f)$, a power spectral density as a tabular function of frequency.

If on any RANDPS card $a \neq b$, the equations are called coupled, otherwise they are called uncoupled.

4.64.7.3 The Uncoupled Case

The following eight steps are accomplished in subroutine RAND5.

1. The XYCDB is read for a list of requested points. This list is stored in core. (Subroutine RAND6).

2. Core is allocated for as many points as possible at one word per frequency. If all points will not fit in core, another pass will be made on this file.

3. Compute $S_{aa}(f)$ at each load change (subroutine TAB).

4. Read in the data from the SØRT2 data block and compute:

$$S_{ja}(f) = |U_j(f)|^2 S_{aa}(f), \tag{2}$$

where $U_j(f)$ is the response of the j^{th} point at frequency f.

5. These are summed over all loads to form the power spectral density function:

$$S_j(f) = \sum_a S_{ja}(f), \tag{3}$$

where 'a' runs over all subcase id's on the RANDPS cards.

6. When all subcases for the points in core have been processed, the mean response $\bar{q}_j$ is calculated in subroutine RAND3 for each point j:

$$\bar{q}_j = \left\{\frac{1}{2} \sum_{i=1}^{N-1} [(S_j(f_i) + S_j(f_{i+1})] (f_{i+1} - f_i)\right\}^{1/2}, \tag{4}$$

where N = number of frequencies. The mean response is output with both the PSDF and the autocorrelation function.

7. If PSDF for point j is requested, one id and data record are written on the PSDF data block.

8. If an autocorrelation function is requested for point j, the $S_j(f)$ are transformed to the time domain to give the autocorrelation function:

$$R_j(\tau_m) = \sum_{i=1}^{N-1} \left\{ \frac{1}{4\pi^2\tau^2_m} \left[\frac{S_j(f_{i+1}) - S_j(f_i)}{(f_{i+1} - f_i)}\right] [\cos(2\pi\tau_m f_{i+1}) - \cos(2\pi\tau_m f_i)] + \right.$$

$$\left. \frac{1}{2\pi\tau_m} [S_j(f+1) \sin(2\pi\tau_m f_{i+1}) - S_j(f_i) \sin(2\pi\tau_m f_i)] \right\}, \tag{5}$$

where i is the index of the frequencies; N is highest frequency; τ_m is defined by

$$\tau_m = \tau_o + \frac{m}{M}(\tau_{max} - \tau_o), \tag{6}$$

where τ_o is the starting time lag, M is the number of time lag intervals, and τ_{max} is the maximum time lag ($o < \tau_o < \tau_m$), all of which are defined on a RANDT1 Bulk Data card. Note that if, in Equation 5, $\tau_m = 0$, then

$$R_j(\tau_m) = \bar{q}_j^2. \tag{7}$$

If more points for this data block remain to be done, the file is rewound and another pass is made. If additional file types are requested, steps 1 through 8 outlined above are repeated. This completes the uncoupled case processing.

4.64.7.4 The Coupled Case

The following 6 steps are accomplished in subroutine RAND8.

1. A list of unique subcase id's is extracted from the RANDPS cards.

2. The XYCDB is read for a list of requested points. This list is stored in core (subroutine RAND6).

3. An array of core is reserved for each point as follows:
Let NFREQ = the number of frequencies used and NUNØ be the number of unique subcase id's mentioned on the RANDPS cards. Each point requires 2 NFREQ*NUNØ words of storage.

As many points as possible are done at once. The data file is read and the data are stored (real/imaginary) for each point until all subcases for all points in core have been processed.

4. For each RANDPS card $S_{ab}(f_i)$ is looked up for all f (subroutine TAB).
For each point in core $S_j^1(f)$ is computed:

$$S_j^1(f) = H_{ja}(f)\, S_{ab}(f)\, \bar{H}_{jb}(f), \tag{8}$$

where $H_{ja}(f)$ denotes the value of point j for subcase a. The bar over the third factor in Equation 8 denotes the complex conjugate. These $S_j^1(f)$ are summed over all RANDPS cards to form $S_j(f)$:

$$S_j(f) = \left|\sum_{ab}\sum H_{ja}(f)\, S_{ab}(f)\, \overline{H}_{jb}(f)\right|. \qquad (9)$$

Note that $S_{ba} = \overline{S}_{ab}$, the complex conjugate.

5. The mean response and autocorrelation functions are computed as in Equations 5, 6 and 7.

6. If more points for this file remain to be done, the file is rewound and another pass is made.

If additional file types are requested, steps 1 thru 6 are repeated. If not, the coupled case processing is complete.

4.64.8 Subroutines

4.64.8.1 Subroutine Name: RAND7

1. Entry Point: RAND7

2. Purpose: To initialize for both the coupled and uncoupled cases.

3. Calling Sequence: CALL RAND7(IFILE,NFILE,PSDL,DIT,ICØUP,NFREQ,NPSDL,NTAU,LTAB, CASECC,XYCDB).

PSDL,DIT,CASECC,XYCDB are GINØ file numbers for their respective data blocks - - integer - input.

IFILE - Array of GINØ file numbers of data files to RANDØM - integer - input.

NFILE - Number of files in IFILE - integer - input.

ICØUP - -1 No RANDØM analysis to be done.

- 0 uncoupled algorithm to be used - integer - output.

- 1 coupled algorithm to be used.

NFREQ - Number of frequencies - integer - output.

NPSDL - Number of RANDPS cards selected - integer - output.

NTAU - Number of τ's on RANDT1 cards - integer - output.

LTAB - Amount of core taken up by table storage - integer - output.

CØMMØN/RANDMX/

RAND7 stores most of its output data in /RANDMX/. See core storage layout of /RANDMX/ (section 4.64.9).

4.64.8.2 Subroutine Name: RAND5

1. Entry Point: RAND5

2. Purpose: To compute uncoupled PSDF and AUTØ numbers.

3. Calling Sequence: CALL RAND5(NFREQ,NPSDL,NTAU,XYCDB,LTAB,IFILE,PSDF,AUTØ,NFILE)

PSDF,AUTØ - GINØ file numbers of respective files - integer -input.

Other variables are as in RAND7 (Section 4.64.8.1).

4.64.8.3 Subroutine Name: RAND8

1. Entry Point: RAND8

2. Purpose: To compute coupled PSDF and AUTØ numbers.

3. Calling Sequence: CALL RAND8 (Same as RAND5).

4.64.8.4 Subroutine Name: RAND1

1. Entry Point: RAND1

2. Purpose: To put one ØFP type ID on PSDF and AUTØ.

3. Calling sequence: CALL RAND1 (FILE,MID,TYPE,ID,CØMP,Q).

FILE - GINØ file number of output file - integer - input.

MID - File type (PSDF = 4001,AUTØ = 4002) - integer - input.

TYPE - Curve type - DISP,VELØ,ACCE,LØAD,SPLF,ELFØ, or STRE - BCD, input.

ID - Point id - integer - input.

CØMP - Point component - integer - input.

Q - Mean deviation - real - input.

4.64.8.5 Subroutine Name: RAND2

1. Entry Points: RAND2, RAND2A

2. Purpose: To read a SØRT2 type output file until it finds a point id selected by the user in a list.

3. Calling Sequence: CALL RAND2 (FILE,ILIST,LØAD,IF,LEN,LLIST, DATA)

CALL RAND2A (DATA)

FILE - GINØ file number of the SØRT2 data file - integer - input.

ILIST - List of user desired points - input and output.

LØAD - Subcase id of first data record in ILIST - integer - output.

IF - Format of data - real/imaginary or magnitude/phase - integer - output.

LEN - Length of the data line for this record - integer - output.

LLIST - Length of the ILIST array.

DATA - Data array - input.

4.64.8.6 Subroutine Name: RAND3

1. Entry Point: RAND3

2. Purpose: To compute the mean response $\overline{q}$.

3. Calling Sequence: CALL RAND3 (F,S,Q,N)

F - Array of frequencies - real - input.

S - Array of power spectral density functions - real - input.

Q - Mean response - real - output.

N - Length of the F and S arrays - integer - input.

4.64.8.7 Subroutine Name: RAND4

1. Entry Point: RAND4

2. Purpose: To compute the autocorrelation function $R(\tau)$.

3. Calling Sequence: CALL RAND4 (F,S,TAU,R,N)

F,S,N are as described in RAND3.

TAU - τ point at which R is to computed - real - input.

R - Autocorrelation function at TAU - real - output.

4.64.8.8 Subroutine Name: RAND6

1. Entry Point: RAND6

2. Purpose: To extract from the XYCDB a list of user requested points for RANDØM output.

3. Calling Sequence: CALL RAND6 (XYCDB,BUFFER,NPØINT,IZ,INPUT)

XYCDB - GINØ file number of the XYCDB data block - integer - input.

BUFFER - GINØ buffer - array - input.

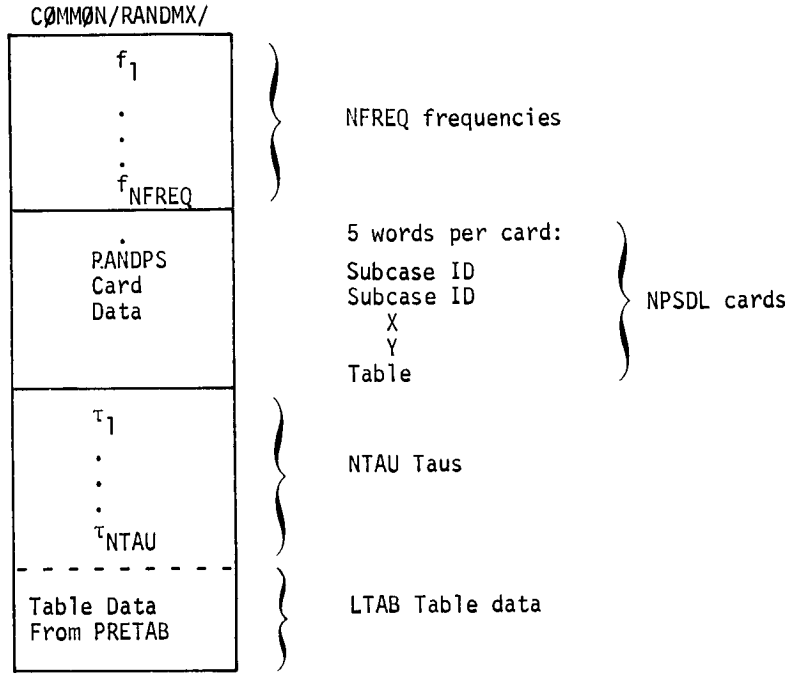
NPØINT - Number of points requested by the user for this file - integer - output.

IZ - Array in which RAND6 stores the list of requests - integer - output.

INPUT - GINØ file number of data file for which list of request is desired.

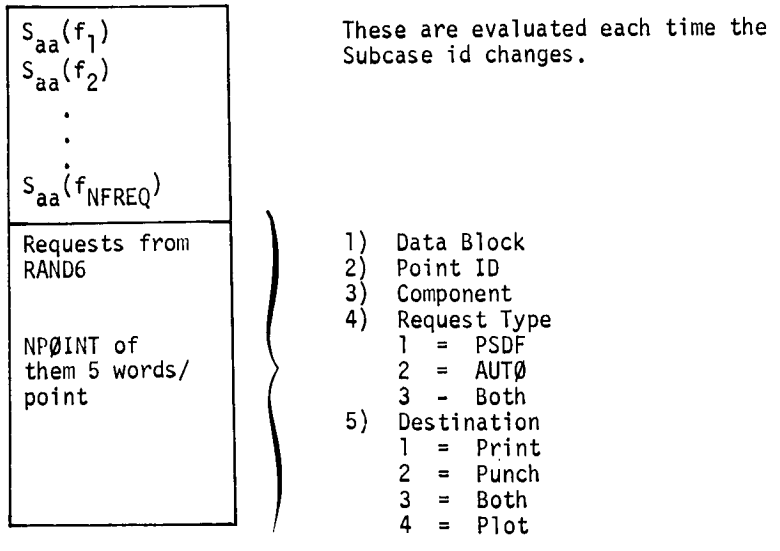
4.64.9 Design Requirements

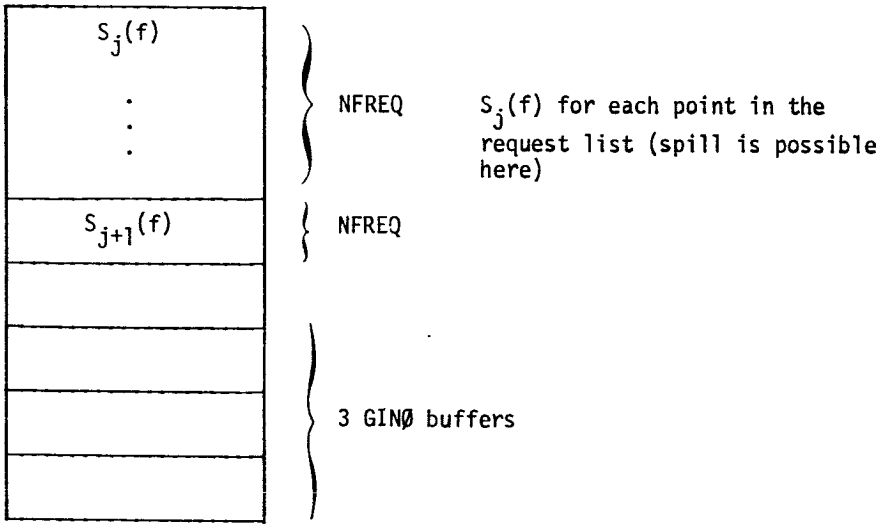
Open Core at /RANDMX/ is arranged as follows:



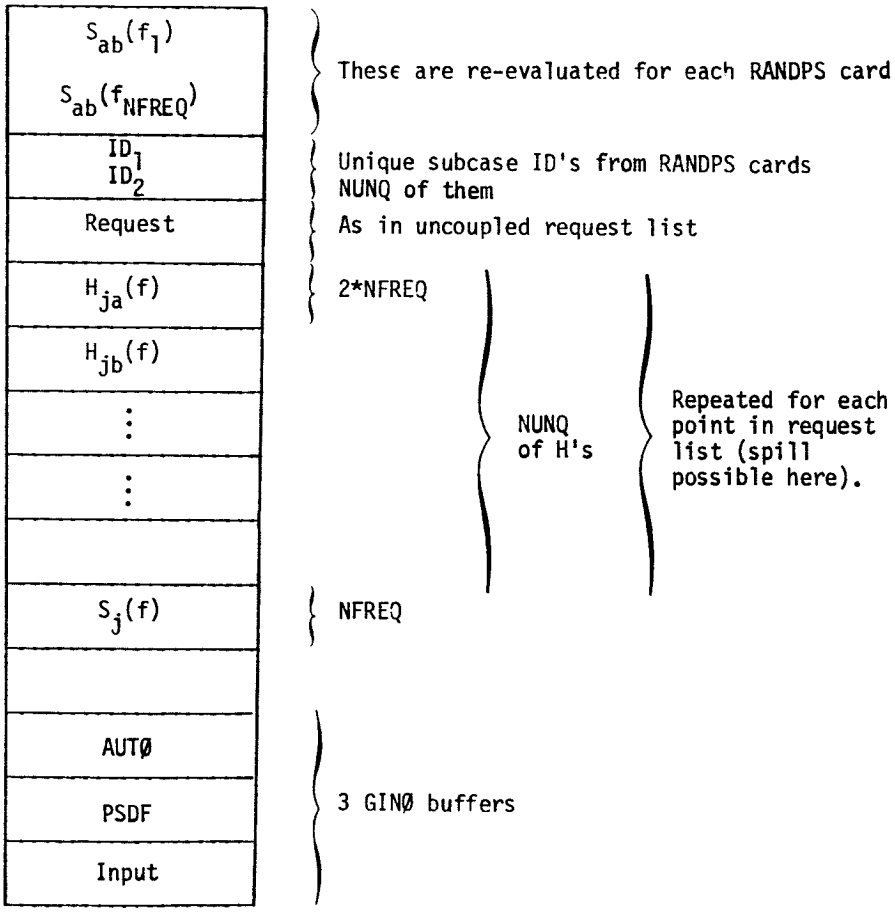
The above data are placed in core by RAND7 and are the same for both the coupled and uncoupled cases. The remaining data are core dependent.

Uncoupled case data:





Coupled case data:



4.64.10 Diagnostic Messages

RANDØM is defined as an output processor and thus must not stop due to user input error. Hence all messages are of a warning nature.

Random may issue message 3048.

4.65 FUNCTIONAL MODULE TRD (TRANSIENT ANALYSIS - DISPLACEMENT)

4.65.1 Entry Point: TRD

4.65.2 Purpose

To solve the transient problem.

4.65.3 DMAP Calling Sequence

```
TRD     CASECC,USETD,DLT,TRL,NLFT,DIT,KHH,BHH,MHH,GMD,GØD,PHIDH/UHVT,PDT,PST,PPT,PNLH/V,N,
        FØRM/V,N,LUSETD/V,N,MPCFl/V,N,SINGLE/V,N,ØMIT/V,N,NØNCUP/V,N,NØUE     $
```

4.65.4 Input Data Blocks

CASECC - Case Control Data table.

USETD - Displacement set definitions table-dynamics.

DLT - Dynamic Loads Table.

TRL - Transient Response List.

NLFT - Non-Linear Forcing Table.

DIT - Direct Input Tables.

KHH - Modal stiffness matrix - h set.

BHH - Modal damping matrix - h set.

MHH - Modal mass matrix - h set.

GMD - Multipoint constraint transformation matrix - dynamics.

GØD - Omitted coordinate transformation matrix - dynamics.

PHIDH - Transformation Matrix from d - set to modal coordinates.

Notes:

1. CASECC cannot be purged.
2. USETD cannot be purged.
3. DLT cannot be purged if a dynamic load was selected in CASECC.
4. TRL cannot be purged.

5. NLFT cannot be purged if nonlinear loads are selected in CASECC.

6. GMD cannot be purged if MPCF1 $\geq$ 0.

7. GØD cannot be purged if ØMIT $\geq$ 0.

8. PHIDH cannot be purged if FØRM = MØDAL.

4.65.5 Output Data Blocks

UHVT - Modal transient solution vectors - h set.

PDT - Linear dynamic load matrix for transient analysis - d set.

PST - Linear load vector for transient analysis - s set.

PPT - Linear dynamics loads for transient analysis - p set.

PNLH - Nonlinear loads in modal transient problem - h set.

Notes:

1. UHVT cannot be purged.

2. PDT cannot be purged.

3. PST cannot be purged if SINGLE $\geq$ 0.

4. PPT cannot be purged.

5. PNLH cannot be purged if nonlinear loads are selected.

4.65.6 Parameters

FØRM - Input-BCD-no default. If FØRM = MØDAL a modal formulation will be used, otherwise a direct formulation will occur.

LUSETD - Input-integer-no default. LUSETD indicates length of p set.

MPCF1 - Input-integer-no default. If MPCF1 $\geq$ 0 multipoint constraints are present.

SINGLE - Input-integer-no default. If SINGLE $\geq$ 0 single-point constraints are present.

ØMIT - Input-integer-no default. If ØMIT $\geq$ 0 omitted coordinates are present.

NØNCUP - Input-integer-no default. If NØNCUP = -1 an uncoupled solution will be done.

NØUE - Input-integer-no default. NØUE indicates the number of extra points-used in nonlinear load formulation.

4.65.7 Method

4.65.7.1 Overview of the Method

The Transient Analysis module integrates, over specified time periods, equations of motion of a structure having time dependent loads. A general structure may be used with real stiffness, mass and damping matrices. Non-linear effects may be calculated by specifying certain loading functions on the free, physical displacements of the system. This analysis is particularly useful when shock loads are applied to a structure. It is also more efficient than frequency analysis or complex eigenvalue analysis when the applied loads are well defined and the frequency characteristics are secondary to damping and peak load characteristics. This analysis is also the only dynamic general system analysis which allows non-linearities.

4.65.7.2 Logical Phases of Solution

1. The applied load vectors are assembled. The time increment from the TRL data block is used to identify the times at which the loads are assembled. The initial conditions are assembled.

2. The loads are reduced to the solution coordinates.

3. The left hand matrix of the general integration equation, Equation 15 below, and the two right hand matrices are assembled. The triangular decomposition of the left hand matrix is performed.

4. The solution loop of the program may now proceed until the time increment is changed. The steps are:

   a. Compute the non-linear load for this time step. Add this load to the load vectors computed in Step 2.

   b. Multiply the displacement vectors into the right hand matrices and add the resultant vectors to the applied load vector.

   c. Solve for the left hand displacement vector by performing a back substitution into the triangular decomposition of the left hand matrix. If this is an output time step, the velocity and acceleration are computed using differences of the displacement vectors.

d. If the time increment changes for the next time step, the program returns to step 3. If the increment is the same, steps 4a thru 4d are repeated.

5. If the equations are in the uncoupled modal formulation form (i.e., no transfer functions, direct input matrices, or non-linear functions), the solution logic is much faster. For each coordinate, the displacement, velocity and acceleration may be computed independently versus time. Steps 3 and 4 are omitted.

4.65.7.3 Algorithms for Each Logical Phase

1. Assembly of Applied load vectors: CASECC is read and the selected time step, load, non-linear load, and initial condition set ids are extracted. The initial displacement and velocity vectors are packed on a scratch file for later use. The computation and output data on the TSTEP card are stored in core. The DLT is read to build a list of load "id's", and table "id's" and scale factors for the simple components of a load. Core is zeroed, and loads for as many times as possible are constructed in core and output. Two types of loads are available, TLØAD1 and TLØAD2.

For the TLØAD1 load,

$$P(t) = AF(t-\tau), \tag{1}$$

where F is a user input table.

For the TLØAD2 load,

$$P(t) = \begin{cases} At^{\beta}e^{c\tilde{t}} \cos(2\pi f \tilde{t} + P) & 0 \le \tilde{t} \le T2-T1 \\ 0 & \text{elsewhere} \end{cases} \tag{2}$$

where $t = \tilde{t} - T_1 - \tau$ and T_1, T_2, f, P, C and β are user input coefficients.

(Subroutines TRD1A, PRETAB and TAB).

2. Reduction of loads to the solution coordinates:

If m's are present (MPCF1$\geq$0),

$$\begin{Bmatrix} P_p \end{Bmatrix} \Rightarrow \begin{Bmatrix} \bar{P}_{ne} \\ \hline P_m \end{Bmatrix}, \tag{3}$$

$$\{P_{ne}\} = [G_o^d]^T \{P_m\} + \{\bar{P}_{ne}\}. \tag{4}$$

If s's are present (SINGLE $\geq$ 0),

$$\{P_{ne}\} \Longrightarrow \left\{\frac{P_{fe}}{P_s}\right\}. \tag{5}$$

$\{P_s\}$ is reduced to the output times and output on data block PS.

If o's are present (ØMIT $\geq$ 0),

$$\{P_{fe}\} \Longrightarrow \left\{\frac{\overline{P}_d}{P_o}\right\}, \tag{6}$$

$$\{P_d\} = [G_o^d]^T \{P_o\} + \{\overline{P}_d\}. \tag{7}$$

$\{P_d\}$ is reduced to the output times and output on data block PØ.

If this is a modal formulation (FØRM = MØDAL),

$$\{P_h\} = \{\Phi_{dn}\}^T \{P_d\}. \tag{8}$$

$\{P_p\}$ is reduced to output times and output on data block PP.

3. Solution of the coupled equations: The matrix

$$[D] = \left(\frac{1}{\Delta t^2}[M] + \frac{1}{2\Delta t}[B] + \frac{1}{3}[K]\right), \tag{9}$$

is formed and decomposed. The matrix

$$[C] = \left(\frac{2}{\Delta t^2}[M] - \frac{1}{3}[K]\right), \tag{10}$$

is formed and saved. The matrix

$$[E] = \left[\frac{-1}{\Delta t^2}[M] + \frac{1}{2\Delta t}[B] - \frac{1}{3}[K]\right], \tag{11}$$

is formed and saved.

The solution loops then proceed until a time step change occurs. The initial conditions are brought in and the starting equation

$$[D]\ \{u_1\} = \frac{1}{3}\{P^1_{-1} + P^1_0 + P_1\} + \{N_0\} + [C]\ \{u_0\} + [E]\ \{u^1_{-1}\}, \tag{12}$$

is solved for $\{u_1\}$, where $\{u_0\}$ is the starting displacement vector;

$$\{u^1_{-1}\} = \{u_0\} - \{\dot{u}_0\}\ \Delta t, \tag{13}$$

$\{\dot{u}_0\}$ is the starting velocity vector;

$$\{P^1_0\} = [K]\ \{u_0\} + [B]\ \{\dot{u}_0\}; \tag{14}$$

$\{N_0\}$ is the non-linear load calculated from $\{u_0\}$; and

$$\{P^1_{-1}\} = [K]\ \{u^1_{-1}\} + [B]\ \{\dot{u}_0\} = \{P^1_0\} - \Delta t\ [K]\ \{\dot{u}_0\}. \tag{15}$$

Note that the load computed at t = 0 is never used but is replaced by $\{P^1_0\}$. $\{u_2\}$ through $\{u_n\}$ are now computed from the general equation:

$$[D]\ \{u_{i+2}\} = \frac{1}{3}\{P_i + P_{i+1} + P_{i+2}\} + \{N_{i+1}\} + [C]\ \{u_{i+1}\} + [E]\ \{u_i\}. \tag{16}$$

If non-linear loads are selected, they are evaluated directly at the solution points for time step by the following process. NØLIN1 loads are computed as,

$$P_i(t) = S\ T\ (u_j(t)), \tag{17}$$

where T is a user selected table, i is the loaded solution point, j is the deflecting point, u_j is the previously computed displacement at point j. NØLIN2 loads are computed as,

$$P_i(t) = S\ u_j\ (t)\ u_k\ (t), \tag{18}$$

where i, j, and k are as in NØLIN1 loads.

NØLIN3 loads are computed as,

$$P_i(t) = \begin{cases} S\ \{u_j(t)\}A, & u_j(t)>0 \\ 0, & u_j(t)\leq 0 \end{cases} \tag{19}$$

NØLIN4 loads are computed as,

$$P_i(t) = \begin{cases} -S\ \{-u_i(t)\}A, & u_i(t)< 0 \\ 0, & u_i(t) \geq 0. \end{cases} \tag{20}$$

The user specifies the set of times at which data is to be saved. If the current time is an output time, the displacement vector for time $t = t_i$ is output.

The velocity vector given by:

$$\{\dot{u}_i\} = \frac{1}{2\Delta t} [\{u_{i+1}\} - \{u_{i-1}\}], \tag{21}$$

is output.

The acceleration vector given by

$$\{\ddot{u}_i\} = \frac{1}{\Delta t_i^2} [\{u_{i+1}\} + \{u_{i-1}\} - 2\ \{u_i\}], \tag{22}$$

is output.

If the time step is scheduled to change at t_{i+1} from Δt_1 to Δt_2, the displacement for time i+1 has been calculated. $\{u_{i-1}\}$, $\{u_i\}$, and $\{u_{i+1}\}$ are saved along with $\{P_{i+1}\}$. The matrices are formed and decomposed as in Equations 9,10, and 11 for $\Delta t = \Delta t_2$.

The following equation is used for computing $\{u_{i+2}\}$,

$$[D]\ \{u_{i+2}\} = \frac{1}{3}\ \{P_i^1 + P_{i+1} + P_{i+2}\} + \{N_{i+1}\} + [C]\ \{u_{i+1}\} + [E]\ \{u_i^1\}. \tag{23}$$

The vectors $\{P_i^1\}$ and $\{u_i^1\}$ in the above equation are calculated as follows. Define

$$\{\dot{u}_{i+1}\} = \frac{1}{\Delta t_1} (\{u_{i+1}\} - \{u_i\}), \tag{24}$$

$$\{\ddot{u}_{i+1}\} = \frac{1}{\Delta t_1^2} (\{u_{i+1}\} - 2\{u_i\} + \{u_{i-1}\}), \tag{25}$$

$$\{\dot{u}_i^1\} = \{\dot{u}_{i+1}\} - \{\ddot{u}_{i+1}\} \Delta t_2, \tag{26}$$

then:

$$\{u_i^1\} = \{u_{i+1}\} - \Delta t_2 \{\dot{u}_{i+1}\} + \frac{\Delta t_2^2}{2} \{\ddot{u}_{i+1}\}, \tag{27}$$

$$\{P_i^1\} = [M] \{\ddot{u}_{i+1}\} + [B] \{\dot{u}_i^1\} + [K] \{u_i^1\}. \tag{28}$$

4. Solution of Uncoupled Modal Equation: If the method of matrix formulation is modal and no transfer functions or direct input matrices are used, the equations may be solved in a more accurate, more direct manner. The diagonal terms of MHH, BHH, and KHH are stored in core. The following data are necessary to solve the transient behavior of a modal coordinate (ξ_i).

m_i = Modal mass of mode (MHH)

b_i = Modal damping coefficient (BHH)

K_i = Modal stiffness (KHH)

$$\omega_{oi} = (K_i/m_i)^{1/2}, \tag{29}$$

$$\beta_i = \frac{b_i}{2m_i}, \tag{30}$$

$$\omega_i^2 = |\omega_{oi}^2 - \beta^2|, \tag{31}$$

t_j = time of the j^{th} time step,

h_j = time increment after the j^{th} time,

f_{ij} = applied load on coordinate i at the j^{th} time.

The following coefficients are generated for each distinct time increment and stored in core.

There are four cases. ($\varepsilon = 10^{-5}$ and the subscript i is implied).

a. If $\omega_o^2 > \beta^2 + \varepsilon$ (underdamped):

$$F = e^{-\beta h} (\cos \omega h + \frac{\beta}{\omega} \sin \omega h) , \tag{32}$$

$$G = \frac{1}{\omega} e^{-\beta h} \sin \omega h , \tag{33}$$

$$A = \frac{1}{hk\omega} \{e^{-\beta h} [(\frac{\omega^2-\beta^2}{\omega^2_o} - \beta h) \sin \omega h - (\frac{2\omega\beta}{\omega^2_o} + h\omega) \cos \omega h] + \frac{2\beta\omega}{\omega^2_o}\} , \tag{34}$$

$$B = \frac{1}{hk\omega} \{e^{-\beta h} [(- \frac{\omega^2-\beta^2}{\omega_o^2}) \sin \omega h + \frac{2\omega\beta}{\omega_o^2} \cos \omega h] + \omega h - \frac{2\beta\omega}{\omega_o^2}\} , \tag{35}$$

$$F' = - \frac{\omega_o^2}{\omega} e^{-\beta h} \sin \omega h , \tag{36}$$

$$G' = e^{-\beta h}(\cos \omega h - \frac{\beta}{\omega} \sin \omega h) , \tag{37}$$

$$A' = \frac{1}{hk\omega} [e^{-\beta h} \{(\beta + h\omega_o^2) \sin \omega h + \omega \cos \omega h\} - \omega] , \tag{38}$$

$$B' = \frac{1}{hk\omega} [-e^{-\beta h} (\beta \sin \omega h + \omega \cos \omega h) + \omega] , \tag{39}$$

b. If $|\omega_o^2 - \beta^2| < \varepsilon$ (critically damped):

$$F = e^{-\beta h}(1 + \beta h) , \tag{40}$$

$$G = h e^{-\beta h} , \tag{41}$$

$$A = \frac{1}{hk}\left[\frac{2}{\beta} - \frac{1}{\beta} e^{-\beta h} (2 + 2h\beta + h^2 \beta^2)\right] , \tag{42}$$

$$B = \frac{1}{hk\beta}\left[-2 + \beta h + e^{-\beta h} (2 + \beta h)\right] , \tag{43}$$

$$F' = -\beta^2 h e^{-\beta h} , \tag{44}$$

$$G' = e^{-\beta h}(1 - \beta h) , \tag{45}$$

$$A' = \frac{1}{hk}\left[e^{-\beta h} (1 + h\beta + h^2\beta^2) - 1\right] , \tag{46}$$

$$B' = \frac{1}{hk}\left[1 - e^{-\beta h} (\beta h + 1)\right] . \tag{47}$$

c. If $\omega_o^2 < \beta^2 - \varepsilon$ (over damped):

$$F = e^{-\beta h} (\cosh \omega h + \frac{\beta}{\omega} \sinh \omega h) , \tag{48}$$

$$G = \frac{1}{\omega} e^{-\omega h} \sinh \omega h , \tag{49}$$

$$A = \frac{1}{hk\omega}\left\{e^{-\beta h}\left[\left(\frac{\omega^2 + \beta^2}{\omega_o^2} - h\beta\right) \sinh \omega h - \left(\frac{2\omega\beta}{\omega_o^2} + h\omega\right) \cosh \omega h\right] + \frac{2\omega\beta}{\omega_o^2}\right\} , \tag{50}$$

$$B = \frac{1}{hk\omega}\left\{e^{-\beta h}\left[\frac{\omega^2 + \beta^2}{\omega_o^2} \sinh \omega h + \frac{2\omega\beta}{\omega_o^2} \cosh \omega h\right] + \omega h - \frac{2\beta\omega}{\omega_o^2}\right\} , \tag{51}$$

$$F' = -\frac{\omega_o^2}{\omega} e^{-\beta h} \sinh \omega h , \tag{52}$$

$$G' = e^{-\beta h} (\cosh \omega h - \frac{\beta}{\omega} \sinh \omega h) , \tag{53}$$

$$A' = \frac{1}{hk\omega}\left[e^{-\beta h}\left\{(\beta + h\omega_o^2) \sinh \omega h + \omega \cosh \omega h\right\} - \omega\right] , \tag{54}$$

$$B' = \frac{1}{hk\omega}\left[- e^{-\beta h} (\beta \sinh \omega h + \omega \cosh \omega h) + \omega\right] . \tag{55}$$

d. If $|\omega_o| = |\beta| \leq \xi$ (undamped):

$$F = 1, \tag{56}$$

$$G = h, \tag{57}$$

$$A = h^2/3m, \tag{58}$$

$$B = h^2/6m, \tag{59}$$

$$F' = 0, \tag{60}$$

$$G' = 1, \tag{61}$$

$$A' = h/2m, \tag{62}$$

$$B' = h/2m. \tag{63}$$

The equations for each displacement, velocity, and acceleration in terms of the applied loads and previous displacement and velocity are:

$$\xi_{i,j+1} = F_i\xi_{i,j} + G_i\dot{\xi}_{i,j} + A_i f_{i,j} + B_i f_{i,j+1}, \tag{64}$$

$$\dot{\xi}_{i,j+1} = F'_i\xi_{i,j} + G'_i\dot{\xi}_{i,j} + A'_i f_{i,j} + B'_i f_{i,j+1}, \tag{65}$$

$$\ddot{\xi}_{i,j+1} = \frac{P_{i,j+1}}{m_i} + \frac{b_i\dot{\xi}_{i,j+1}}{m_i} - \frac{K_i\xi_{i,j+1}}{m_i}. \tag{66}$$

4.65.8 Subroutines

Utility routines PRETAB, TAB, SSG2A, CALCV, SSG2B, ADD, and DECØMP are used. See subroutine descriptions, section 3 for details.

4.65.8.1 Subroutine Name: TRD1A

1. Entry Point: TRD1A

2. Purpose: To assemble the loads at all time steps.

3. Calling Sequence: CALL TRD1A (DLT,TRL,CASECC,DIT,PPA,IC,LUSETD,NLFTP,NGRØUP, ITRL,MØDAL)

DLT, TRL, CASECC, DIT are GINØ file numbers of their respective data blocks - integer - input.

PPA - GINØ file number of applied loads - p set - for all times - integer - input.

IC - GINØ file number of initial condition matrix - integer - input.

LUSETD - Length of p set - integer - input.

NLFTP - Non-linear load set id selected in CASECC - integer - output.

NGRØUP - Number of time step changes - integer - output.

ITRL - Number of records to skip in TRL to obtain selected TSTEP card - integer - output.

MØDAL - If MØDAL = 1, a modal formulation is being used - integer - input.

4.65.8.2 Subroutine Name: TRD1B

1. Entry Point: TRD1B

2. Purpose: To reduce the applied loads to the solution set and remove all but output time loads.

3. Calling Sequence: CALL TRD1B (PPA,USETD,GMØ,GØD,PHIDH,MPCF1,SINGLE,ØMIT,FØRM, PD,PS,PP,PAPPLD,SCR1,SCR2,SCR3,SCR4,NGRØUP,TRL,ITRL)

PPA - Same as for TRD1A

USETD,GMØ, GØD,PHIDH,PD, PS,PP,TRL - GINØ file numbers of their respective data blocks - integer - input.

SCR1,..., SCR4 - GINØ file numbers of 4 scratch files.

MPCF1,SINGLE, ØMIT,FØRM - Module input parameters as explained in section 4.65.6.

NGRØUP,ITRL - Same as for TRD1A - integer - input.

PAPPLD - GINØ file number of applied loads - integer - input.

4.65.8.3 Subroutine Name: INITL

1. Entry Point: INITL

2. Purpose: To form [C] and [E] matrices and to form and decompose the [D] matrix.

3. Calling Sequence: CALL INITL (ØFFSET,DELTA)

CØMMØN/TRDXX/ See section 4.65.8.4.

ØFFSET - Length of reserved area of core - integer - input.

DELTA - Current time increment - real - input.

4.65.8.4 Subroutine Name: TRD1C

1. Entry Point: TRD1C

2. Purpose: To solve the coupled equations.

3. Calling Sequence: CALL TRD1C (IC,PAPPLD,NGRØUP,NLFTP,UDV,I,SCR1,DIT,NLFT,NØUE MØDA1,PNL)

IC,NGRØUP NLFTP - Are as described in TRD1A - integer - input.

UDV,DIT NLFT,PNL - Are GINØ file numbers of their respective data blocks - integer - input.

SCR1 - GINØ file number of a scratch file.

PAPPLD - Is as described in TRD1B.

NØUE - Module parameter.

MØDA1 - -1 if FØRM ≠ MØDAL. 1 if FØRM = MØDAL - integer - input.

I - Current loop count. Runs from 1 to number of time step changes - integer - input.

CØMMØN/TRDXX/IK(7)IM(7),IB(7),C,ULL,LLL,E,SCR1,SCR2,IØPEN

IK(7) - Matrix control block for K matrix.

IM(7) - Matrix control block for M matrix.

IB(7) - Matrix control block for B matrix.

C - GINØ file number for C matrix.

ULL,LLL - GINØ file numbers for decomposition products of D matrix.

E - GINØ file number for E matrix.

SCR1,SCR2- GINØ file numbers for 2 scratch files.

IØPEN - 1 implies C,ULL,LLL, and E are open.
0 implies C,ULL,LLL, and E are closed.

4.65.8.5 Subroutine Name: FØRM1

1. Entry FØRM1

2. Purpose: To compute $\{u_{-1}\}$, $\{P'_0\}$, and $\{P_{-1}\}$ for starting the integration procedure.

3. Calling Sequence: CALL FØRM1 (UØ,UDØTØ,UI,PØ,PI,DELTAT,IBUF)

UØ - Array of core containing $\{u_0\}$ - real - input.

UDØTØ - Array of core containing $\{\dot{u}_0\}$ - real - input.

UI - Array of core for storage of $\{u_{-1}\}$ - real - output.

PØ - Array of core for storage of $\{P'_0\}$ - real - output.

PI - Array of core for storage of $\{P_{-1}\}$ - real - output.

DELTAT - Current time step size - real - input.

IBUF - GINØ buffer

CØMMØN/TRDXX/ (see above).

4.65.8.6 Subroutine Name: MATVEC

1. Entry Point: MATVEC

2. Purpose: To form the product{X} = {X} + [A] {Y} where [A] is a matrix and {Y} is a vector.

3. Calling Sequence: CALL MATVEC (Y,X,FILEA,IBUF)

Y - Array of core containing Y array real - input.

X - Array of core containing X array real - input/output.

FILEA - Matrix control block for A. If FILEA(1) $\leq$ 0, MATVEC will return.

IBUF - GINØ buffer. If IBUF $\leq$ 0, MATVEC will assume the file is already in core.

COMMON/TPDXX/ (See section 4.65.8.4)

4.65.8.7 Subroutine Name: STEP

1. Entry Point: STEP

2. Purpose: To integrate forward 1 time step.

3. Calling Sequence: CALL STEP (U2,U1,UØ,P,IBUF)

U2 - Array which will contain $\{u_{i+2}\}$ - real - output.

U1 - Array containing $\{u_{i+1}\}$ - real - input.

UØ - Array containing $\{u_i\}$ - real - input.

P - Array containing combined load - real - input.

IBUF - GINØ buffer - input.

COMMON/TRDXX/ (See section 4.65.8.4)

4.65.8.8 Subroutine Name: INTFBS

1. Entry Point: INTFBS

2. Purpose: To perform the forward-backward substitution necessary to solve the system of equations: [A] {Y} = {X} for {Y}.

3. Calling Sequence: CALL INTFBS (X,Y,IBUF)

X - Load vector (i.e. right hand side) - real - input.

Y - Solution vector - real - output.

IBUF - GINØ buffer.

CØMMØN/TRDXX/ (See section 4.65.8.4)

CØMMØN/INFBS/FILEL(7),FILEU(7)

FILEL - Matrix control block of the lower triangular factor from the decomposition of A.

FILEU - Matrix control block of the upper triangular factor from the decomposition of A.

4.65.8.9 Subroutine Name: TRD1D

1. Entry Point: TRD1D

2. Purpose: To compute the non-linear loads at each time step.

3. Calling Sequence: CALL TRD1D

CØMMØN/TRDD1/NLFT,DIT,NLFTP,NØUT,ICØUNT,ILØØP,MØDA1,NZ,ICØRE,IU2,IP4,IPNL(7),NMØDES, NSTEP,PNL

The variables DIT,NLFT,NLFTP,MØDA1 and PNL are defined as in TRD1C (see section 4.65.8.4).

NØUT - Output interval - integer - input.

ICØUNT - Current time step counter - integer - input.

ILØØP - Current time change counter - integer - input.

NZ - Length of open core - integer - input.

ICØRE - Pointer to first unused cell of open core - integer - input.

IU2 - Pointer to displacement vector - 1 - integer - input.

IP4 - Pointer to load area -1 - integer - input.

IPNL - Matrix control block for PNL - integer - input/output.

NMØDES - Number of modes if modal formulation is being used - integer - input.

NSTEP - Number of times steps for this time increment - integer - input.

4.65.8.10 Subroutine Name: TRD1E

1. Entry Point: TRD1E

2. Purpose: To solve the uncoupled modal equations.

3. Calling Sequence: CALL TRD1E (MHH,BHH,KHH,PH,UHV,NGRØUP)

MHH,BHH,KHH, PH,UHV - GINØ file numbers of their respective data blocks - integer - input.

NGRØUP - Number of time step changes - integer - input.

4.65.8.11 Subroutine Name: FØRM2

1. Entry Point: FØRM2

2. Purpose: To compute $\{u_i'\}$ and $\{P_i'\}$ when changing time steps. (See Equations 23 through 28)

3. Calling Sequence: CALL FØRM2 (UDDIP1,UDIP1,UIP,PIP,IBUF)

UDDIP1 - Array of core containing $\{\ddot{u}_{i+1}\}$ - real - input.

UDIP1 - Array of core containing $\{\dot{u}_{i+1}\}$ - real - input.

UIP - Array of core containing $\{u_i'\}$ - real - output.

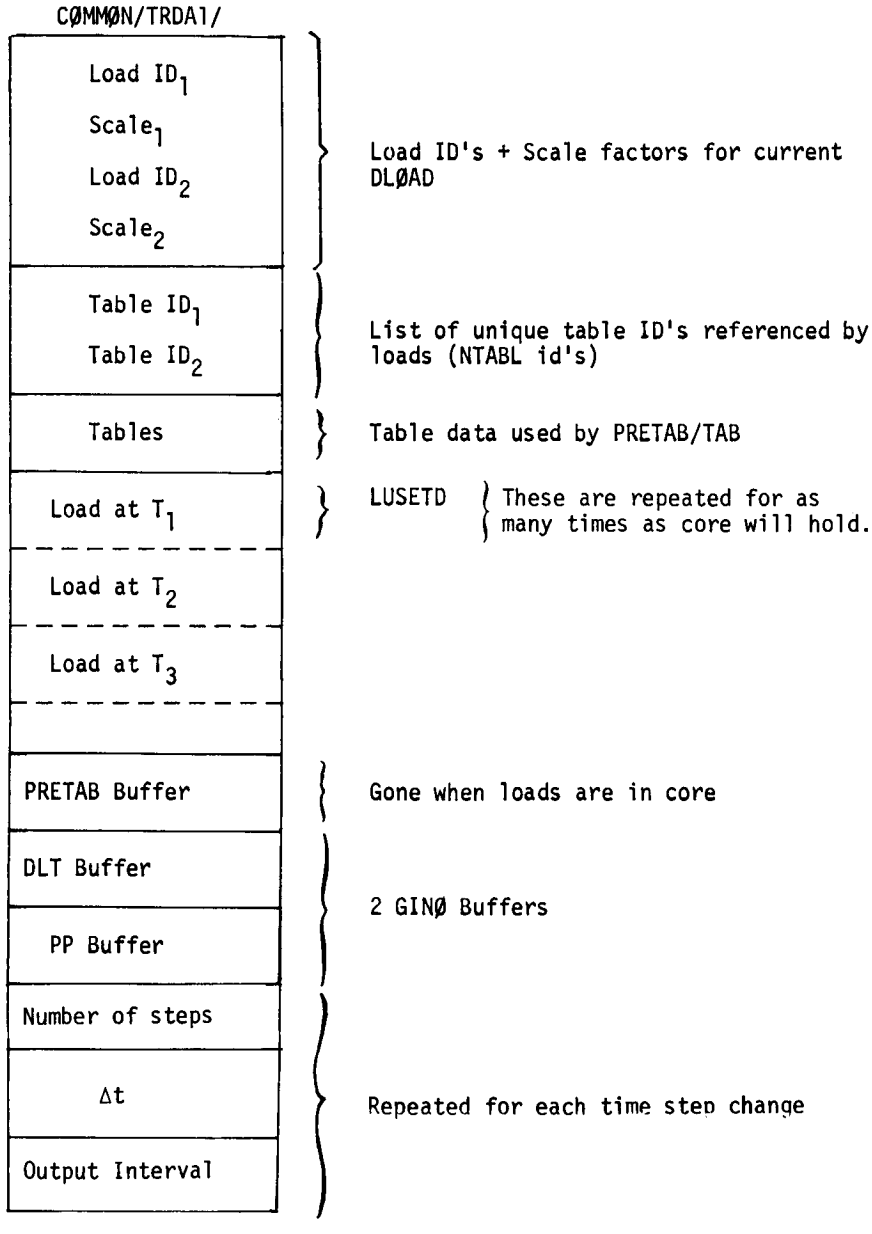
PIP - Array of core containing $\{P_i'\}$ - real - output.

IBUF - GINØ buffer

CØMMØN/TRDXX/ (See section 4.65.8.4)

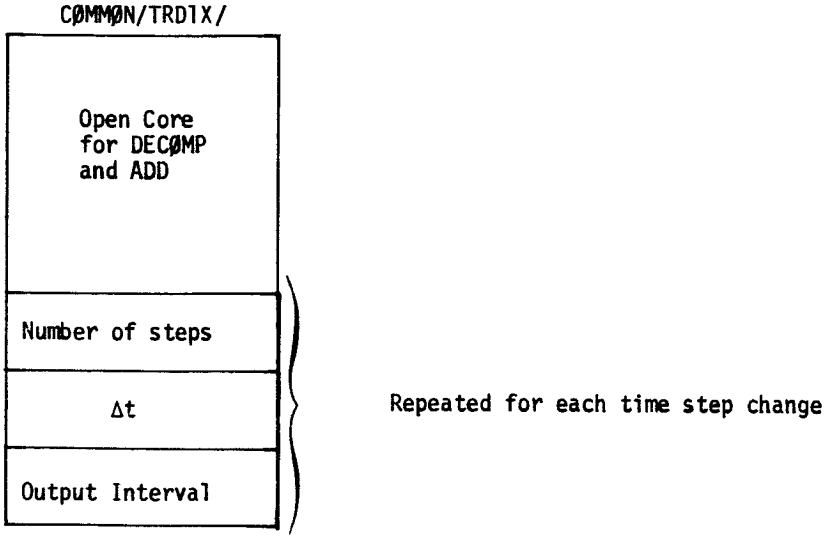
4.65.9 Design Requirements

1. Open core at /TRDA1/ is illustrated as follows:



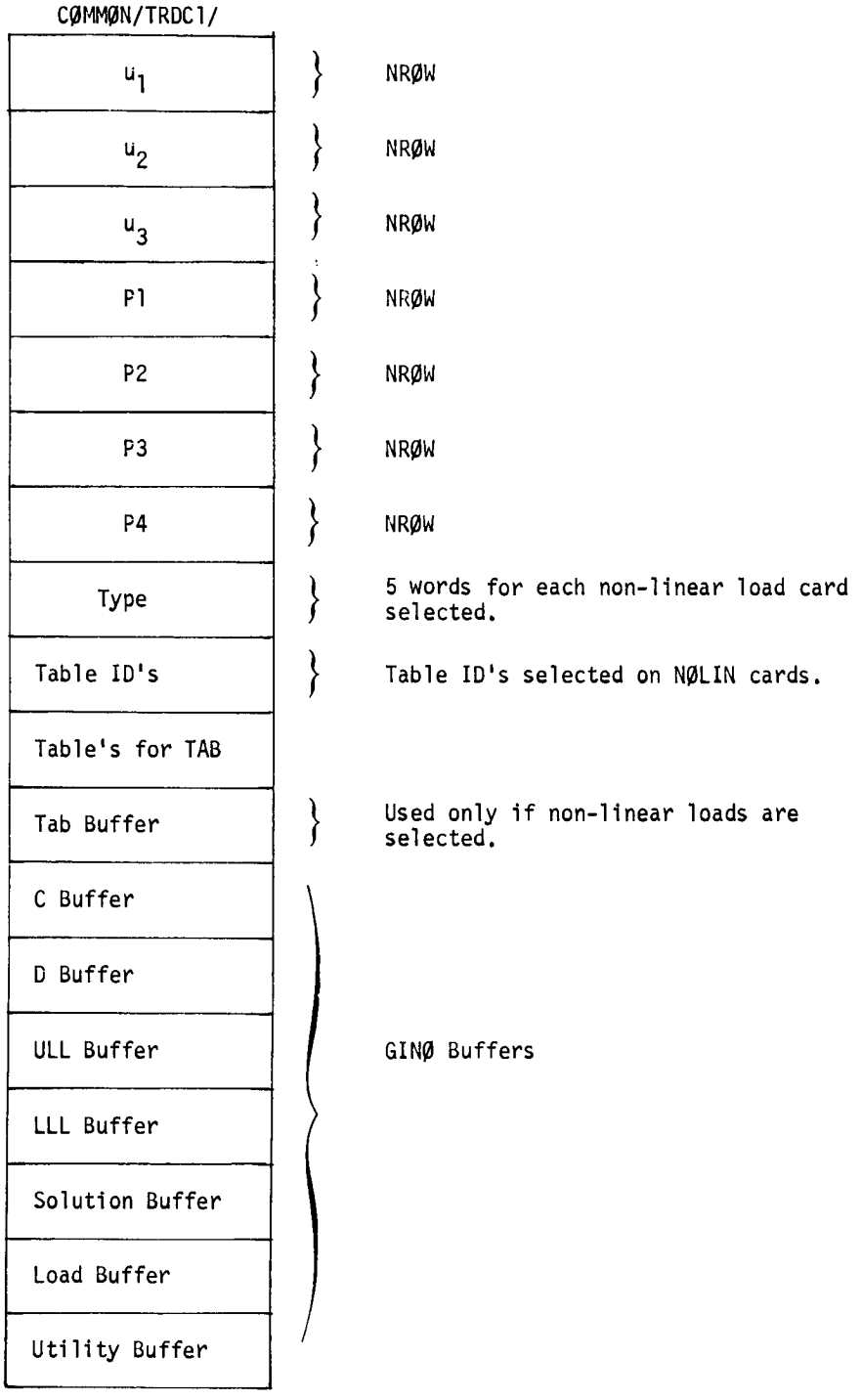
There must be enough core to assemble one time step load.

2. Open Core at /TRD1X/ is illustrated as follows:

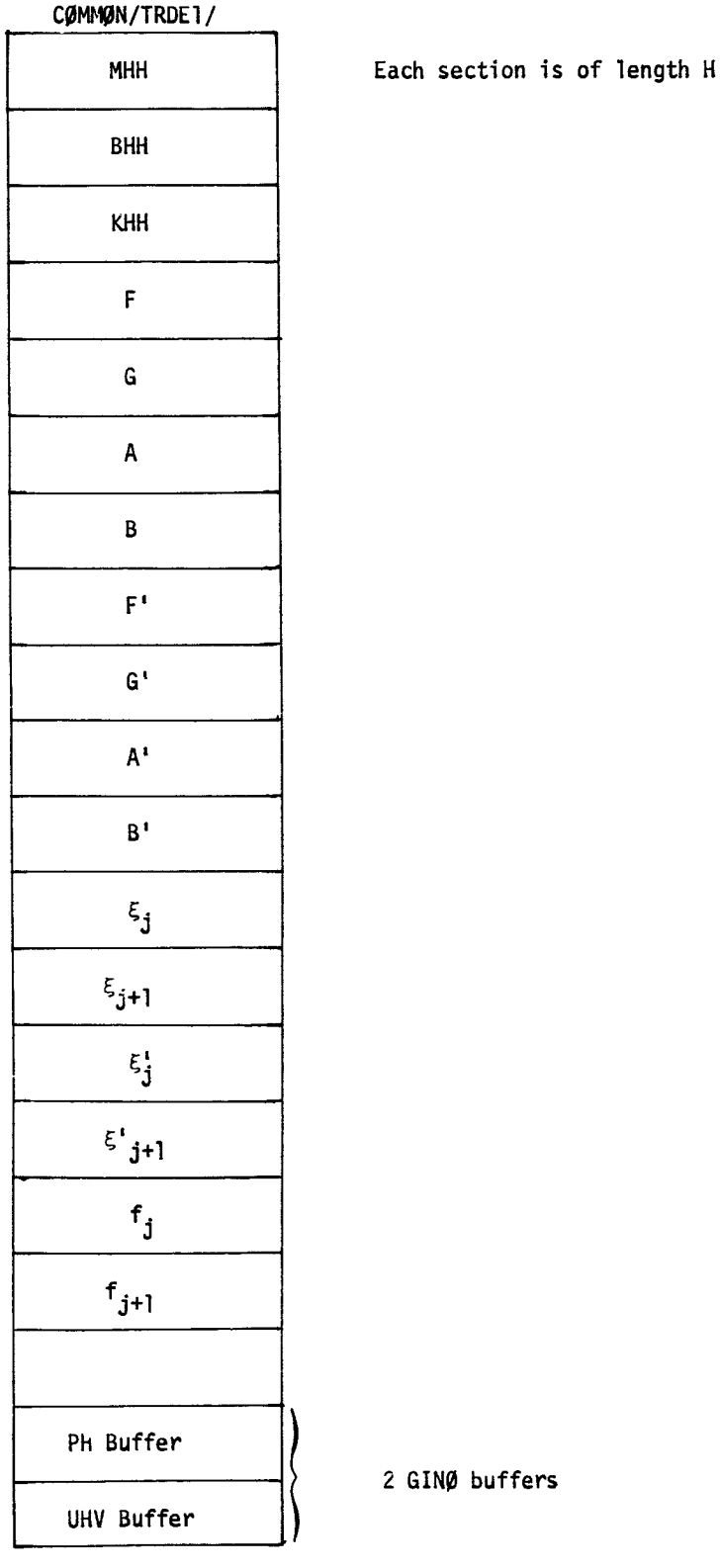


This table is at the bottom of open core through the module.

3. Open Core at /TRDC1/ is illustrated as follows:



4. Open Core at /TRDE1/ is illustrated as follows:



4.65.10 Diagnostic Messages

TRD may issue the following messages

3001, 3002, 3003, 3005, 3007, 3008, 3031, 3044, 3045, 3046.

4.66 FUNCTIONAL MODULE GKAM (GENERAL K ASSEMBLER MODAL)

4.66.1 Entry Point: GKAM

4.66.2 Purpose

To assemble the modal mass, damping and stiffness matrices.

4.66.3 DMAP Calling Sequence

```
GKAM    USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/V,N,NØUE/C,Y,
        LMØDES/C,Y,LFREQ/C,Y,HFREQ/V,N,NØM2PP/V,N,NØB2PP/V,N,NØK2PP/V,N,NØNCUP/V,N,
        FMØDE   $
```

4.66.4 Input Data Blocks

USETD - Displacement set definitions table dynamics.

PHIA - Eigenvectors matrix giving the eigenvectors (displacements) in the a set.

MI - Modal mass matrix.

LAMA - Real Eigenvalue Table.

DIT - Direct Input Table.

M2DD - Direct input mass matrix - d set.

B2DD - Direct input damping matrix - d set.

K2DD - Direct input stiffness matrix - d set.

CASECC - Case Control Data Table.

Notes:

1. USETD may be purged if NØUE < 0.
2. PHIA cannot be purged.
3. MI cannot be purged.
4. LAMA cannot be purged.
5. DIT cannot be purged if SDAMP $\neq$ 0 in CASECC.
6. CASECC cannot be purged.
7. M2DD cannot be purged if NØM2PP $\geq$ 0.
8. B2DD cannot be purged if NØB2PP $\geq$ 0.
9. K2DD cannot be purged if NØK2PP $\geq$ 0.

4.66.5 Output Data Blocks

MHH - Modal mass matrix - h set.

BHH - Modal damping matrix - h set.

KHH - Modal stiffness matrix - h set.

PHIDH - Transformation matrix from d set to modal coordinates.

Note: No output matrix can be purged.

4.66.6 Parameters

NØUE - Input-integer-no default. NØUE indicates presence and number of extra points.

LMØDES - Input-integer-default = 0. LMØDES selects the first LMØDES eigenvectors (or all if there are less than LMØDES) to use for the modal coordinates.

LFREQ - Input-real-default = 0.0. If LMØDES = 0, eigenvectors with eigenvalues between LFREQ and HFREQ are used in the modal formulation.

HFREQ - Input-real-default = 0.0. See LFREQ.

NØM2PP - Input-integer-no default. If NØM2PP < 0, M2DD will not be used.

NØB2PP - Input-integer-no default. If NØB2PP < 0, B2DD will not be used.

NØK2PP - Input-integer-no default. If NØK2PP < 0, K2DD will not be used.

NØNCUP - Output-integer-no default. If no direct input matrices exist the problem is considered uncoupled and NØNCUP is set to -1.

FMØDE - Output-integer-no default. The mode number of the first selected eigenvector is stored in FMØDE.

4.66.7 Method

The general system assembly module for the modal method is used when the real eigenvalues for the structure have been determined. With this method, it is possible to decrease the order of the problem without sacrificing accuracy. The module forms the conversion matrix between modal displacements and all free physical displacements of the system. It then forms the general matrices in terms of displacements of the modes and the extra points.

CASECC is read, and the selected structural damping table "id" is stored.

LAMA is read and the selected eigenvalues are stored in core. If an eigenvalue is selected, the corresponding column of PHIA is copied onto PHIDH1, a scratch file.

If extra points are not present (NØUE < 0), PHIDH = PHIDH1. If extra points are present:

$$[\Phi_{dh}] = \left[\begin{array}{c|c} \Phi_a & 0 \\ \hline 0 & I \end{array}\right]. \tag{1}$$

This is accomplished in subroutine GKAM1B.

The "H" matrices are formed:

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\Phi_{dh}]^T [M^2_{dd}] [\Phi_{dh}] , \tag{2}$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\Phi_{dh}]^T [B^2_{dd}] [\Phi_{dh}] , \tag{3}$$

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\Phi_{dh}]^T [K^2_{dd}] [\Phi_{dh}] , \tag{4}$$

where m_i = diagonal terms of MI, and

$$b_i = m_i \omega_i g(\omega_i), \tag{5}$$

$$k_i = m_i \omega_i^2 . \tag{6}$$

ω_i is the frequency for the mode from LAMA and $g(\omega_i)$ is the tabular structural damping table selected in CASECC. If no selection is made $g(\omega_i) \equiv 0.0$. The "H" matrices are formed using subroutines GKAM1A, SSG2B, PRETAB, TAB, CALCV, MERGE.

4.66.8 Subroutines

4.66.8.1 Subroutine Name: GKAM1B.

1. Entry Point: GKAM1B.

2. Purpose: To construct $[\Phi_{dh}]$ if extra points are present.

3. Calling Sequence: CALL GKAM1B (USETD,SCR1,SCR2,PHIDH,PHIDH1,MØDES,CØRE,LHSET,NØUE)

USETD - GINØ file number of USETD - integer - input.

SCR1 - GINØ file number of 1st scratch file - integer - input.

SCR2 - GINØ file number of 2nd scratch file - integer - input.

PHIDH - GINØ file number of PHIDH - integer - input.

PHIDH1 - GINØ file number of PHIDH1 - integer - input.

MØDES - Number of modes selected - integer - input.

CØRE - Array of open core.

LHSET - Length of h set - integer - output.

NØUE - Extra point flag NØUE $\geq$ 0 indicates presence of extra points - integer - input.

4.66.8.2 Subroutine Name: GKAM1A.

1. Entry Point: GKAM1A.

2. Purpose: To form $[M_{hh}]$, $[B_{hh}]$, or $[K_{hh}]$.

3. Calling Sequence: CALL GKAM1A (MI,PHIDH,DIT,SCR1,SCR2,IØPT,IHH,NØI2DD,CØRE,MØDES, SDITD,LHSET,I2DD,IMSKIP,SCR3)

MI - GINØ file number of MI - integer - input.

PHIDH - GINØ file number of PHIDH - integer - input.

DIT - GINØ file number of DIT - integer - input.

SCR1 - GINØ file number of scratch 1 - integer - input.

SCR2 - GINØ file number of scratch 2 - integer - input.

SCR3 - GINØ file number of scratch 3 - integer - input.

IHH - GINØ file number of HH file (M, B, or K) being constructed - integer - input.

I2DD - GINØ file number of 2DD file being used with IHH (K2DD, M2DD or B2DD) - integer - input.

IØPT - Flag for equation to use

1 $\Longrightarrow$ MHH

2 $\Longrightarrow$ BHH

3 $\Longrightarrow$ KHH

- integer - input.

NØI2DD - NØI2DD < 0 implies I2DD purged - integer - input.

MØDES - Number of modes selected - integer - input.

SDTID - Id of structural damping table to be used for BHH - integer - input.

LHSET - Length of H set - integer - input.

IMSKIP - Number of records to skip in MI before extracting diagonal terms - integer - input.

CØRE - Array of modes selected.

4.66.9 Design Requirements

Three scratch files are necessary. Open core at /GKAM1X/ is used for mode storage. One packed eigenvector must be held in core.

4.66.10 Diagnostic Messages

Fatal error messages 3007 and 3008 may be issued by GKAM.

4.67 FUNCTIONAL MODULE DDR1 (DYNAMIC DATA RECOVERY - PART 1)

4.67.1 Entry Point: DDR1

4.67.2 Purpose: To transform modal solutions to physical solutions:

$$\{u_d\} = [\Phi_{dh}] \{u_h\} . \qquad (1)$$

4.67.3 DMAP Calling Sequence

```
DDR1   UHV,PHIDH/UDV  $
```

4.67.4 Input Data Blocks

UHV	-	Solution set displacement vectors.
PHIDH	-	Transformation matrix from d set to modal coordinates.

4.67.5 Output Data Blocks

UDV	-	Displacement vectors - d set.

4.67.6 Parameters

None

4.67.7 Method

Subroutine SSG2B is called to compute $\{u_d\}$ as in Equation 1.

4.67.8 Subroutines

DDR1 has no auxiliary subroutines. See section 3.5.13 for a description of SSG2B.

4.67.9 Design Requirements

One scratch file is needed.

4.68 FUNCTIONAL MODULE DDR2 (DYNAMIC DATA RECOVERY - PART 2)

4.68.1 Entry Point: DDR2

4.68.2 Purpose

To compute mode acceleration displacements.

4.68.3 DMAP Calling Sequence

```
DDR2   USETD,UDV,PDF,K2DD,B2DD,MDD,FRL,ULL,LLL,DM/UDV1,UEVF,PAF/V,N,TYPE/V,N,NØUE/V,N,REACT/
       V,N,FRQSET  $
```

4.68.4 Input Data Blocks

USETD - Displacement set definitions table dynamics.

UDV - Displacement vectors - d set.

PDF - Dynamic load matrix for frequency analysis - d set.

K2DD - Direct input stiffness matrix - d set.

B2DD - Direct input damping matrix - d set.

MDD - Dynamic mass matrix - d set.

FRL - Frequency Response List.

ULL - Upper triangular factor of KLL - ℓ set.

LLL - Lower triangular factor of KLL - ℓ set.

DM - Rigid body transformation matrix.

Notes:

1. USETD must not be purged.
2. UDV must not be purged.
3. PDF must not be purged.
4. FRL must not be purged if TYPE = FREQ.
5. MDD must not be purged.
6. ULL, LLL must not be purged.
7. DM must not be purged if REACT $\geq$ 0.

4.68.5 Output Data Blocks

UDV1 - Displacements after mode acceleration - d set.

UEVF - Displacements at the extra points.

PAF - Equivalent load vector for mode acceleration computations - a set.

4.68.6 Parameters

TYPE - Input-BCD-no default. TYPE determines the type of mode acceleration which will be used, TRAN for transient or FREQ for frequency response.

NØUE - Input-integer-no default. NØUE $\geq$ 0 indicates presence of extra points.

REACT - Input-integer-no default. REACT $\geq$ 0 indicates presence of supports.

FRQSET - Input-integer-no default. FRQSET chooses the frequency list if TYPE = FREQ.

4.68.7 Method

The equivalent load vector is computed:

$$\{P_d^a\} = \{P_d\} - [K_{dd}^2]\{u_d\} - [B_{dd}^2]\{\dot{u}_d\} - [M_{dd}]\{\ddot{u}_d\} . \qquad (1)$$

For a transient analysis problem $\{u_d\}$, $\{\dot{u}_d\}$, and $\{\ddot{u}_d\}$ are given explicitly. For Frequency Response Analysis:

$$\{\dot{u}_d\} = i\omega\{u_d\} , \qquad (2)$$

$$\{\ddot{u}_d\} = -\omega^2\{u_d\} , \qquad (3)$$

where ω is the forcing frequency and $\{u_d\}$ is the complex response vector. ω comes from FRQSET in FRL. The vector $\{P_d^a\}$ is the sum of applied loads and inertia loads due to the motion of the system approximated by its lower modes. The static solution using these loads will provide a better answer for displacements.

If extra points are present (NØUE $\geq$ 0), then

$$\{P_d^a\} \Rightarrow \left\{\begin{array}{c} P_a^a \\ \hline P_e \end{array}\right\} , \tag{4}$$

$$\{u_d\} \Rightarrow \left\{\begin{array}{c} u_a^a \\ \hline u_e \end{array}\right\} . \tag{5}$$

$\{u_e\}$ is placed in data block UEVF. Subroutines CALCV and SSG2A perform this calculation.

If supports are present (REACT $\geq$ 0), then

$$\{P_\ell^a\} \Rightarrow \left\{\begin{array}{c} P_\ell \\ \hline P_r \end{array}\right\} , \tag{6}$$

$$\{u_a\} \Rightarrow \left\{\begin{array}{c} u_\ell \\ \hline u_r \end{array}\right\} . \tag{7}$$

Solve for $\{u_a^a\}$:

$$[L_{\ell\ell}]\,[U_{\ell\ell}]\,\{u_\ell^a\} = \{P_\ell^a\} . \tag{8}$$

This is accomplished in subroutine SSG3A.

If supports are present, then

$$\{u_a^a\} = \left\{\begin{array}{c} \{u_\ell^a\} + [D]\,\{u_r\} \\ \hline u_r \end{array}\right\} , \tag{9}$$

otherwise, $\{u_a^a\} = \{u_\ell^a\}$. Subroutine SDR1B performs this calculation.

If extra points are present, then

$$\{u_d^a\} \Leftarrow \left\{\begin{array}{c} u_a^a \\ \hline u_e \end{array}\right\} . \qquad (10)$$

Note: If the problem type is transient, $\{u_d^a\}$ must be merged with $\{\dot{u}_d\}$ and $\{\ddot{u}_d\}$.

4.68.8 Subroutines Called

CALCV - See section 3.5.5.

SSG2A - See section 3.5.7.

SSG2B - See section 3.5.13.

SSG3A - See section 3.5.18.

SDR1B - See section 3.5.8.

4.68.8.1 Subroutine Name: DDR1A.

1. Entry Point: DDR1A.

2. Purpose: To construct the equivalent load vector $\{P_d^a\}$.

3. Calling Sequence: CALL DDR1A(PDF,K2DD,B2DD,MDD,UDV,PAF,FRL,FRQSET,SCR1,SCR2,SCR3,SCR4, TYPE,SCR5).

PDF, K2DD, B2DD, MDD, UDV, PAF, FRL, SCR1-5 - GINØ file number of appropriate data block - integer - input.

FRQSET - Frequency set list id - integer - input. FRQSET will be used only if TYPE = FREQ.

TYPE - Problem type - BCD - input.

4.68.8.2 Subroutine Name: DDR1B

1. Entry Point: DDR1B.

2. Purpose: To merge displacements with previously computed velocity and acceleration in a transient problem.

3. Calling Sequence: CALL DDR1B (UDV,UAD,UADV).

UDV - GINØ file number of displacement, velocity and acceleration file - integer - input.

UAD - GINØ file number of equivalent displacements - integer - input.

UADV - GINØ file number of new displacements, velocity and acceleration - integer - input.

4.68.9 Design Requirements

Open core for DDR2 begins at /DDR1X/. Open core for DDR1A begins /DDRA1/. Open core for DDR1B begins /DDRB1/. Six scratch files are needed.

4.68.10 Diagnostic Messages

None.

4.69 OUTPUT MODULE XYPLØT (X-Y DATA PLOTTER)

4.69.1 Entry Point: XYPLØT

4.69.2 Purpose

To process information supplied by module XYTRAN through a single data block and output to either PLT1 (BCD plot tape) or PLT2 (binary plot tape) for labeling and plotting X-Y data on an off-line plotter.

4.69.3 DMAP Calling Sequence

```
XYPLØT     XYPLTT// $
```

4.69.4 Input Data Blocks

XYPLTT - Plotting Control Values Table. Note if XYPLTT is purged, XYPLØT returns control without action.

4.69.5 Output Data Blocks

None. (All output consists of physical tapes produced for off-line plotters and possibly user warning messages to the installation output unit for printing).

4.69.6 Parameters

None.

4.69.7 Method

XYPLØT initially determines open core size and assigns buffers for its input file and output file. The remaining core is used to store data points read in for each plot. The input file is then opened and spaced forward over the header record containing the data block name. Should the system not be able to locate this file, a warning message is output and XYPLØT returns control to the calling program without further action. Otherwise XYPLØT reads in the first I.D. record from the input file. A check is made to determine if the word count of this record is correct. If not, the following records are checked until either the correct

word count is found or the error count reaches a specified limit. If the specified limit is reached, XYPLØT assumes the input file is invalid and returns control to the calling program after printing a warning message.

If the I.D. record had the proper word count, XYPLØT checks if new axes are necessary. If not, the next data record is read, and the data pairs are plotted on the previous axes. When new axes are necessary, a check is made to determine if they go on the lower half of a plot. If not, XYPLØT makes a number of I.D. data validity checks. Whenever possible, where I.D. data are questionable, default values are assigned and processing continues following a warning message that this particular plot may be invalid.

After the validity checks, XYPLØT terminates the previous plot and initializes the plotting parameters for the NASTRAN plotting software. This is done for each new plot so that it is possible to produce alternate plots on two different plotters. Normally, however, plots will be done for only one plotter on any single entry to XYPLØT. If required, a new plot is initiated, and curve and axes titles are prepared from the I.D. data and generated. If not a new plot, only the axes titles are done.

At this time XYPLØT computes the constants which will be used to transform the curve data into actual plotter counts. These constants are saved and used until new axes are drawn.

Following this, XYPLØT determines if any tick marks are to be placed along the X axis and at the X maximum and X minimum lines. If there are to be tick marks, the number and spacing (linear or logarithmic) is computed for them and plotted. As the X direction tick marks are prepared, a check is made to determine if Y grid lines are requested. If so, a grid line is prepared at each tick mark and plotted. Logarithmic tick mark labels are prepared and plotted at the same time as the tick marks and X grid lines, if any.

After the tick marks are completed, the X and Y axes are plotted if requested. Finally the linear tick marks are labeled in both the X and Y directions if requested.

Once the curve titles, tick marks, and labeling have been accomplished, XYPLØT reads in the next record from the input data file. Normally all the data pairs for any I.D. record can be brought into core memory with a single read. However, provision is made for additional reads if the open core space is not sufficient to contain all the data on the initial read. A check is made to determine if there are an even number of data values (i.e., an X and Y value for each data

point). If not, a warning message is printed and the last value ignored. The data are then checked against the previously defined X and Y minimums and maximums. Any data outside these limits are ignored and not plotted. The remaining data points are then converted to plotter counts and plotted in one of three modes. The three modes are: point plot with choice of symbol; line plot; combination of the first two.

After finishing the data, XYPLØT reads in the next I.D. record and continues as before until an end-of-file is reached. At this point it closes the input file, terminates the current plot and returns control to the calling program.

4.69.8 Subroutines

XYPLØT calls the following plotter utility subroutines: AXIS, LINE, PRINT, SØPEN, PLTSET, STPLØT, SYMBØL, TIPE, TYPFLT, and TYPINT. The descriptions of these subroutines may be found in section 3.4.

4.69.9 Design Requirements

4.69.9.1 Allocation of Core Storage

XYPLØT uses open core for two GINØ buffers and the remainder as one large buffer for data points. It appears as follows:

Normally the data pairs buffer will be sufficiently large to hold all the data pairs for a single curve at one time. However, this is not necessary and XYPLØT could operate if the data pairs buffer were only two words long, although not efficiently. As an output module, XYPLØT has been programmed to avoid any system fatal errors. The worst condition that should occur is that no plots are produced. In all cases XYPLØT returns to the calling program so that other system functions may be continued.

4.69.9.2 Environment

The beginning of open core for XYPLØT is defined by /XYPLXX/. XYPLØT uses no scratch files. Common storage requirements consist of /XXPARM/ and /PLTDAT/ which are defined in the block data deck PLØTBD which must be loaded with XYPLØT. /CHAR94/ and SYMBLS/ are also defined in PLØTBD and are necessary for the subroutines called by XYPLØT. See section 2.5 for a description of these common blocks.

When XYPLØT is called, there must be at least one physical tape set up to receive the plotted output, otherwise XYPLØT returns to the calling program without further action.

4.69.10 Diagnostic Messages

Diagnostic messages 991 through 997 may be output on the installation printer device as a result of XYPLØT operation. Generally they are self-explanatory and usually point out particular plots which are questionable rather than giving the user a precise method of solving the problem. This is not possible since XYPLØT receives all its information through a series of other modules rather than from the user directly. See section 6 of the User's Manual for details.

4.70 OUTPUT MODULE ØFP (OUTPUT FILE PROCESSOR)

4.70.1 Entry Point: ØFP

4.70.2 Purpose

ØFP outputs to the system output file, in user-oriented, self-explanatory formats, data blocks prepared for output by other functional modules.

4.70.3 DMAP Calling Sequence

```
ØFP  DB1,DB2,DB3,DB4,DB5,DB6//V,N,CARDNØ  $
```

4.70.4 Input Data Blocks

One to six input data blocks in the output order desired. Any or all input data blocks may be purged.

4.70.5 Output Data Blocks

None

4.70.6 Parameters

CARDNØ - Input and output - integer - default = 0. CARDNØ is incremented by one and punched in columns 73-80 for each card punched by ØFP.

4.70.7 Method

4.70.7.1 Overall Logic Flow

The ØFP logic consists of defining one GINØ buffer and then entering one overall loop of six passes (one pass for each data block). All input data blocks are then handled identically one at a time.

Within each data block, each odd numbered (Identification) record and its respective immediately following even numbered (Data) record are considered as a pair, and is a completely separate entity. There is, and need be, no correspondence between these two records and the previous two records, or between these two records and the following two records.

Thus, within the loop for a given data block, after the file on which the data block resides is opened and its header record is skipped, ØFP reads an Identification record, defines various pointers and descriptors, and then, if any data are present in the Data record, processes this data line by line until the end-of-record is reached. This process continues for all Identification-Data record pairs.

4.70.7.2 Defining Descriptors and Pointers

Because ØFP was confronted with outputting a vast array of data classes having many data format and heading format configurations, it was decided that in order to keep ØFP from becoming a mammoth module of format statements, a system of pointers would be used in conjunction with all the different micro-format elements required.

Information in the Identification record is sufficient to select an initial class pointer. This class pointer, with the addition of a subclass pointer, points to an array of six pointers, five of which define five micro-line formats (from the master set of micro-line formats), and one of which points to a string of micro-data format pointers. These micro-data format pointers then each point to a micro-data format capable of outputting a single variable.

This design is such as to make possible the definition of macro-formats and to allow for easy modification and addition of more output data classes.

4.70.8 Subroutines

4.70.8.1 Subroutine Name: ØFPPUN

1. Entry Point: ØFPPUN
2. Purpose: To write output on the system punch unit.
3. Calling Sequence: CALL ØFPPUN (BUF,NWDS,IØPT,IDD,PNCHED)

   BUF - Array to be output.

   NWDS - Number of words in BUF to output.

   IØPT - { 1 = Vector output.
          { 2 = General output.

   IDD - { 0 = SØRT1 (1st word Integer).
         { 1 = SØRT2 (1st word Real).

PNCHED - {.FALSE. = Punch heading cards.
{.TRUE. = Do not punch heading cards.

4.70.8.2 Subroutine Name: ØFP1

1. Entry Point: ØFP1
2. Purpose: To call PAGE and write five micro-line formats.
3. Calling Sequence: CALL ØFP1

4.70.8.3 Subroutine Name: ØFP1A

1. Entry Point: ØFP1A
2. Purpose: An auxiliary routine to ØFP1. Called by ØFP1 only.
3. Calling Sequence: CALL ØFP1A(LINE)

   LINE - Integer - Branch to format pointer.

4.70.8.4 Block Data Subprogram Name: ØFP1BD

ØFP1BD defines common block /ØFPBD1/.

4.70.8.5 Block Data Subprogram Name: ØFP2BD

ØFP2BD defines common block /ØFPBD2/.

4.70.8.6 Block Data Subprogram Name: ØFP3BD

ØFP3BD defines common block /ØFPBD3/.

4.70.8.7 Block Data Subprogram Name: ØFP4BD

ØFP4BD defines common block /ØFPBD4/.

4.70.8.8 Block Data Subprogram Name: ØFP5BD

ØFP5BD defines common block /ØFPBD5/.

4.70.9 Design Requirements

The common blocks listed above interface between the main subroutines ØFP and ØFP1A. In addition CØMMØN/ØFPXXX/ is used to define open-core which contains the following.

L1, L2, L3, L4, L5 — Five words which indicate the five format numbers defining the heading for the current data being output.

ID - A fifty word buffer for storage of the first fifty words of an identification record from the data block to be output.

BUFF - A GINØ buffer.

The pointer system required by the design operates as described below. The arrays B,C,D,E, and ESINGL, referenced in the discussion below appear in subroutine ØFP.

1. The variable I is set equal to the Data type specified in the data block. The variable J is set equal to the class of data: 1 = Real - SØRT1, 2 = Complex - SØRT1, etc. Then the base pointer, CPØINT = B(I,J), is found.

B array

	SØRT 1		SØRT 2	
	Real	Complex	Real	Complex
Data type 1	0	130	120	132
Data type 2	2	134	122	136
.	4	138	124	140
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Data type N	.	.	.	.

For Future Expansion

Example:
For I = 2, J = 4.

CPØINT = B(I,J)
= 136

2. CPØINT is a index into the C array. Define: DPØINT = C(CPØINT). DPØINT is an index into the D array. Also

L1 = C(CPØINT + 1),

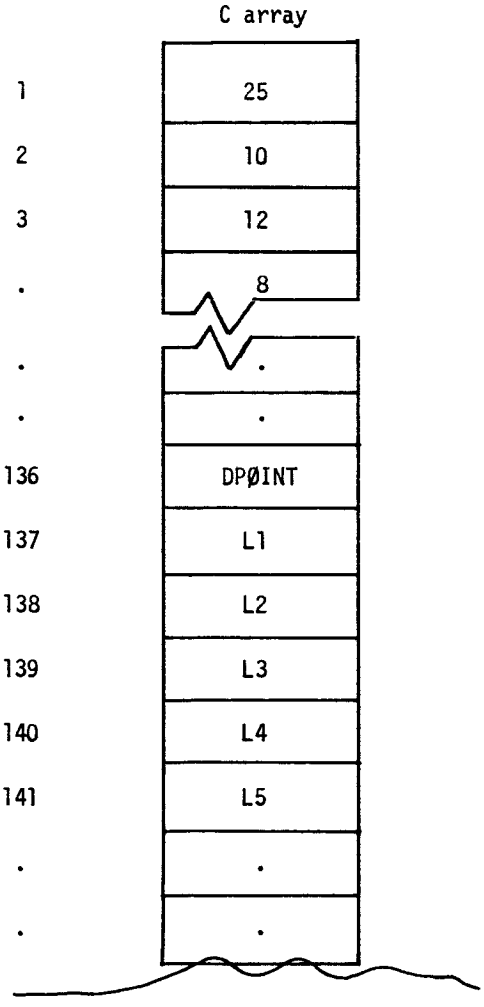
L2 = C(CPØINT + 2),

L3 = C(CPØINT + 3),

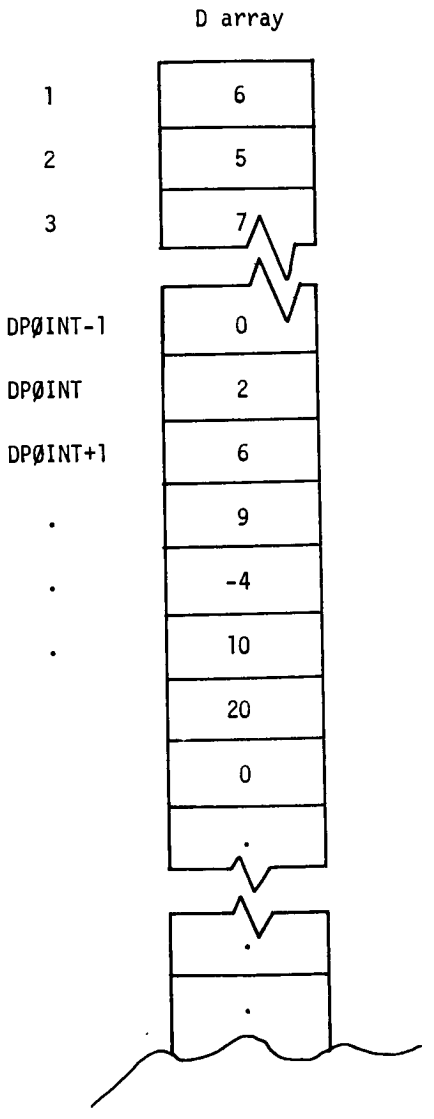
L4 = C(CPØINT + 4),

and L5 = C(CPØINT + 5).

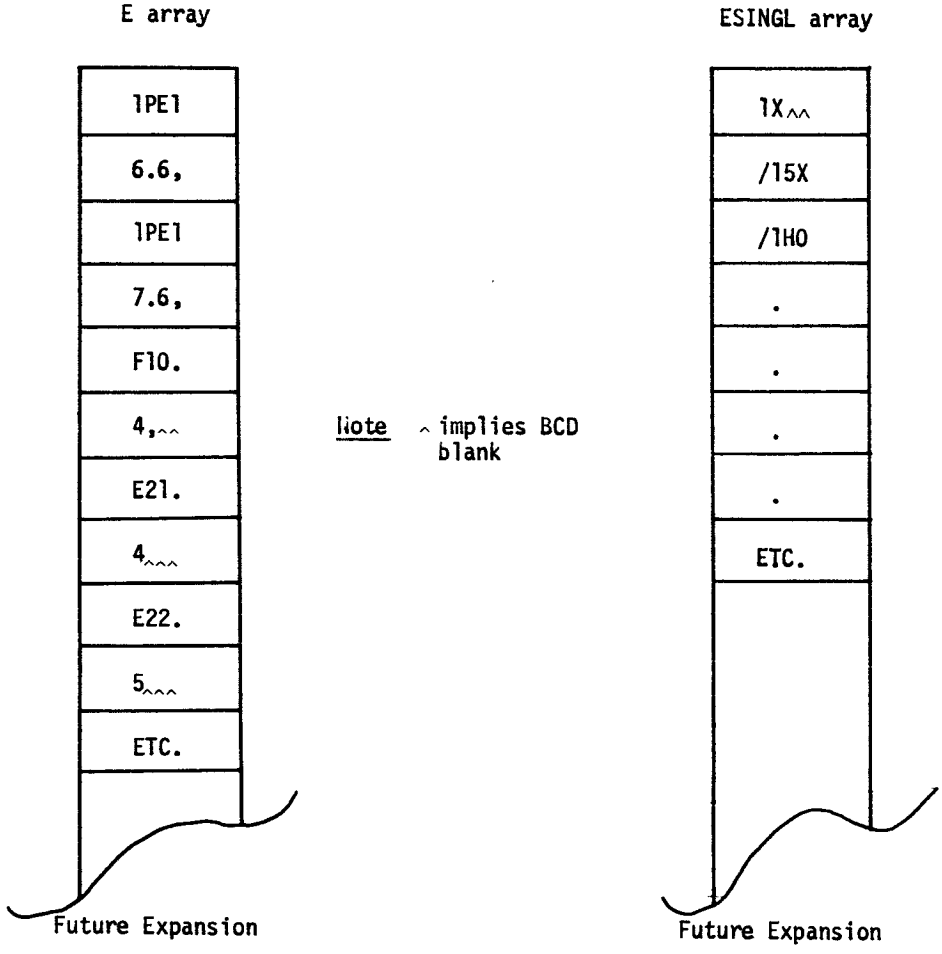
These are the 5 line format numbers which make up the heading format for the type of data currently being processed.



3. Word DPØINT of the D array defines the beginning of a string of pointers into the E array. This string is terminated by the first word containing a zero. Each word of this string thus defines a string of words in the E array which contains Hollerith data for construction of a format. Should a word in the D array be negative, the absolute value is used to point into the ESINGL array which contains Hollerith data also.



4. The E array contains Hollerith data pertaining to the output of a variable; the ESINGL array contains Hollerith data pertaining to spacing and carriage control only.



4.70.10 Diagnostic Messages

If, during some phase of outputting a data block, ØFP encounters an error condition, work on that data block will cease, a warning message will be printed, and a call to the NASTRAN table-printer for table printing of this data block will be made. ØFP will then continue processing the remaining input data blocks.

4.71 OUTPUT MODULE MATPRN (GENERAL MATRIX PRINTER)

4.71.1 Entry Point: MATPRN.

4.71.2 Purpose

To print general matrix data blocks.

4.71.3 DMAP Calling Sequence

```
MATPRN    KGG,PL,PG,B2PP,UPV//  $
```

4.71.4 Input Data Blocks

KGG - Any matrix data block.

PL - Any matrix data block.

PG - Any matrix data block.

B2PP - Any matrix data block.

UPV - Any matrix data block.

Notes:

1. Any or all input data blocks can be purged.
2. If any data block is not a matrix, the TABPT routine will be called.

4.71.5 Output

The non-zero band of each column of the input matrix is unpacked and is printed in single precision format on the system output file.

4.71.6 Parameters

None.

4.71.7 Method

Subroutine MATDUM is called for each non-purged input file.

4.71.8 Subroutines

MATDUM - See subroutine description, section 3.4.28.

4.72 OUTPUT MODULE MATGPR (DISPLACEMENT METHOD MATRIX PRINTER)

4.72.1 Entry Point: MATGPR

4.72.2 Purpose

To print displacement method matrices, identifying values with external grid point numbers.

4.72.3 DMAP Calling Sequence

```
MATGPR    GPL,USET,SIL,ANYMAT//C,N,CØLSET/C,N,RØWSET   $
```

4.72.4 Input Data Blocks

GPL - Grid Point List (This may also be GPLD if extra points are present.)

USET - Displacement set definitions table (This may also be USETD if extra points are present.)

SIL - Scalar Index List (This may also be SILD if extra points are present.)

ANYMAT- Any displacement method matrix.

Notes:

1. Unless CØLSET = RØWSET = 'H', GPL, USET and SIL must be present.
2. If ANYMAT is purged, MATGPR will return.

4.72.5 Output Data Blocks

The non-zero terms of ANYMAT are given external identification and printed on the system output file.

4.72.6 Parameters

CØLSET - Input-BCD-no default. CØLSET indicates the set to which the columns of ANYMAT belong. If CØLSET is not one of the following: M,Ø,R,SG,SB,L,A,F,S,N,G,E,P,NE,FE,D,H then MATGPR will return.

RØWSET - Input-BCD-default = X. RØWSET indicates the set to which the rows of ANYMAT belong. If RØWSET is not a legal set name, RØWSET = CØLSET.

4.72.7 Method

The BCD parameters CØLSET and RØWSET are converted to bit positions in USET. CØLSET must be one of the following 17 symbols: M,Ø,R,SG,SB,L,A,F,S,N,G,E,P,NE,FE,D,H or else MATGPR will return. If ROWSET is not a legitimate symbol RØWSET = CØLSET.

GPL, USET, and SIL are placed in core. Each column and non-zero row element is identified according to the following scheme:

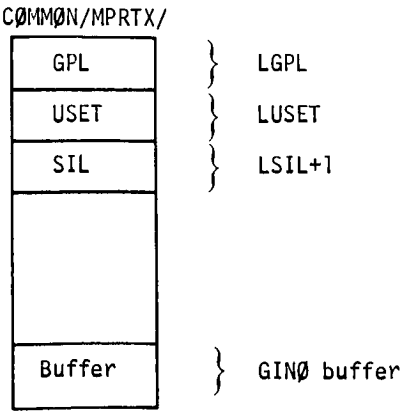
1. USET is searched for the number of members belonging to the g set (p set if USETD is used) before the current member of the matrix set.
2. This number is looked up in SIL to obtain the internal grid point number and type of point (scalar, grid, or extra).
3. The internal grid point number points into GPL for the external ID.

4.72.8 Subroutines

MATGPR has no auxiliary subroutines.

4.72.9 Design Requirements

1. Open core is defined at /MPRTX/.
2. Layout of open core is as follows:



4.72.10 Diagnostic Messages

MATGPR may issue the following diagnostic messages:

3007 and 3008.

4.73 OUTPUT MODULE MATPRT (MATRIX PRINTER)

4.73.1 Entry Point: PRTINT

4.73.2 Purpose

To print a matrix data block.

4.73.3 DMAP Calling Sequence

```
MATPRT    X//C,N,RC/C,N,Y  $
```

4.73.4 Input Data Block

X - Matrix data block to be printed. If X is purged, then nothing is done.

4.73.5 Output Data Blocks

None.

4.73.6 Parameters

RC - Indicates whether X is stored by rows (RC = 1) or columns (RC = 0) - integer - input.

Y - Indicates whether X is to be printed (Y < 0, do not print X; Y > 0, print X) - integer - input - default value = -1.

4.73.7 Method

Each column (or row) of the matrix is broken into groups of 6 terms (3 terms if complex) per printed line. If all the terms in a group = 0, the line is not printed. If the entire column (or row) = 0, it is not printed. If the entire matrix = 0, it is not printed.

4.73.8 Subroutines

4.73.8.1 Subroutine Name: INTPRT

1. Entry Point: INTPRT
2. Purpose: To print a matrix data block using subroutine MATPRT.
3. Calling Sequence: CALL INTPRT (A,CR,Ø,NAME)

where:

A - Storage for 1 column (row) of the matrix + 1 GINØ buffer.

CR - { 0 if the matrix is stored by columns.
1 if the matrix is stored by rows.

Ø - { 0 if the matrix is not to be printed.
1 if the matrix is to be printed.

NAME - 8 character name of the matrix (2 words, 4 characters per word).

3. Method: Subroutine MATPRT is called to print the matrix. Whenever MATPRT returns for a matrix name or column/row id to be printed, the name of the matrix ($NAME_1$,$NAME_2$) or the column or row id (as indicated by 'CR'), is printed.

4.73.8.2 Subroutine Name: MATPRT

1. Entry Points: MATPRT, PRTMAT

2. Purpose: To print a matrix data block.

3. Calling Sequence: CALL MATPRT ($\$N_1$,$\$N_2$,A,ØPT,CØLNUM)

CALL PRTMAT ($\$N_1$,$\$N_2$)

CØMMØN/XXMPRT/MCB(7)

where:

N_1 - FØRTRAN statement number defining the return executed whenever a new page has been started (the calling program is expected to print the matrix and column id. CØLNUM = current column number).

N_2 - FØRTRAN statement number defining the return executed whenever the column id must be printed in the middle of a page (CØLNUM = current column number).

A - Storage for 1 column of the matrix + one GINØ buffer.

ØPT - See subroutine description for VECPRT, below, for the explanation of this argument.

CØLNUM - Current column number being printed (output).

MCB - Matrix control block.

3. Method: The matrix is unpacked and printed one column at a time. Whenever either of the nonstandard returns ($\$N_1$,$\$N_2$) is executed, the calling program must call PRTMAT to continue the printing of the matrix.

4. Additional Subroutines Called: VECPRT.

4.73.8.3 Subroutine Name: VECPRT

1. Entry Points: VECPRT, PRTVEC

2. Purpose: To print a vector.

3. Calling Sequence: CALL VECPRT ($\$N_1$,$\$N_2$,P,N,A,ØPT)

CALL PRTVEC ($\$N_1$,$\$N_2$)

where:

N_1 - FØRTRAN statement number defining the return executed whenever a new page has been started (the calling program is expected to print the vector id and any other subtitles desired).

N_2 - FØRTRAN statement number defining the return executed whenever the vector id is to be printed in the middle of a page.

P - Vector type and precision.

N - Number of components in the vector.

A - Location of the vector.

ØPT -
- = 0 if all the vector components are to be printed, regardless of its sparsity, and if it is to be printed starting on a new page if it will not fit on the current page.
- = +1 if only the printed lines which would have at least one non-zero component are to be printed, and if the vector is to be printed starting on a new page if it will not fit on the current page.
- = -1 if only the printed lines which would have at least one non-zero component are to be printed, and if as much of the vector as possible is to be printed on the current page.

3. Method: The vector will be printed as a single precision real or complex vector. The components will be printed 6 per line if real, 3 per line if complex. In addition, the first and last components of each line will be identified on each side of the line by their respective component members. In addition whenever either of the nonstandard

returns (N_1,N_2) is executed the calling program must call PRTVEC to continue the printing of the vector.

4. Additional Subroutines Called: FØRMAT.

4.73.8.4 Subroutine Name: FØRMAT

1. Entry Point: FØRMAT

2. Purpose: To print a line of 1 to 6 real numbers (optionally centered) preceded and followed by integer id's of the first and last number printed.

3. Calling Sequence: CALL FØRMAT (A,N1,N2,N3,L1,L2)

where:

A - Array from which the 1 to 6 real numbers are to be printed.

N1 - Index of the 1st number in the array to be printed.

N2 - Index of the last number in the array to be printed.

N3 - Increment to be used in extracting the 2nd, 3rd, etc., numbers in the array to be printed.

L1 - Integer id of the 1st number to be printed.

L2 - Integer id of the last number to be printed.

3. Method: If L1 and L2 are both positive, the numbers will be centered on the page. If either L1 or L2 is not positive, the numbers will be printed based upon the centering of 6 numbers.

4.73.9 Design Requirements

Open core is defined at /XXPRTI/. Open core contains one GINØ buffer followed by one unpacked real or complex single precision column of the matrix.

4.74 OUTPUT MODULE SEEMAT (PICTORIAL MATRIX PRINTER)

4.74.1 Entry Point: SEEMAT

4.74.2 Purpose

To show nonzero matrix elements on printer or plotter output positioned pictorially by row and column within the outlines of the matrix.

4.74.3 DMAP Calling Sequence

SEEMAT M1,M2,M3,M4,M5//C,N,{PRINT / PLØT}/V,N,PFILE/V,N,PACK/C,N,PLØTTER/C,N,MØDELN1/C,N,
MØDELB1/C,N,MØDELN2/C,N,MØDELB2 $

Note that parameters PLØTTER, MØDELN1, MØDELB1, MØDELN2 and MØDELB2 are all described in paragraph 4 in section 4.74.6.

4.74.4 Input Data Blocks

M1, M2, M3, M4, M5 } Matrix Data Blocks, any of which may be purged.

4.74.5 Output Data Blocks

None. The formatted matrix picture is output on the system output file or on a plot tape depending on the value of the first parameter.

4.74.6 Parameters

1. PRINT implies use of the system output file. (Any value other than PLØT implies PRINT). PLØT implies use of one of the plotters. Either of the plotter tapes PLT1 or PLT2 will be used, depending on the type of plotter requested.

2. PFILE is the plot number (Used only if first parameter is PLØT).

   Input/output variable integer parameter. Frame or sheet number. The value of this parameter will be incremented by one (1) for each frame (sheet) created by SEEMAT.

   The default value for this parameter is 0.

3. PACK is reserved for a future modification that will allow the representation of a nonzero block of the matrix with a single character. This parameter may be specified as C,N only. (see example in paragraph 4 below)

4. Plotter Name and Model Identification (Used only if parameter 1 = PLØT.)

Each plotter name has associated with it two model identifiers. Each of these model identifiers may either be an integer (MØDELNi) value or BCD (MØDELBi) value. If model identifier "i" (i = 1, 2) is an integer, insert its value for MØDELNi; if model identifier "i" (i = 1, 2) is BCD, insert its value for MØDELBi. In either case, specify the other value for model identifier "i" (MØDELBi and MØDELNi, respectively) as C,N only.

Below is a list of model identifiers allowable for each plotter name. A detailed explanation of this list can be found in section 4 of the User's Manual. Each plotter has associated with it a default model and several optional models. The model underlined is the default model. To access this default model, do not specify any of the last four DMAP parameters. For example to specify the CALCØMP 765, 205 (see section 4 of the User's Manual) the following DMAP statement may be used:

```
SEEMAT     M1,M2,M3,M4,M5//C,N,PLØT/V,N,PFILE/C,N/C,N,CALCØMP  $
```

Plotter Name	Model Identifiers
BL	{LTE,30 / STE,30}
EAI	{3500,300 / 3500,45}
SC	4020,0
CALCØMP	765,205 / 765,210 / 765,105 / 765,110 / 763,205 / 763,210 / 763,105 / 763,110 / 565,205 / 565,210 / 565,105 / 565,110 / 565,305 / 565,310 / 563,205 / 563,210

Plotter Name	Model Identifiers
	563,105 563,110 563,305 563,310
DD	80,B
NASTRAN	M,O / T,O D,O M,1 T,1 D,1

where:

BL is a Benson-Lehner plotter

EAI is an Electronic Associates plotter

SC is a Stromberg Carlson plotter

CALCØMP is a California Computer plotter

DD is a Data Display plotter

NASTRAN is the NASTRAN general purpose plotter

4.74.7 Method

The matrix is partitioned into blocks which can be printed on a single sheet of output paper or plotted on a single frame or sheet of plotter output media. Only blocks containing nonzero elements will be printed. Row and column indices are indicated. The user of this module is cautioned to make sure that his line count limit is large enough. A default of 20,000 lines is provided by NASTRAN. This may be changed via the statement "MAXLINES = value" in the NASTRAN Case Control Deck. The transpose of the matrix is always printed.

The columns of the matrix are examined for nonzero terms. Let the matrix be partitioned into blocks, where a block consists of NL columns and 100 rows, where NL is the number of data lines per page obtained from /SYSTEM/. For each block containing nonzero terms, a BCD block image is stored in open core in packed bit format. Only blocks containing nonzero terms are stored. When NL columns have been passed, the blocks containing nonzero terms are printed on

the system output file or plotted. Note that since NASTRAN matrices are stored by column, the transpose of the matrix is what actually appears on the printed or plotted output. Blocks used for the first NL columns may now be re-used for subsequent groups of NL columns. This process is continued until all columns of the matrix have been processed. As many as five matrices may be handled during a single call to SEEMAT.

4.74.8 Subroutines

The plotter environment subroutines are utilized by SEEMAT. See section 3.4 for descriptions of the plotter utility routines.

4.74.8.1 Subroutine MAPSET

1. Entry Points: MAPSET, MAP

2. Purpose: Converts physical units to plotter units for module SEEMAT.

3. Calling Sequence: CALL MAPSET (X1,Y1,X2,Y2,KI1,KJ1,KI2,KJ2,L)
   CALL MAP (X,Y,KI,KJ)

   X,Y,Xi,Yi = Physical coordinates

   KI,KJ,KIi,KJi = Plotter coordinates

   L = Output Format Flag, input
   1 = KI,KJ are integer
   2 = KI,KJ are real

The meaning of i follows:

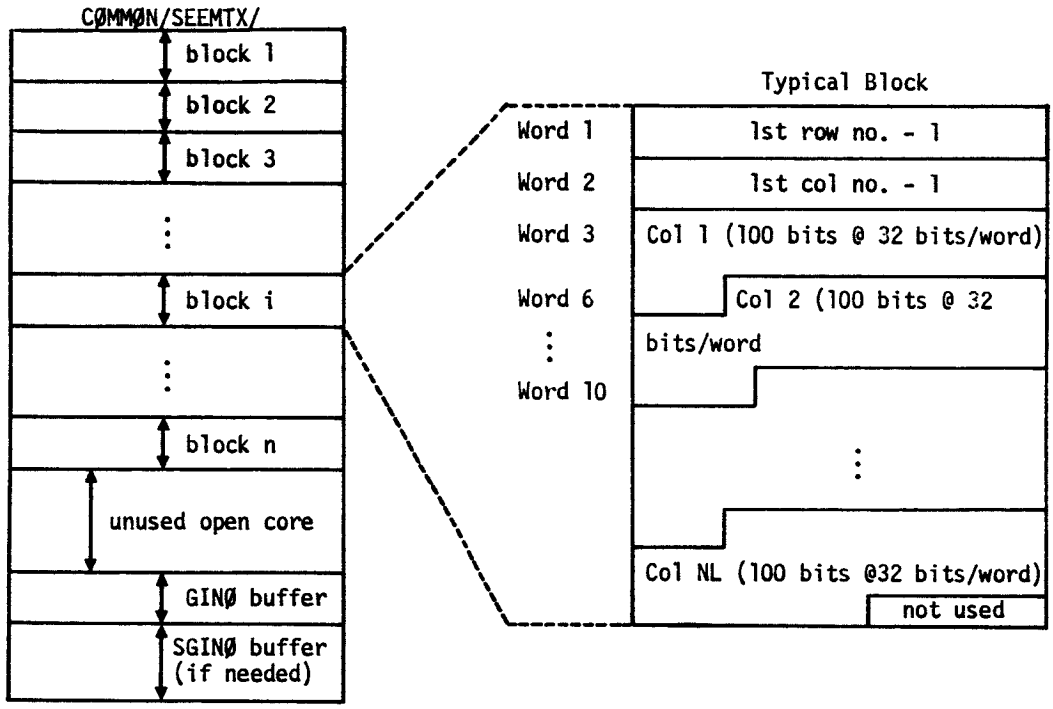
i = 1 point is lower left corner of frame

i = 2 point is upper right corner of frame

i = blank point is an arbitrary point on frame.

4.74.9 Design Requirements

4.74.9.1 Open Core Design



4.74.9.2 Data Requirements and Restrictions

1. All nonpurged input data blocks must be matrices. Error diagnostics will occur in the unpacking routines if an attempt is made to input a table data block to SEEMAT.

2. If the number of blocks needed overflows the available open core (e.g., a large full matrix can do this), a nonfatal diagnostic message will be output on the System Output File and processing for that matrix will be terminated. The user may decrease NL by adding a Case Control Card LINE = NL as a means of overcoming this restriction (printer only). Since the type of matrix for which one is interested in seeing the topology is usually sparse and at least partially banded, this restriction should not prove serious.

4.74.10 Diagnostic Messages

Diagnostic conditions detected by SEEMAT are nonfatal and result in appropriate error messages and termination of the processing of the current input matrix data block. The one exception is the condition of no open core for GINØ buffers, which should not occur in practice.

4.75 OUTPUT MODULE TABPT (TABLE PRINTER)

4.75.1 Entry Point: TABPT.

4.75.2 Purpose

To print table data blocks.

4.75.3 DMAP Calling Sequence

```
TABPT    TAB1,TAB2,TAB3,TAB4,TAB5//   $
```

4.75.4 Input Data Blocks

TAB1 - Any NASTRAN data block.

TAB2 - Any NASTRAN data block.

TAB3 - Any NASTRAN data block.

TAB4 - Any NASTRAN data block.

TAB5 - Any NASTRAN data block.

Note: Any or all input data blocks can be purged.

4.75.5 Output

Each word in a data block is identified as real, BCD, or integer and printed on the system output file. The trailer data is also printed.

4.75.6 Parameters

None.

4.75.7 Method

Subroutine TABPRT is called for each non-purged input file.

4.75.8 Subroutines

TABPRT - See subroutine description, section 3.4.29.

4.76 OUTPUT MODULE PRTMSG (MESSAGE WRITER)

4.76.1 Entry Point: PRTMSG

4.76.2 Purpose

To process a data block of user-oriented messages.

4.76.3 DMAP Calling Sequence

```
PRTMSG     MSG//  $
```

4.76.4 Input Data Blocks

MSG - Messages to be printed (if purged, nothing is done).

4.76.5 Output Data Blocks

None

4.76.6 Parameters

None

4.76.7 Method

In addition to messages, the MSG data block may contain titles and subtitles. Before the first message is printed, a new page is started. From then on, a message count is maintained so as to start another new page when the maximum number of lines per page is exceeded. All messages are assumed to be only one line long. However, there is logic included to provide for messages of more than one line, forcing a new page at any time, and the alteration of titles and subtitles at any time. The description below of subroutine WRTMSG details all the included logic capability.

4.76.8 Subroutines

PRTMSG uses the utility routines EJECT and FREAD (see sections 3.4.62 and 3.4.15).

4.76.8.1 Subroutine Name: PRTMSG

1. Entry Point: PRTMSG

2. Purpose: To print the user messages in the MSG data block.

3. Calling Sequence: CALL PRTMSG

CØMMØN/ØUTPUT/TITLE(32,6) - See ØUTPUT miscellaneous table description in section 2.5.

Where:

TITLE = NASTRAN title, subtitle, label, and three extra subtitles.

4. Method: Open the MSG data block, and skip record 0. If the MSG data block does not exist, nothing else is attempted. Otherwise, the three extra subtitles are set to all blanks, and WRTMSG is called.

4.76.8.2 Subroutine Name: WRTMSG (General purpose subroutine)

1. Entry Point: WRTMSG

2. Purpose: To process a data block of user-oriented messages.

3. Calling Sequence: CALL WRTMSG (MSG)

CØMMØN/SYSTEM/ - See SYSTEM table description in section 2.4.1.8.

Where:

MSG = GINØ file name of the MSG data block.

and in /SYSTEM/

MAXLIN = Maximum number of lines permitted per page.

CØUNT = Number of lines thus far printed on the current page.

4. Method:

a. Save the current NASTRAN title, subtitle, and label. Force the first message to start on a new page (CØUNT=MAXLIN).

b. Read one word (N) from MSG. If an end-of-record condition occurs, force the first message in the next record to start on a new page (CØUNT=MAXLIN). Then repeat this step.

c. If N < 0, the next 32 words are assumed to be a replacement for TITLE (1-32,N). Force the next message to start on a new page (CØUNT=MAXLIN). Repeat step b.

d. If N > 0, a list and format follow. The next N items are assumed to be the list items. If N = 0, only a format follows.

e. Read one word (NF) from MSG. If NF < 0, NF = number of lines to be generated by this message (repeat this step). If NF = 0, this message will be printed starting on a new page. (CØUNT=MAXLIN, repeat this step). Unless otherwise instructed, this subroutine assumes that each message will generate only 1 line of output. In either case, integer function EJECT is called to maintain the page line count. If this message will not fit on this page, any extra title(s) explicitly specified are printed below the NASTRAN title, subtitle, and label.

f. If NF > 0, NF = size of the format (the format must be a continuous string of characters, contrary to the usual NASTRAN method of specifying at most 4 characters per word). The next NF words are assumed to be the format to be used with the list items read in step d, in one the following FØRTRAN statements:

```
      WRITE (MØ,FØR)  [if no list is specified].
or
      WRITE (MØ,FØR)  (LIST(I), I = 1,N)
```

Repeat step b.

g. When the end of the MSG data block is encountered in step b, the NASTRAN title, subtitle, and label are restored, and the MSG data block is closed with a rewind.

5. Design Requirements:

a. The message data block (MSG) must be opened before calling WRTMSG.

b. In general, a set of messages is one record of the data block. Each set of messages will start on a new page.

4.76.9 Design Requirements

Open core is defined at /XXPMSG/, and is used only for one GINØ buffer which is defined at the beginning of open core.

4.77 OUTPUT MODULE PRTPARM (PARAMETER AND DMAP MESSAGE PRINTER)

4.77.1 Entry Point: PRTPRM

4.77.2 Purpose

To print parameter values and DMAP messages.

4.77.3 DMAP Calling Sequence

PRTPARM //C,N,α/C,N,β $

4.77.4 Input Data Blocks

None

4.77.5 Output Data Blocks

None

4.77.6 Parameters

α - Integer value (no default value)

β - BCD value (default value = XXXXXXXX)

4.77.7 Method

As a parameter printer, use $\alpha = 0$. There are two options:

1. β = parameter name will cause the printout of the value of that parameter.

   Example: PRTPARM //C,N,0/C,N,LUSET $

2. β = XXXXXXXX will cause the printout of the values of all parameters in the current XVPS. Since this is the default value, it need not be specified.

   Example: PRTPARM //C,N,0 $

As a DMAP message printer, use $\alpha \neq 0$. There are two options:

1. $\alpha > 0$ causes the printout of the j^{th} message of category β where $j = |\alpha|$ and β is one of the values shown below. (The number of messages available in each category is also shown).

   Example: PRTPARM //C,N,1/C,N,DMAP $

2. $\alpha < 0$ causes the same action as $\alpha > 0$ with the additional action of program termination. Thus, PRTPARM may be used as a fatal message printer.

Example: PRTPARM //C,N,-2/C,N,PLA $

4.77.8 Remarks

1. β is always a value.

2. TABLE OF β CATEGORY VALUES

Rigid Format	Value of Beta	Number of Messages
Static Analysis	STATICS	4
Static Analysis with Inertia Relief	INERTIA	4
Normal Mode Analysis	MØDES	4
Static Analysis with Differential Stiffness	DIFFSTIF	6
Buckling Analysis	BUCKLING	7
Piecewise Linear Analysis	PLA	6
Direct Complex Eigenvalue Analysis	DIRCEAD	5
Direct Frequency and Random Response	DIRFRRD	6
Direct Transient Response	DIRTRD	5
Modal Complex Eigenvalue Analysis	MDLCEAD	6
Modal Frequency and Random Response	MDLFRRD	7
Modal Transient Response	MDLTRD	7
DMAP	DMAP	1

3. For details on error messages for the i^{th} Rigid Format see section 3.(i + 1).2 in the User's Manual.

4.77.9 Subroutines

PRTPRM has no auxiliary subroutines.

4.77.10 Diagnostic Messages

Values of α and β inconsistent with the above under "Method" will result in diagnostic messages from PRTPARM.

4.78 MATRIX MODULE ADD (ADD TWO MATRICES)

4.78.1 Entry Point: DADD

4.78.2 Purpose

To compute [C] = α[A] + β[B].

4.78.3 DMAP Calling Sequence

```
ADD   A,B/C/C,Y,ALPHA=(1.0,2.0)/C,Y,BETA=(3.0,4.0) $
```

4.78.4 Input Data Blocks

A - Any matrix $\neq$ B

B - Any matrix $\neq$ A

Note: A and/or B can be purged.

4.78.5 Output Data Blocks

C - Matrix.

The type of C is maximum of the types of A, B, α, β. The shape of C is the shape of A if A is present. Otherwise it is that of B.

Note: C cannot be purged.

4.78.6 Parameters

ALPHA - Input-complex-no default value. This is the scalar multiplier for A.

BETA - Input-complex-no default value. This is the scalar multiplier for B.

Note: If Im(α) or Im(β) = 0.0, the parameter will be considered real.

4.78.7 Method

If [A] is not purged, the number of columns, rows, and form of [C] = number of columns, rows, and form of [A]. Otherwise the [B] descriptors are used. The type of [C] is the maximum compatible type of [A], [B], ALPHA and BETA. ALPHA and BETA are assumed to be real if their imaginary parts are zero.

4.78.8 Subroutines

ADD - See subroutine description, Section 3.5.10.

4.78.9 Design Requirements

Open core is defined at /DADDA/.

4.78.10 Diagnostic Messages

None.

4.79 MATRIX MODULE MPYAD (MULTIPLY ADD)

4.79.1 Entry Point: DMPYAD

4.79.2 Purpose

MPYAD performs the multiplication of two matrices and, optionally, addition of a third matrix to the product: $[D] = [A][B] \pm [C]$

4.79.3 DMAP Calling Sequence

```
MPYAD     A,B,C/D/C,N,T/C,N,SIGNAB/C,N,SIGNC/C,N,PREC   $
```

4.79.4 Input Data Blocks

A - Left hand matrix in the matrix product [A][B]

B - Right hand matrix in the matrix product [A][B]

C - Matrix to be added to [A][B]

Notes:

1. If no matrix is to added, C must be purged.
2. A, B, C must be physically different data blocks.
3. A and B must not be purged.
4. Either A or B (but not both) may be a NASTRAN diagonal matrix. In this case, C must be purged.

4.79.5 Output Data Block

D - Matrix resulting from the MPYAD operation.

Note: D may not be purged.

4.79.6 Parameters

T - Integer-input-no default. $T = \begin{cases} 1, \text{ perform } [A]^T[B] \\ 0, \text{ perform } [A][B] \end{cases}$

SIGNAB - Integer-input-no default. SIGNAB = {+1, perform [A][B]; -1, perform -[A][B]}

SIGNC - Integer-input-no default. SIGNC = {+1, add [C]; -1, subract [C]}

PREC - Integer-input-no default. PREC = {1, elements of [D] will be output in single-precision. 2, elements of [D] will be output in double-precision.}

4.79.7 Examples

1. [D] = [A][B] + [C] (D double precision)

```
MPYAD     A,B,C/D/C,N,0/C,N,1/C,N,2   $
```

2. $[D] = [A]^T[B] - [C]$ (D single precision)

```
MPYAD     A,B,C/D/C,N,1/C,N,1/C,N,-1/C,N,1   $
```

3. [D] = -[A][B] (D double precision)

```
MPYAD     A,B,/D/C,N,0/C,N,-1/C,N,0/C,N,2  $
```

4.79.8 Method

DMPYAD reads the trailers for the data blocks A, B and C. /MPYADX/ is initialized. If neither [A] nor [B] is diagonal, MPYAD is called, the trailer for D is written, and the module exits. Otherwise, /DMPYX/ is initialized, and DMPY is called to perform the diagonal multiplication. If the matrix [C] is present, /ADDX/ is initialized, and ADD is called to perform the matrix addition. The trailer for D is written and the module exits.

4.79.9 Subroutines

DMPYAD calls the following matrix operations:

MPYAD (see section 3.5.12 for details)

DMPY (see section 3.5.21 for details)

ADD (see section 3.6.10 for details)

4.79.10 Design Requirements

4.79.10.1 Allocation of core storage

See descriptions for MPYAD, DMPY and ADD.

4.79.10.2 Environment

The module MPYAD consists of one subroutine, DMPYAD. One scratch file is used. Three common blocks define open core, one for each of the three overlay segments containing the matrix operations:

/MPYA1D/ included at end of segment containing MPYAD.

/MPYA2D/ included at end of segment containing DMPY.

/MPYA3D/ included at end of segment containing ADD.

4.80 MATRIX MODULE SØLVE (SOLVES THE MATRIX EQUATION [A][X] = [B])

4.80.1 Entry Point: SØLVE

4.80.2 Purpose

To solve the matrix equation,

$$[A][X] = \pm [B] \tag{1}$$

4.80.3 DMAP Calling Sequence

```
SØLVE    A,B/X/V,Y,SYM/V,Y,SIGN/V,Y,PREC/V,Y,TYPE   $
```

4.80.4 Input Data Blocks

A - A square real or complex matrix.

B - A rectangular matrix.

Note: If B is purged, the identity matrix is assumed.

4.80.5 Output Data Blocks

X - A rectangular matrix.

4.80.6 Parameters

SYM - Input-integer-default = 0
- 0 - use unsymmetric decomposition
- 1 - use symmetric decomposition.
- -1 - try symmetric decomposition, use unsymmetric if [A] is singular.

SIGN - input-integer-default = 1
- 1 - solve [A][X] = [B]
- -1 - solve [A][X] = -[B]

PREC - Input-integer-default = 1
- 1 - use single precision arithmetic
- 2 - use double precision arithmetic

TYPE - Input-integer-default = 1
- 1 - output type of matrix [X] is real single precision
- 2 - output type of matrix [X] is real double precision

3 - output type of matrix [X] is complex single precision

4 - output type of matrix [X] is complex double precision

4.80.7 Method

Depending upon the SYM flag and the type of [A], either SDCØMP CDCØMP, or DECØMP is called to form

$$[A] = [L][U] \quad . \tag{2}$$

FBS or GFBS is called to solve

$$[L][Y] = \pm [B] \quad , \tag{3}$$

and

$$[U][X] = [Y] \quad . \tag{4}$$

4.80.8 Subroutines

The above mentioned subroutines are the only ones called by SØLVE and are documented in section 3.5.

4.80.9 Design Requirements

The appropriate subroutines should be referenced for the design requirements peculiar to each routine.

4.80.10 Diagnostic Messages

The individual routines should be referred to for diagnostic messages.

4.81 MATRIX MODULE DECØMP (MATRIX DECOMPOSITION)

4.81.1 Entry Point: DDCØMP

4.81.2 Purpose

To decompose a square matrix [A] into lower [L] and upper [U] triangular factors.

4.81.3 DMAP Calling Sequence

```
DECØMP    A/L,U/V,Y,KSYM/V,Y,CHØLSKY/V,N,MINDIAG/V,N,DET/V,N,PØWER/V,N,SING    $
```

4.81.4 Input Data Blocks

A - A square matrix.

4.81.5 Output Data Blocks

L - Lower triangular factor of [A].

U - Non-standard upper triangular factor of [A].

4.81.6 Parameters

KSYM - Input-integer-no default. 1, use symmetric decomposition. 0, use unsymmetric decomposition.

CHØLSKY - Input-integer-default = 0. 1, use Cholesky decomposition. 0, do not use Cholesky decomposition.

MINDIAG - Output-real-no default. The minimum diagonal term of [U].

DET - Output-complex single precision-no default. The scaled value of the determinant of [A].

PØWER - Output-integer-no default. Integer PØWER of 10 by which DET should be multiplied to obtain the determinant of [A].

SING - Output-integer-no default. SING is set to -1 if [A] is singular.

4.81.7 Method

Depending upon the type of [A] and the KSYM flag, a calling sequence is set up, and either

CDCØMP, DECØMP, or SDCØMP is called.

4.81.8 Subroutines

The major subroutines used are DECØMP, CDCØMP and SDCØMP. Descriptions of these subroutines can be found in sections 3.5.15, 3.5.16, and 3.5.14 respectively.

4.81.9 Design Requirements

The individual subroutine writeups should be consulted for the particular restrictions of each routine.

4.81.10 Diagnostic Messages

See the appropriate subroutine descriptions.

4.82 MATRIX MODULE FBS (FORWARD-BACKWARD SUBSTITUTION)

4.82.1 Entry Point: DFBS

4.82.2 Purpose

To solve the equation,

$$[L]\,[U]\,[X] = \pm\,[B] \qquad (1)$$

where [L] and [U] are the upper and lower triangular factors obtained via matrix module DECØMP.

4.82.3 DMAP Calling Sequence

```
FBS    L,U,B/X/C,N,A/C,N,B/C,N,C/C,N,D    $
```

4.82.4 Input Data Blocks

L,U - Matrices output from module DECØMP.

B - Rectangular matrix.

4.82.5 Output Data Blocks

X - Rectangular matrix.

4.82.6 Parameters

A - Input-integer-no default.
- 1 matrix [L][U] is symmetric
- 0 matrix [L][U] is unsymmetric

B - Input-integer-no default.
- 1 solve [L][U][X] = [B]
- -1 solve [L][U][X] = -[B]

C - Input-integer-no default.
- 1 - use single precision arithmetic
- 2 - use double precision arithmetic

D - Input-integer-no default.
- 1 - output [X] in single precision
- 2 - output [X] in double precision

4.82.7 Method

Depending upon the value of the parameter A, either FBS or GFBS is called.

4.82.8 Subroutines

The above routines are the only ones called by DFBS. Their descriptions are given in section 3.5.17 for FBS and 3.5.19 for GFBS.

4.82.9 Design Requirements

The appropriate routines should be referenced for their individual requirements.

4.82.10 Diagnostic Messages

The individual subroutines should be referred to for the messages.

4.83 MATRIX MODULE PARTN (PARTITION A MATRIX)

4.83.1 Entry Point: PARTN1

4.83.2 Purpose

To partition [A] into [A11], [A12], [A21] and [A22]:

$$[A] \Longrightarrow \left[\begin{array}{c|c} A11 & A21 \\ \hline A12 & A22 \end{array}\right]. \qquad (1)$$

4.83.3 DMAP Calling Sequence

```
PARTN    A,RP,CP/A11,A12,A21,A22/V,Y,SYM/V,Y,TYPE/V,Y,FØRM1/V,Y,FØRM2/V,Y,FØRM3/V,Y,FØRM4 $
```

4.83.4 Input Data Blocks

A - Matrix to be partitioned.

RP - Row partitioning vector - single precision column vector.

CP - Column partitioning vector - single precision column vector.

Notes:

1. If A is purged, PARTN returns.

2. If RP is purged, A is partitioned as follows:

$$[A] \Longrightarrow \left[\begin{array}{c} A11 \\ \hline A12 \end{array}\right]. \qquad (2)$$

3. If CP is purged and SYM > 0, A is partitioned as follows:

$$[A] \Longrightarrow [A11 \mid A21]. \qquad (3)$$

4. If CP is purged and SYM ≤ 0, A is partitioned as follows:

$$[A] \Longrightarrow \left[\begin{array}{c|c} A11 & A21 \\ \hline A12 & A22 \end{array}\right], \qquad (4)$$

where RP is used as both the row and column partitioner.

5. RP and CP cannot both be purged.

4.83.5 Output Data Blocks

A11 - Partition of A.

A12 - Partition of A.

A21 - Partition of A.

A22 - Partition of A.

Notes:

1. Any or all output data blocks can be purged.
2. For the shape of outputs (number of rows and columns) see section 4.83.7 below.

4.83.6 Parameters

SYM - Input-integer-no default. SYM chooses between a symmetric partition and an unsymmetric partition. If SYM $\leq$ 0, CP is used as RP. If SYM > 0, CP and RP are distinct.

TYPE - Input-integer-no default. TYPE of output matrices. 0 < TYPE $\leq$ 4.

FØRM1 - Input-integer-no default. Form of A11.

FØRM2 - Input-integer-no default. Form of A12.

FØRM3 - Input-integer-no default. Form of A21.

FØRM4 - Input-integer-no default. Form of A22.

4.83.7 Method

Let N1 = number of non-zero terms in RP.

Let N2 = number of non-zero terms in CP.

Let NRØWA = number of rows in A.

Let NCØLA = number of columns in A.

CASE:1 RP purged.

A11 is a (NRØWA-N2) x NCØLA matrix.

A12 is a N2 x NCØLA matrix.

A21 is not written.

A22 is not written.

CASE 2: CP purged and SYM > 0.

A11 is a NRØWA x (NCØLA - N1) matrix.

A12 is not written.

A21 is a NRØWA x N1 matrix.

A22 is not written.

CASE 3: CP purged and SYM $\leq$ 0.

A11 is a (NRØWA - N1) x (NCØLA - N1) matrix.

A12 is a N1 x (NCØLA - N1) matrix.

A21 is a (NRØWA - N1) x N1 matrix.

A22 is a N1 x N1 matrix.

CASE 4: Neither RP nor CP purged.

A11 is a (NRØWA - N2) x (NCØLA - N1) matrix.

A12 is a N2 x (NCØLA - N1) matrix.

A21 is a (NRØWA - N2) x N1 matrix.

A22 is a N2 x N1 matrix.

In general if $a_{ij} \in [A]$, then:

$a_{ij} \in [A11]$ if RP(J) = CP(I) = 0

$a_{ij} \in [A12]$ if CP(I) $\neq$ 0, RP(J) = 0

$a_{ij} \in [A21]$ if CP(I) = 0, RP(J) $\neq$ 0

$a_{ij} \in [A22]$ if CP(I) $\neq$ 0, RP(J) $\neq$ 0

4.83.8 Subroutines

4.83.8.1 Subroutine Name: PARTN2

1. Entry Point: PARTN2

2. Purpose: Initialization routine for PARTN1 and MERGE1. It calls PARTN3 to build the bit strings from the partitioning vectors CP and RP and sets default options based on SYM.

3. Calling Sequence: CALL PARTN2 (CP,RP,CØRE,BUF)

CP = GINØ file name of column partitioning vector

RP = GINØ file name of row partitioning vector

CØRE = Location of first word open core

BUF = Location of GINØ buffer.

4.83.8.2 Subroutine Name: PARTN3

1. Entry Point: PARTN3

2. Purpose: Builds bit strings as directed by PARTN2.

3. Calling Sequence: CALL PARTN3 (FILE,SIZE,ØNES,IZ,NZ,HERE,BUF,CØRE)

FILE = GINØ file name
SIZE = Length of partitioning vector
ØNES = Number of non-zero terms in vector
IZ = Pointer to working core
NZ = Length of working core
HERE = Logical Flag
BUF = Location of GINØ buffer
CØRE = Location of open core

4.83.9 Design Requirements

Open core is defined at /PARTN1/.

4.83.10 Diagnostic Messages

Messages 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 3002, and 3008 may be issued.

4.84 MATRIX MODULE MERGE (MERGE MATRICES TOGETHER)

4.84.1 Entry Point: MERGE1

4.84.2 Purpose

To form

$$[A] \Leftarrow \left[\begin{array}{c|c} A11 & A21 \\ \hline A12 & A22 \end{array}\right]. \qquad (1)$$

4.84.3 DMAP Calling Sequence

```
MERGE    A11,A12,A21,A22,RP,CP/A/V,Y,SYM/V,Y,TYPE/V,Y,FØRM  $
```

4.84.4 Input Data Blocks

A11 - Matrix ≠ A12, A21, A22.

A12 - Matrix ≠ A11, A21, A22.

A21 - Matrix ≠ A11, A12, A22.

A22 - Matrix ≠ A11, A12, A21.

RP - Row partitioning vector - single precision vector.

CP - Column partitioning vector - single precision vector.

Notes:

1. Any or all of A11, A12, A21, A22 can be purged which implies [AIJ] = [0].
2. RP and CP cannot both be purged.
3. See method section for meaning when RP or CP is purged.

4.84.5 Output Data Blocks

A - Merged matrix from A11, A12, A21, A22.

Notes: A cannot be purged.

4.84.6 Parameters

SYM - Input-integer-no default. SYM $\leq$ 0, CP is used as RP. SYM > 0, CP and RP are distinct.

TYPE - Input-integer-no default. Type of A. 1 implies A is real single precision, 2 implies A is real double precision, 3 implies A is complex single precision, 4 implies A is complex double precision.

FØRM - Input-integer-no default. Form of A (see section 2.2).

4.84.7 Method

MERGE is the inverse of PARTN in the sense that if A11, A12, A21, A22 were produced by PARTN using RP, CP, FØRM, SYM, and TYPE from A, MERGE will reproduce A. See PARTN (section 4.83) for options on RP, CP and SYM.

4.84.8 Subroutines

Subroutines PARTN2 and PARTN3 are used. These routines are described in Section 4.83.

4.84.9 Design Requirements

Open core is defined at /MERGE1/.

4.84.10 Diagnostic Messages

Messages 2161, 2162, 2163, 2164, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 3002, and 3008 may be issued.

4.85 MATRIX MODULE TRNSP (TRANSPOSE A MATRIX).

4.85.1 Entry Point: DTRANP

4.85.2 Purpose

To form $[A]^T$ given [A].

4.85.3 DMAP Calling Sequence

```
TRNSP    A/AT  $
```

4.85.4 Input Data Blocks

A - Any matrix data block.

Note: If [A] is purged, TRNSP returns.

4.85.5 Output Data Blocks

AT - The matrix transpose of [A].

Note: AT cannot be purged.

4.85.6 Parameters

None.

4.85.7 Method

Subroutine TRNSP is called.

4.85.8 Subroutines

TRNSP - See subroutine description, section 3.5.25.

4.85.9 Design Requirements

Open core is defined at /DTRANX/. Eight scratch files are used.

4.86 MATRIX MODULE SMPYAD (STRING MULTIPLY ADD)

4.86.1 Entry Point: SMPYAD

4.86.2 Purpose

To multiply a series of matrices together.

4.86.3 DMAP Calling Sequence

```
SMPYAD    A,B,C,D,E,F/G/C,N,N/C,N,SIGNX/C,N,SIGNF/C,N,PG/C,N,TA/C,N,TB/C,N,TC/C,N,TD $
```

4.86.4 Input Data Blocks

A, B, C, D, E - Up to 5 matrices to be multiplied together, from left to right.

F - Matrix to be added to the above product.

Notes:

1. If one of the five multiplication matrices is required in the product (see parameter "N" below) and is purged, the multiplication will not be done.

2. If the F matrix is purged, no matrix will be added to the product.

4.86.5 Output Data Blocks

G - Resultant matrix (may not be pre-purged).

4.86.6 Parameters

N - Number of matrices involved in the product - integer - input.

SIGNX - Sign of the product matrix (e.g., [A][B][C][D][E]) - integer - input.
1 for plus, -1 for minus.

SIGNF - Sign of the matrix to be added to the product matrix - integer - input.
1 for plus, -1 for minus.

PG - Output precision of the final result - integer - input.
1 for single precision, 2 for double precision.

TA, TB, TC, TD - Transpose indicators for the [A][B][C] and [D] matrices (1 if transposed matrix to be used in the product; 0 if untransposed) - integer - input.

Note: All the parameters except "N" have default values. They are these:

1. SIGNX = 1 (sign of product is plus)
2. SIGNF = 1 (sign of added matrix is plus)
3. PG = 1 (single precision result)
4. TA, TB, TC, TD = 0 (use untransposed [A], [B], [C], and [D] matrices in the product)

4.86.7 Method

The method is the same as for the MPYAD module with one exception and one addition:

1. None of the matrices may be diagonal.
2. Except for the final product, all intermediate matrix products are generated in double precision.

The matrices are multiplied together from right-to-left, i.e., the first product calculated is the product of matrix n-1 and matrix n.

4.86.8 Subroutines

MPYAD is called (see section 3.5.12 for details).

4.86.9 Design Requirements

1. Two scratch files are required.
2. Open core is the /MPYADX/ common block, the same one as used by the MPYAD module, (see section 4.79).

4.87 STRUCTURAL ELEMENT DESCRIPTIONS

The finite structural element subroutines used in NASTRAN have a number of different calculations associated with them. These subroutines are found in the modules SMA1, SMA2, SSG1, SDR2, DSMG1, PLA3 and PLA4.

All modules excluding IFP having anything to do with the NASTRAN structural elements, their geometry, or associated data blocks, use the basic element data found in common block /GPTA1/. /GPTA1/ is set in its own block data subprogram, and/or by (in the presence of dummy-user-elements) the routine DELSET. Refer to Section 2.5.2.1 for further information regarding /GPTA1/.

The element subroutines in the SMA1 (Structural Matrix Assembler - Phase 1) module generate element stiffness matrix partitions. The stiffness matrix, [K], for a structural element consists of a 6 by 6 partition for each combination of the connected grid points. For example, a RØD element is connected to two grid points, "a" and "b". The stiffness matrix partitions are: $[K_{aa}]$, $[K_{ab}]$, $[K_{ba}]$ and $[K_{bb}]$. A triangular element (e.g., TRMEM) is connected to three points. It will generate nine partitions: $[K_{aa}]$, $[K_{ab}]$, $[K_{ac}]$, $[K_{ba}]$, $[K_{bb}]$, $[K_{bc}]$, $[K_{ca}]$, $[K_{cb}]$ and $[K_{cc}]$. In order to generate a particular partition, $[K_{ij}]$, it is often necessary to generate [K]. However, only those partitions $[K_{ij}]$, where i is the pivot point (see section 1.8) and j = 1,2,...,n (n being the number of grid points associated with the element), are output by an element stiffness matrix generation subroutine, e.g., KRØD. These partitions are output from an element subroutine in the form of calls to the "insertion" subroutine SMA1B (see Section 4.27). There is one call for each 6 by 6 partition if the element is a structural element, and one call for each 1 by 1 "partition" if the element is a scalar element. The unused partitions are recalculated and used when $j \neq i$ appears as a pivot point in a subsequent ECPT record. An alternate procedure for matrix generation, which is not used, would be to calculate all of the element matrices once and store them on an auxiliary storage unit for use when needed. The alternate procedure is less efficient for large problems, where efficiency really counts, because the recalculation time is less than the time required to recover element matrices from the auxiliary unit.

Element structural damping matrices, $[K^4]$, are proportional to the element stiffness matrices, the proportionality constant being g_e, the structural damping coefficient input on a material (e.g., MAT1) bulk data card. An element stiffness matrix generation routine, e.g., KRØD, of module SMA1 will output, through the calling sequence to subroutine SMA1B: 1) an element stiffness

matrix partition, 2) the structural damping coefficient, and 3) a flag, which will signal SMA1B that the scalar multiplication of the matrix by the structural damping coefficient is to take place.

The element subroutines (e.g., MRØD, MCØNMX) in the SMA2 (Structural Matrix Assembler - Phase 2) module generate element mass matrix partitions. The remarks in the third paragraph above concerning element stiffness matrix partitions apply here also when the reader makes the substitutions: "mass" for "stiffness", "[M]" for "[K]", "MRØD" for "KRØD", and "SMA2B" for "SMA1B".

Only the element VISC and DAMPi generate viscous damping terms which contribute to the damping matrix, $[B_{gg}]$, and conversely, the only elements which contribute to $[B_{gg}]$ are the VISC and DAMPi elements. These terms are calculated in module SMA2. The damping matrix partitions are passed to subroutine SMA2B in a fashion similar to that for mass matrix partitions.

Element static loading functions due to temperature and enforced deformations are generated in the SSG1 (Static Solution Generator - Phase 1) module, and the mathematical descriptions for these functions are given in this Section (4.87). (See the Module Functional Description for SSG1, Section 4.41, for the equations governing direct applied loads and gravity loads.) The output of an element routine are load vectors which are placed in the $\{P_g\}$ load vector (see Section 4.41).

Element stresses and forces due to displacements are calculated in the SDR2 (Stress Data Recovery - Phase 2) module. These calculations are performed in two phases. Phase 1 generates element stress matrices for each element for which the user has requested element stress and/or force output. These element stress matrices are written on a scratch file for use in phase 2. In phase 2, the displacement vector for the current subcase is read into core, and, for each element for which stress and/or force output is requested, the corresponding element stress matrix is read and passed to the phase 2 element subroutine. The phase 2 element subroutine then calculates element stresses and forces. A list of the stresses and forces output in phase 2 for each element is given in Sections 2.3.51 and 2.3.52 respectively.

Differential stiffness matrix partitions are calculated for some elements. These are calculated in module DSMG1 (Differential Stiffness Matrix Generator - Phase 1) for large displacement analysis and buckling problems. The output of an element routine of the DSMG1 module are the 6 by 6 differential stiffness matrix partitions, $[K^d_{ij}]$, where i is the pivot point. The "insertion" subroutine for module DSMG1, similar to subroutine SMA1B of module SMA1, is DS1b.

Nonlinear, plastic effects in the structure may be determined by solving for the element stress and modifying the elastic properties of an element in an iterative loop. Element stresses are calculated in the PLA3 (Piecewise Linear Analysis - Phase 3) module, and element stiffness matrices with modified elastic properties are calculated in the PLA4 (Piecewise Linear Analysis - Phase 4). The outputs of an element subroutine of the PLA3 module are: 1) element stresses, which have the same formats as the element stresses output from a phase 2 element subroutine of module SDR2, and 2) updated incremental stress data in the ESTNL1 data block, which are used as input to the PLA3 module in the next pass of the Piecewise Linear Analysis (PLA) Rigid Format DMAP loop. The outputs of an element subroutine of the PLA4 module are: 1) element stiffness matrix partitions (the remarks on element stiffness matrix partitions in the second paragraph apply here as well, except that the "insertion" subroutine is PLA4B) and 2) updated incremental stress data in the ECPTNL1 data block, which are used as input to the PLA4 module in the next pass of the PLA Rigid Format DMAP loop.

The following data are needed to generate the element matrices in the above modules.

1. Element Connection and Properties Table (ECPT) Data.
2. Transformation matrices, $[T_i]$, from the global coordinate system to the basic coordinate system.
3. Material Property Data.
4. Element Deformation Data (used only in modules SSG1, SDR2 and DSGM1).
5. Grid Point Temperature Data (used only in modules SSG1, SDR2 and DSGM1).

The ECPT data are input to an element subroutine by a module driver from the ECPT data block or the EST (Element Summary Table) data block. The data in each of these data blocks are identical, from an individual element subroutine point of view. The ECPT data block is used in modules SMA1, SMA2 and DSGM1; the EST data block is used in modules SSG1 and SDR2. For the special case of Piecewise Linear Analysis, the ECPTNL (Element Connection and Properties Table for Nonlinear Elements) data block is used in module PLA4, and the ESTNL (Element Summary Table for Nonlinear Elements) data block is used in module PLA3. The ECPT and EST data blocks are generated in the Table Assembler (TA1) module (see Section 4.26) from the following data blocks: ECT (Element Connection Table, Section 2.3.4.1), EPT (Element Property Table, Section 2.3.2.5), BGPDT (Basic Grid Point Definition Table, Section 2.3.3.5), and GPTT (Grid Point Temperature Table, Section 2.3.7.2).

The ECPT data for an element consist of four separate parts: 1) connection data 2) property data, 3) basic grid point definition data and 4) the element temperature for material properties. The connection data consists of data on a connection bulk data card (e.g., CRØD), except for the property identification number (the property identification number on the connection and property cards is used only to relate the two cards during the assembly of the ECPT and EST data blocks, and it does not appear in either the connection data or property data). Note also that grid point identification numbers have been converted to internal numbers, Scalar Index List (SIL) numbers, which correspond to degrees of freedom numbers. Property data consist of data on a property bulk data card (e.g., PRØD) with the above noted exception. Basic grid point definition data consist of, for each grid point connecting the element, 1) the identification number of the coordinate system in which displacements are defined at the grid point and 2) the coordinates of the grid point in the basic coordinate system. The element temperature for material properties is the average value given for each element in the GPTT data block. This temperature is placed in the ECPT/EST data in the Table Assembler module from the element temperatures in the GPTT data block and the set identification number, n, from the TEMPERATURE(MATERIAL) = n card in the User's Case Control Deck. Note that n is transmitted to the Table Assembler via the tenth word of /SYSTEM/ (see Section 2.4.1.8).

The transformation matrices, $[T_i]$, from the global coordinate system to the basic coordinate system, are supplies to an element subroutine by the utility routines TRANSD and TRANSS. These utility routines use the CSTM (Coordinate System Transformation Matrices, Section 2.3.3.4) data block in conjunction with the basic grid point definition data at a point i to compute $[T_i]$. Hence all modules which deal with element calculations require the CSTM data block as input. TRANSD returns, to an element subroutine, a double precision matrix, $[T_i]$, used by element routines in the following modules which use double precision arithmetic: SMA1, SMA2, DSGM1 and PLA4; TRANSS returns, to an element subroutine, a single precision matrix, $[T_i]$, used by element routines in the following modules which use single precision arithmetic: SSG1, SDR2 and PLA3.

Material property data are contained in the MPT (Material Properties Table, Section 2.3.2.6) and the DIT (Direct Input Tables, Section 2.3.2.7) data blocks. Both of these data blocks are output from the IFP (Input File Processor) Preface module. The utility routine MAT (see Section 3.4.36) fetches required material property data for element routines. These data are returned in single precision form.

Element deformation data are contained in the EDT (Element Deformation Table, Section 2.3.2.8) data block which is output by the IFP Preface Module. Element deformation data is admissible only for the RØD (including CØNRØD), TUBE and BAR elements.

Element temperature data are contained in the GPTT (Grid Point Temperature Table, Section 2.3.7.2), which is output by the GP3 (Geometry Processor - Phase 3) module. The temperature data contained in this data block are used for static loading functions due to temperature.

Table 1 on the following page gives reference to the Theoretical and User's Manuals where more information on the elements can be found.

Table 1. Structural Element References.

Bulk Data Connection Card Mnemonic	Programmer's Manual Reference	User's Manual Reference	Theoretical Manual Reference
CAXIF2	4.87.15	1.8	17.1
CAXIF3	4.87.15	1.8	17.1
CAXIF4	4.87.15	1.8	17.1
CBAR	4.87.2	1.3.2	5.2, 7.2
CCØNEAX	4.87.9	1.3.6	5.9
CDAMP1	4.87.7	1.3.8	5.6
CDAMP2	4.87.7	1.3.8	5.6
CDAMP3	4.87.7	1.3.8	5.6
CDAMP4	4.87.7	1.3.8	5.6
CELAS1	4.87.7	1.3.8	5.6
CELAS2	4.87.7	1.3.8	5.6
CELAS3	4.87.7	1.3.8	5.6
CELAS4	4.87.7	1.3.8	5.6
CFLUID2	4.87.15	1.7	16.1
CFLUID3	4.87.15	1.7	16.1
CFLUID4	4.87.15	1.7	16.1
CMASS1	4.87.7	1.3.8	5.6
CMASS2	4.87.7	1.3.8	5.6
CMASS3	4.87.7	1.3.8	5.6
CMASS4	4.87.7	1.3.8	5.6
CMFREE	4.87.15	1.7	16.1
CØNM1	4.87.8	1.2.3	5.5
CØNM2	4.87.8	1.2.3	5.5
CØNRØD	4.87.1	1.3.3	5.2, 7.2
CQDMEM	4.87.4	1.3.5	5.8, 7.3
CQDPLT	4.87.5	1.3.5	5.8
CQUAD1	4.87.6	1.3.5	5.8, 7.3
CQUAD2	4.87.6	1.3.5	5.8, 7.3
CRØD	4.87.1	1.3.3	5.2, 7.2
CSHEAR	4.87.3	1.3.4	5.3
CSLØT3	4.87.16	1.8	17.1
CSLØT4	4.87.16	1.8	17.1
CTØRDRG	4.87.12	1.3.7	5.11
CTRAPRG	4.87.11	1.3.7	5.10
CTRBSC	4.87.5	1.3.5	5.8
CTRIA1	4.87.6	1.3.5	5.8, 7.3
CTRIA2	4.87.6	1.3.5	5.8, 7.3
CTRIARG	4.87.10	1.3.7	5.8
CTRMEM	4.87.4	1.3.5	5.8, 7.3
CTRPLT	4.87.5	1.3.5	5.8
CTUBE	4.87.1	1.3.3	5.2, 7.2
CTWIST	4.87.3	1.3.4	5.3
CVISC	4.87.13	1.3.3	5.2

Note: The bulk data connection and property card descriptions in Section 2 of the User's Manual should also be consulted.

4.87.1 The RØD, CØNRØD and TUBE Elements

4.87.1.1 Input Data for the RØD, TUBE, CØNRØD Elements

1. The ECPT/EST entries for the RØD and CØNRØD are:

Symbol	Description
SIL_a, SIL_b	Scalar indices for grid points a and b
N_a, X_a, Y_a, Z_a N_b, X_b, Y_b, Z_b	Local coordinate system number and basic coordinates of grid points
Mat I. D.	Material identification number
A	Cross-section area
J	Polar inertia
μ	Nonstructural mass per unit length
C	Shear stress coefficient
t_μ	Temperature for material properties

2. The TUBE element has the same characteristics as the RØD except for different input properties. The TUBE has d, the outside diameter, and t, the thickness, given. The conversion to RØD properties is:

$$A = \pi(d - t)t$$

$$J = \frac{1}{4}A\left((d - t)^2 + t^2\right)$$

$$C = \frac{d}{2}$$

3. Coordinate system data

Given N_a, X_a, Y_a, Z_a, N_b, X_b, Y_b and Z_b and the CSTM (Coordinate System Transformation Matrices) data block, the 3 by 3 global-to-basic coordinate transformation matrices $[T_a]$ and $[T_b]$ are calculated using the utility routine TRANSD or TRANSS.

4. Material data

Given the "MAT I.D." and t_μ, the material routine, MAT, returns the following data:

- E - Modulus of Elasticity
- G - Shear Modulus
- ν - Poisson's ratio
- ρ - Density
- α - Thermal expansion coefficient
- T_o - Reference temperature
- g_e - Structural damping ratio
- σ_t - Stress limit, tension
- σ_c - Stress limit, compression
- σ_s - Stress limit, shear

1.87.1.2 Stiffness Matrix Calculation (Subroutines KRØD and KTUBE of Module SMA1)

1. Calculate the length of member, (ℓ):

$$\ell = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2 + (Z_a - Z_b)^2} \quad . \tag{1}$$

2. Calculate a normalized direction vector {n} in basic coordinates:

$$\begin{Bmatrix} n_1 \\ n_2 \\ n_3 \end{Bmatrix} = \frac{1}{\ell} \begin{Bmatrix} X_a - X_b \\ Y_a - Y_b \\ Z_a - Z_b \end{Bmatrix} \quad . \tag{2}$$

3. Form the extensional stiffness matrix, $[D_\ell]$:

$$[D_\ell] = \frac{AE}{\ell} \begin{bmatrix} n_1^2 & n_1 n_2 & n_1 n_3 \\ n_1 n_2 & n_2^2 & n_2 n_3 \\ n_1 n_3 & n_2 n_3 & n_3^2 \end{bmatrix} \quad . \tag{3}$$

4. Form the torsional stiffness matrix $[D_r]$:

$$[D_r] = \frac{GJ}{\ell}\begin{bmatrix} n_1^2 & n_1n_2 & n_1n_3 \\ n_1n_2 & n_2^2 & n_2n_3 \\ n_1n_3 & n_2n_3 & n_3^2 \end{bmatrix} . \tag{4}$$

5. $[T_a]$ and $[T_b]$ are the matrices which transform displacement components in the global coordinate system to the basic system.

6. Transforming to global coordinates and combining the results give the partitions of the element stiffness matrix:

$$[k_{aa}] = \left[\begin{array}{c|c} T_a^T D_\ell T_a & 0 \\ \hline 0 & T_a^T D_r T_a \end{array}\right] , \tag{5}$$

$$[k_{ab}] = -\left[\begin{array}{c|c} T_a^T D_\ell T_b & 0 \\ \hline 0 & T_a^T D_r T_b \end{array}\right] , \tag{6}$$

$$[k_{bb}] = \left[\begin{array}{c|c} T_b^T D_\ell T_b & 0 \\ \hline 0 & T_b^T D_r T_b \end{array}\right] , \tag{7}$$

$$[k_{ba}] = [k_{ab}]^T . \tag{8}$$

The element damping matrices are equal to the stiffness matrices times g_e, the structural damping coefficient.

4.87.1.3 Lumped Mass Matrix Calculation (Subroutines MRØD and MTUBE of Module SMA2)

The total mass of the element, m, is

$$m = \rho A\ell + \mu\ell . \tag{9}$$

The partitions of the element mass matrix are:

$$[M_{aa}] = [M_{bb}] = \frac{m}{2} \begin{bmatrix} 1 & & & & \\ & 1 & & 0 & \\ & & 1 & & \\ & & & 0 & \\ & 0 & & 0 & \\ & & & & 0 \end{bmatrix}, \tag{10}$$

$$[M_{ab}] = [M_{ba}] = [0] . \tag{11}$$

4.87.1.4 Element Load Calculations (Subroutine EDTL of Module SSG1)

The element loading calculations are calculated using the EST data, the element loading temperature, $\bar{T}$, and the enforced deformation δ.

1. Calculate ℓ, $\{n\}$, $[T_a]$ and $[T_b]$ as in section 4.87.1.2.

2. Calculate:

$$\bar{t} = (t_a + t_b)/2 - T_o, \tag{12}$$

$$\{P_a\} = \frac{EA}{\ell} \begin{bmatrix} [T_a]^T \\ \hline 0 \end{bmatrix} \{n\} (\delta + \alpha\ell\bar{T} - \alpha\ell T_o), \tag{13}$$

$$\{P_b\} = -\frac{EA}{\ell} \begin{bmatrix} [T_b]^T \\ \hline 0 \end{bmatrix} \{n\} (\delta + \alpha\ell\bar{T} - \alpha\ell T_o). \tag{14}$$

3. $\{P_a\}$ and $\{P_b\}$ are placed in the load vector in positions corresponding to points a and b.

4.87.1.5 Element Stress Calculations (Subroutines SRØD1 and SRØD2 of Module SDR2).

The stress functions calculated in phase 1 (Subroutine SRØD1) are:

$$[S_a^t] = \frac{E}{\ell} \{n\}^T [T_a], \qquad (1x3); \tag{15}$$

$$[S_b^t] = -\frac{E}{\ell}\{n\}^T[T_b], \quad (1x3); \tag{16}$$

$$[S_a^r] = \frac{GC}{\ell}\{n\}^T[T_b], \quad (1x3); \tag{17}$$

$$[S_b^r] = -\frac{GC}{\ell}\{n\}^T[T_b], \quad (1x3). \tag{18}$$

$$S_T = -\alpha E, \tag{19}$$

$$S_\delta = -\frac{E}{\ell}. \tag{20}$$

The miscellaneous constants A, $\frac{J}{C}$, T_o, σ_t, σ_c and σ_s are also saved for phase 2 calculations.

Note J/C is set to zero if C = 0. The superscripts t and r denotes translational and rotational stress matrices respectively.

The stress and force values are calculated in phase 2 (Subroutine SRØD2) using the displacement vectors $\{u_a\}$ and $\{u_b\}$, the loading temperature, $\bar{T}$, and the enforced deformation δ. Note that $\{u_i^t\}$ and $\{u_i^r\}$ (i = a, b) denote the 3 by 1 translational and rotational components of $\{u_i\}$.

1. Partition

$$\{u_a\} \Longrightarrow \left\{\begin{array}{c} u_a^t \\ \hline u_a^r \end{array}\right\}, \tag{21}$$

$$\{u_b\} \Longrightarrow \left\{\begin{array}{c} u_b^t \\ \hline u_b^r \end{array}\right\}. \tag{22}$$

2. The stresses are:

$$\sigma = [S_a^t]\{u_a^t\} + [S_b^t]\{u_b^t\} + S_\delta\delta + S_T[\bar{T} - T_o], \tag{23}$$

$$\tau = [S_a^r]\{u_a^r\} + [S_a^r]\{u_b^r\}. \tag{24}$$

The margins of safety in tension or compression, $M.S._t$ or $M.S._c$ respectively, are calculated as follows:

If $\sigma \geq 0$ then:

$$\text{M.S.} = \begin{cases} \dfrac{\sigma_t}{\sigma} - 1 \ , & \sigma_t > 0 \\ \text{Integer "1"}, & \sigma_t \leq 0 \text{ or } \sigma = 0 \end{cases} , \tag{25}$$

If $\sigma < 0$, then: define $\sigma_c' = -|\sigma_c|$.

$$\text{M.S.} = \begin{cases} \dfrac{\sigma_c'}{\sigma} - 1 \ , & \sigma_c' \neq 0 \\ \text{Integer "1"}, & \sigma = 0 \text{ or } \sigma_c' = 0 \end{cases} . \tag{26}$$

The margin of safety for torsion

$$\text{M.S.} = \begin{cases} \dfrac{\sigma_s}{|\tau|} - 1, & \sigma_s > 0 \text{ and } \tau \neq 0 \\ \text{Integer "1"}, & \sigma_s \leq 0 \text{ or } \tau = 0 \end{cases} \tag{26a}$$

The forces are:

$$P = A\sigma \ , \tag{27}$$

$$T = \frac{J}{C}\tau \ . \tag{28}$$

4.87.1.6 Differential Stiffness Matrix Calculation (Subroutine DRØD of Module DSMG1)

The data input from the ECPT, MPT and CSTM data blocks are as listed in section 4.87.1.1. The following variables are calculated in the same manner as those for the stiffness matrix variables (section 4.87.1.2)

ℓ	length of rod
n_1, n_2, n_3	The direction cosines of the rod axis (+ from b to a) in the basic coordinate system
$[T_a]$, $[T_b]$	The transformation matrices from global coordinates to the basic coordinate system at the grid points.

Only the linear translational displacements at the grid points are extracted from the displacement vector. Call these $\{u_a^t\}$ and $\{u_b^t\}$ (3x1 single precision vectors.)

1. Calculate the axial load in the element (+ implies tension):

$$\frac{F_x}{\ell} = \frac{AE}{\ell^2}\left\{\{n\}^T\left[[T_a]\{u_a^t\} - [T_b]\{u_b^t\}\right] - \delta - \alpha\ell\bar{T} - T_o\right\} \quad . \tag{29}$$

2. A pair of axes perpendicular to the rod axis is constructed. Select the smallest component of $\{n\}$. Define n_i as the component of $\{n\}$ which is the smallest; let j and k be the other two components. Construct $\{m\}$ such that

$$m_i = 1, \quad m_j = m_k = 0. \tag{30}$$

Let

$$\{y\} = \frac{\{m\} \times \{n\}}{|\{m\} \times \{n\}|} \ , \tag{31}$$

and

$$\{z\} = \frac{\{n\} \times \{y\}}{|\{n\} \times \{y\}|} \ , \tag{32}$$

where x denotes the cross product.

The actual partitions of the differential stiffness matrix relating to displacements in global coordinates are:

$$[K_{aa}^d] = \frac{F_x}{\ell}[T_a]^T\left[\{y\}\{y\}^T + \{z\}\{z\}^T\right][T_a] \ , \tag{33}$$

$$[K_{ab}^d] = \frac{-F_x}{\ell}[T_a]^T\left[\{y\}\{y\}^T + \{z\}\{z\}^T\right][T_b] \ , \tag{34}$$

$$[K_{bb}^d] = \frac{F_x}{\ell}[T_b]^T\left[\{y\}\{y\}^T + \{z\}\{z\}^T\right][T_b] \ , \tag{35}$$

$$[K_{ba}^d] = [k_{ab}^d]^T \tag{36}$$

The actual 6x6 partitions are formed by expanding:

$$[k^d_{aa}] \Longrightarrow \left[\begin{array}{c|c} k^d_{aa} & 0 \\ \hline 0 & 0 \end{array}\right], \text{ etc.} \tag{37}$$

4.87.1.7 Piecewise Linear Analysis Calculations (Subroutine PSRØD of Module PLA3 and Subroutine PKRØD of Module PLA4)

The additional ECPTNL and ESTNL entries are:

ε^*_o - The previously computed strain value once removed.

ε^* - The previously computed strain value.

E^* - The previously computed modulus of elasticity.

T* - The previously computed torsional moment (present in the ESTNL entry only).

All of the above values are initially zero with the exception of E*, which is initially the original modulus of elasticity present on a MAT1 card.

For both stress calculation and stiffness matrix generation, the quantities ℓ and $\{n\}$ are generated as in section 4.87.1.2.

Using $\{\Delta u^t_a\}$ and $\{\Delta u^t_b\}$, the 3x1 translational displacement vectors, calculate the increment of strain:

$$\Delta\varepsilon = \frac{1}{\ell}\{n\}^T\left[[T_a]\{\Delta u^t_a\} - [T_b]\{\Delta u^t_b\}\right], \tag{38}$$

$$\Delta\varepsilon^* = \varepsilon^* - \varepsilon^*_o \ . \tag{39}$$

Define the following terms:

$$\varepsilon_1 = \varepsilon^* + \Delta\varepsilon, \qquad \text{(current strain);} \tag{40}$$

$$\varepsilon_2 = \varepsilon_1 + \gamma(\Delta\varepsilon) \ , \tag{41}$$

(estimated next strain);

where γ is the ratio of the next load increment to the present load increment.

We calculate:

$$\sigma_1 = f(\varepsilon_1), \tag{42}$$

$$\sigma_2 = f(\varepsilon_2), \tag{43}$$

where f is the tabular stress-strain function. (When $\varepsilon^* = 0$, define $\sigma_1 = E_o\varepsilon_1$)

For stiffness matrix generation, the new material properties are:

$$E = \begin{cases} \dfrac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1}, \text{ if } \varepsilon_2 \neq \varepsilon_1 \\ E^*, \text{ if } \varepsilon_2 = \varepsilon_1 \end{cases}; \tag{44}$$

and

$$G = \frac{E}{E_o} G_o, \tag{45}$$

where E_o and G_o are elastic moduli obtained from the MAT1 bulk data card via subroutine MAT.

For plastic element stresses and forces the values are:

$$\sigma = \sigma_1 , \tag{46}$$

$$P = A\alpha_1, \tag{47}$$

$$T = \frac{JG^*}{\ell} \{n\}^T \left([T_a]\{\Delta u_a^r\} - [T_b]\{\Delta u_b^r\}\right) + T^* , \tag{48}$$

$$\tau = \frac{CT}{J} \quad (\tau = 0 \text{ if } C = 0 \text{ or } J = 0), \tag{49}$$

where

$$G^* = \frac{E^*}{E_o} G_o . \tag{50}$$

The new ESTNL and ECPTNL entries are:

$$\varepsilon^*_{on} = \varepsilon^* \quad , \tag{51}$$

$$\varepsilon^*_{n} = \varepsilon_1 \quad , \tag{52}$$

$$E^*_{n} = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \quad , \tag{53}$$

$$T^*_{n} = T \quad . \tag{54}$$

4.87.1.8 Coupled Mass Matrix Calculation (Subroutine MCRØD of Module SMA2)

1. The length of the element, ℓ, the normalized direction vector, {n}, and the mass of the element, m, are calculated as in Equations 1 and 2 in section 4.87.1.2 and Equation 9 in section 4.87.1.3 respectively.

2. The 3 by 3 matrix

$$[\Delta M] = \frac{m}{12}\begin{bmatrix} n_1^2 & n_1n_2 & n_1n_3 \\ n_1n_2 & n_2^2 & n_2n_3 \\ n_1n_3 & n_2n_3 & n_3^2 \end{bmatrix} \tag{55}$$

is calculated.

3. The 3 by 3 element mass matrices in basic coordinates are

$$[m_{aa}] = [m_{bb}] = \begin{bmatrix} m/2 & 0 & 0 \\ 0 & m/2 & 0 \\ 0 & 0 & m/2 \end{bmatrix} - [\Delta M] \quad , \tag{56}$$

and

$$[m_{ab}] = [m_{ba}] = [\Delta M] \quad . \tag{57}$$

4. In global coordinates the 6 by 6 mass matrix partitions are:

$$[M_{ij}] = \left[\begin{array}{c|c} T_i^T m_{ij} T_j & 0 \\ \hline 0 & 0 \end{array}\right] \quad , \tag{58}$$

for i=a or b, j = a or b and where $[T_i]$ is the global-to-basic coordinate transformation matrix for point i.

4.87.1.9 Thermal Analysis Calculations for the RØD Elements (Subroutine KRØD of Module SMA1)

If a "stiffness" matrix for thermal analysis is to be generated, the first word, HEAT, in CØMMØN data block SMA2HT is .TRUE. The length, ℓ, of the element is calculated as in Section 4.87.1.2. The thermal material coefficient, k, is obtained by calling subroutine HMAT, rather than MAT. The 6 x 6 matrix partitions are:

For the pivot point,

$$K_{ii} = \frac{k\,A}{\ell} \begin{bmatrix} 1 & 0 & 0 & | & \\ 0 & 1 & 0 & | & 0 \\ 0 & 0 & 1 & | & \\ \multicolumn{5}{c}{\text{---------------}} \\ & 0 & & | & 0 \end{bmatrix}$$

For $j \neq i$,

$$K_{ij} = -\frac{k\,A}{\ell} \begin{bmatrix} 1 & 0 & 0 & | & \\ 0 & 1 & 0 & | & 0 \\ 0 & 0 & 1 & | & \\ \multicolumn{5}{c}{\text{---------------}} \\ & 0 & & | & 0 \end{bmatrix}$$

4.87.2 The BAR Element

4.87.2.1 Input Data for the BAR Element

1. The ECPT/EST entries for the BAR are:

Symbol	Descriptions
SIL_a, SIL_b	Scalar indices of grid points a and b
N_a, X_a, Y_a, Z_a N_b, X_b, Y_b, Z_b	Local coordinate system number and location in basic coordinates of the grid points
x_1, x_2, x_3	Orientation vector (see Figure 1 in section 1.3 of the User's Manual)
F	Flag for orientation vector definition
P_a, P_b	Pin flags for either end
Mat I. D.	Material property identification number
A	Cross-sectional area
I_1, I_2	Bending inertials in element coordinates about axes normal to reference planes 1 and 2 respectively
I_{12}	Cross-product bending inertia
J	Torsional Inertia
μ	Nonstructural mass per unit length
a_x, a_y, a_z b_x, b_y, b_z	Vectors defining offset distances between BAR ends and grid points (see Figure 1 in section 1.3 of the User's Manual)
K_1, K_2	Shear factors
c_1, c_2, d_1, d_2 f_1, f_2, g_1, g_2	Positions on cross section of four points for stress calculations (see section 1.3.2 of the User's Manual)
t_μ	Temperature for material properties

2. Coordinate system data

The location (X_i, Y_i, Z_i) and local coordinate system number (N_i) of each grid point (i = a or b) are used to calculate the 3 by 3 global-to-basic coordinate transformation matrices, $[T_a]$ and $[T_b]$.

3. Material data

The material identification number "Mat I.D." and t_μ are used to select the following:

E	-	Modulus of elasticity
G	-	Shear modulus
ν	-	Poisson's ratio
ρ	-	Density
α	-	Thermal expansion coefficient
T_o	-	Reference temperature
g_e	-	Structural damping ratio
σ_t	-	Stress limit, tension
σ_c	-	Stress limit, compression
σ_s	-	Stress limit, shear

4.87.2.2 Stiffness Matrix Calculation (Subroutine KBAR of Module SMA1)

1. If the orientation flag F is nonzero, transform the given vector to basic coordinates:

$$\{v_o\} = [T_a] \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} . \tag{1}$$

Otherwise,

$$\{v_o\} = \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} . \tag{2}$$

2. Transfer the relative beam end locations to basic coordinates:

$$\begin{Bmatrix} \delta_{a1} \\ \delta_{a2} \\ \delta_{a3} \end{Bmatrix} = [T_a] \begin{Bmatrix} a_x \\ a_y \\ a_z \end{Bmatrix} , \tag{3}$$

$$\begin{Bmatrix} \delta_{b1} \\ \delta_{b2} \\ \delta_{b3} \end{Bmatrix} = [T_b] \begin{Bmatrix} b_x \\ b_y \\ b_z \end{Bmatrix} . \tag{4}$$

3. The center axis of the beam, defined as {i} is calculated as:

$$\{V_i\} = - \begin{Bmatrix} X_a - X_b + \delta_{a1} - \delta_{b1} \\ Y_a - Y_b + \delta_{a2} - \delta_{b2} \\ Z_a - Z_b + \delta_{a3} - \delta_{b3} \end{Bmatrix}, \tag{5}$$

$$\ell = (V_{i1}^2 + V_{i2}^2 + V_{i3}^2)^{1/2} , \tag{6}$$

$$\{i\} = \frac{1}{\ell} \{V_i\} . \tag{7}$$

4. The bending axis of the beam in plane 2 is:

$$\{k\} = \frac{\{i\} \times \{v_o\}}{|\{i\} \times \{v_o\}|} . \tag{8}$$

5. The bending axis of the beam in plane 1 is:

$$\{j\} = \frac{\{k\} \times \{i\}}{|\{k\} \times \{i\}|} . \tag{9}$$

6. The 6x6 matrix for transforming element displacements in the element coordinates to basic coordinate displacements is:

$$[T_{eb}] = \left[\begin{array}{ccc:ccc} \{i\} & \{j\} & \{k\} & 0 & 0 & 0 \\ 0 & 0 & 0 & \{i\} & \{j\} & \{k\} \end{array}\right] . \tag{10}$$

7. The 6 by 6 matrices for transforming global coordinate displacements to basic coordinate displacements are:

$$[C_a] = \left[\begin{array}{c:c} T_a & 0 \\ \hline 0 & T_a \end{array}\right] , \tag{11}$$

$$[C_b] = \begin{bmatrix} T_b & 0 \\ 0 & T_b \end{bmatrix} \tag{12}$$

8. The 6 by 6 matrices for transforming displacements of the grid points to displacements of the element ends are:

$$[E_a] = \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & 0 & a_z & -a_y \\ 0 & 1 & 0 & -a_z & 0 & a_x \\ 0 & 0 & 1 & a_y & -a_x & 0 \\ \hline & & & 1 & 0 & 0 \\ & 0 & & 0 & 1 & 0 \\ & & & 0 & 0 & 1 \end{array}\right], \tag{13}$$

$$[E_b] = \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & 0 & b_z & -b_y \\ 0 & 1 & 0 & -b_z & 0 & b_x \\ 0 & 0 & 1 & b_y & -b_x & 0 \\ \hline & & & 1 & 0 & 0 \\ & 0 & & 0 & 1 & 0 \\ & & & 0 & 0 & 1 \end{array}\right]. \tag{14}$$

9. The 6 by 6 partitions of the element stiffness matrix in element coordinates are:

$$[K^e_{aa}] = \begin{bmatrix} \frac{AE}{\ell} & 0 & 0 & 0 & 0 & 0 \\ 0 & R_1 & \beta & 0 & -\frac{\ell}{2}\beta & \frac{\ell}{2}R_1 \\ 0 & \beta & R_2 & 0 & -\frac{\ell}{2}R_2 & \frac{\ell}{2}\beta \\ 0 & 0 & 0 & \frac{GJ}{\ell} & 0 & 0 \\ 0 & -\frac{\ell}{2}\beta & -\frac{\ell}{2}R_2 & 0 & k_2 & -\frac{\ell^2}{3}\beta \\ 0 & \frac{\ell}{2}R_1 & \frac{\ell}{2}\beta & 0 & -\frac{\ell^2}{3}\beta & k_1 \end{bmatrix}, \quad (15)$$

$$[K^e_{ab}] = \begin{bmatrix} -\frac{AE}{\ell} & 0 & 0 & 0 & 0 & 0 \\ 0 & -R_1 & -\beta & 0 & -\frac{\ell}{2}\beta & \frac{\ell}{2}R_1 \\ 0 & -\beta & -R_2 & 0 & -\frac{\ell}{2}R_2 & \frac{\ell}{2}\beta \\ 0 & 0 & 0 & -\frac{GJ}{\ell} & 0 & 0 \\ 0 & \frac{\ell}{2}\beta & \frac{\ell}{2}R_2 & 0 & k_4 & -\frac{\ell^2}{6}\beta \\ 0 & -\frac{\ell}{2}R_1 & \frac{\ell}{2}\beta & 0 & -\frac{\ell^2}{6}\beta & k_3 \end{bmatrix}, \quad (16)$$

$$[K^e_{ba}] = [K^e_{ab}]^T , \quad (17)$$

$$[K^e_{bb}] = \begin{bmatrix} \frac{AE}{\ell} & 0 & 0 & 0 & 0 & 0 \\ 0 & R_1 & \beta & 0 & \frac{\ell}{2}\beta & -\frac{\ell}{2}R_1 \\ 0 & \beta & R_2 & 0 & \frac{\ell}{2}R_2 & -\frac{\ell}{2}\beta \\ 0 & 0 & 0 & \frac{GJ}{\ell} & 0 & 0 \\ 0 & \frac{\ell}{2}\beta & \frac{\ell}{2}R_2 & 0 & k_2 & -\frac{\ell^2}{3}\beta \\ 0 & -\frac{\ell}{2}R_1 & -\frac{\ell}{2}\beta & 0 & -\frac{\ell^2}{3}\beta & k_1 \end{bmatrix} . \quad (18)$$

The terms are defined as:

If $I_{12} = 0$:

$$\beta = 0 , \quad (19)$$

$$R_1 = \frac{12EI_1}{\ell^3}\left[1 + \frac{12EI_1}{K_1AG\ell^2}\right]^{-1} , \quad (20)$$

$$R_2 = \frac{12EI_2}{\ell^3}\left[1 + \frac{12EI_2}{K_2AG\ell^2}\right]^{-1} . \quad (21)$$

Note: If $K_i A G = 0$, set $\frac{1}{K_i A G} = 0$, $i = 1$ or 2

If $I_{12} \neq 0$

$$R_1 = \frac{12EI_1}{\ell^3} , \quad (22)$$

$$R_2 = \frac{12EI_2}{\ell^3} , \quad (23)$$

$$\beta = \frac{12EI_{12}}{\ell^3} . \quad (24)$$

Note: In this case no shearing deformations are calculated.

For both cases

$$k_1 = \frac{\ell^2}{4} R_1 + \frac{EI_1}{\ell} , \tag{25}$$

$$k_2 = \frac{\ell^2}{4} R_2 + \frac{EI_2}{\ell} , \tag{26}$$

$$k_3 = \frac{\ell^2}{4} R_1 - \frac{EI_1}{\ell} , \tag{27}$$

$$k_4 = \frac{\ell^2}{4} R_2 - \frac{EI_2}{\ell} . \tag{28}$$

10. Process the end condition ("pin") data. The nonzero digits of the "pin flag" integers P_a and P_b specify the following:

$P =$

- 1 implies no forces are transmitted to the element in the x-direction at the pinned end
- 2 implies no forces are transmitted to the element in the y-direction at the pinned end
- 3 implies no forces are transmitted to the element in the z-direction at the pinned end
- 4 implies no forces are transmitted to the element in the θ_x-direction at the pinned end
- 5 implies no forces are transmitted to the element in the θ_y-direction at the pinned end
- 6 implies no forces are transmitted to the element in the θ_z-direction at the pinned end

1) Nonzero digits of the number P specify the unconnected degrees of freedom on the end of the BAR.

2) Construct the overall element matrix and perform the following operations:

a)

$$\left[\begin{array}{c|c} k^e_{aa} & k^e_{ab} \\ \hline k^e_{ba} & k^e_{bb} \end{array}\right] = \begin{bmatrix} k_{11} & k_{12} & \cdots \\ k_{21} & & \\ \vdots & & k_{12,12} \end{bmatrix} . \tag{29}$$

b) Convert the pin numbers to row numbers in the [k] matrix. If a pin number refers to end "a", it corresponds to the row number. If it refers to end "b", the row number is obtained by adding six to the pin number.

c) For each row of the [k] matrix perform the following operation to obtain the new stiffness matrix [k']

$$k'_{j\ell} = k_{j\ell} - \frac{k_{i\ell}k_{ji}}{k_{ii}} \quad \begin{cases} j = 1,\ldots 12,\ j \neq i \\ \ell = 1,\ldots 12,\ \ell \neq i \end{cases} , \tag{30}$$

and $k'_{j\ell} = 0$ for $j = i$ or $\ell = i$, where i is the row number obtained from the pin number as in b).

This operation causes the i^{th} row and column to be zero, and disconnects that degree of freedom from the matrix. Repeat for each pin index.

d) Repartition the matrix into the four original sections, carrying the zero rows and columns along.

11. The equations to convert the partitions to global coordinates are:

$$[k_{aa}] = \{T^T_{eb}C_aE_a\}^T\ [k^e_{aa}]\ \{T^T_{eb}C_aE_a\} , \tag{31}$$

$$[k_{ab}] = \{T^T_{eb}C_aE_a\}^T\ [k^e_{ab}]\{T^T_{eb}C_bE_b\} , \tag{32}$$

$$[k_{bb}] = \{T^T_{eb}C_bE_b\}^T\ [k^e_{bb}]\ \{T^T_{eb}C_bE_b\} , \tag{33}$$

$$[k_{ba}] = [k_{ab}]^T . \tag{34}$$

4.87.2.3 Lumped Mass Matrix Calculation (Subroutine MBAR of Module SMA2)

$$[M_a] = [M_b] = \begin{bmatrix} m/2 & & & 0 & & \\ & m/2 & & & 0 & \\ & & m/2 & & & 0 \\ 0 & & & 0 & & \\ & 0 & & & 0 & \\ & & 0 & & & 0 \end{bmatrix} , \tag{35}$$

where:

$$m = \ell \, (\rho A + \mu) \ , \tag{36}$$

and:

$$[M_{aa}] = \{T_{eb}^T \, C_a \, E_a\}^T \, [M_a] \, \{T_{eb}^T \, C_a \, E_a\} \ , \tag{37}$$

$$[M_{bb}] = \{T_{eb}^T \, C_b \, E_b\}^T \, [M_b] \, \{T_{eb}^T \, C_b \, E_b\} \ , \tag{38}$$

$$[M_{ab}] = [M_{ba}] = [0] \ . \tag{39}$$

The equations for the generation of the "consistent" or coupled mass matrix for the BAR are given in section 4.87.2.8.

4.87.2.4 Element Load Calculation (Subroutine BAR of Module SSG1)

a) Form ℓ, $\{i\}$, $[C_a]$, $[C_n]$, $[E_a]$, $[E_b]$, and $[k']$ as in Equation 30.

b) Partition the 12 x 12 matrix into four 6 x 6 matrices

$$[k'] \Rightarrow \begin{bmatrix} K_{aa}^e & K_{ab}^e \\ K_{ba}^e & K_{bb}^e \end{bmatrix} \ . \tag{40}$$

c) Form the vector

$$\{u_a^t\} = \begin{Bmatrix} -\alpha\ell(\bar{T} - T_o) - \delta \\ -\frac{\alpha\ell^2}{6}[T'_{1a} + 2T'_{1b}] \\ -\frac{\alpha\ell^2}{6}[T'_{2a} + 2T'_{2b}] \\ 0 \\ -\frac{\alpha\ell}{2}[T'_{2a} + T'_{2b}] \\ \frac{\alpha\ell}{2}[T'_{1a} + T'_{1b}] \end{Bmatrix} , \qquad (41)$$

where $\bar{T}$ is the average of $\bar{T}_a$ and $\bar{T}_b$, δ is the enforced deformation, and T'_i are the gradients.

d) The load vectors in global coordinates are:

$$\{P_a\} = [E_a^T][C_a^T][T_{eb}][K_{aa}^P]\{u_a^t\} \quad ,$$

$$\{P_b\} = [E_b^T][C_b^T][T_{eb}][K_{ba}^P]\{u_a^t\} \quad . \qquad (42)$$

4.87.2.5 Element Stress Calculations (Subroutines SBAR1 and SBAR2 of Module SDR2)

The stress and force data are calculated in two phases. The first phase (subroutine SBAR1) calculates unique stress versus displacement, temperature and enforced deformation functions for each element. The second phase (subroutine SBAR2) applies the various subcase displacement vectors to product the element forces and stresses.

Phase 1 calculations are as follows:

1. Using the algorithms given in the description of the stiffness matrix calculations for the element (Section 4.87.2.2), calculate the following data:

$[T_{eb}]$ = 6x6 element coordinate transformation

$[E_a]$,$[E_b]$ - Offset transformation matrices (6x6)

$[C_a]$,$[C_b]$ - 6x6 global to basic coordinate transformations

$[K_e']$ - 12x12 stiffness matrix in element coordinates with pin joint effects

ℓ - Length of BAR

2. Partition the stiffness matrix $[K_e']$ saving only the upper 6x6 matrices, $[k_{aa}]$ and $[k_{ab}]$.

$$[K_e'] \Rightarrow \left[\begin{array}{c:c} k_{aa} & k_{ab} \\ \hdashline k_{ba} & k_{bb} \end{array}\right] \tag{43}$$

3. The stress matrices are:

$$[S_a] = [k_{aa}][T_{eb}]^T[C_a][E_a] , \tag{44}$$

$$[S_b] = [k_{ab}][T_{eb}]^T[C_b][E_b] . \tag{45}$$

4. The temperature and enforced deformation matrix is:

$$[S_t] = [K_{aa}] \begin{bmatrix} \alpha\ell & 0 & 0 & 0 & 0 \\ 0 & \frac{\alpha\ell^2}{6} & 2\frac{\alpha\ell^2}{6} & 0 & 0 \\ 0 & 0 & 0 & \frac{\alpha\ell^2}{6} & 2\frac{\alpha\ell^2}{6} \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{\alpha\ell}{2} & \frac{\alpha\ell}{2} \\ 0 & -\frac{\alpha\ell}{2} & -\frac{\alpha\ell}{2} & 0 & 0 \end{bmatrix} \quad . \tag{46}$$

Phase 2 element force calculations are as follows:

1. The static element forces are calculated by the equation:

$$\{P\} = [S_a]\{u_a\} + [S_b]\{u_b\} + [S_t] \begin{Bmatrix} \bar{T}_z \\ T'_{1a} \\ T'_{1b} \\ T'_{2a} \\ T'_{2b} \end{Bmatrix} \quad , \tag{47}$$

where $[S_a]$ and $[S_b]$ are the displacement-stress matrices, $\{u_a\}$ and $\{u_b\}$ are the displacement vectors, and $\bar{T}_z$, T'_{1a}, etc. are the element thermal resultants. In terms of the given temperatures at the ends, $\bar{T}_a$ and $\bar{T}_b$, the equation for $\bar{T}_z$ is:

$$\bar{T}_z = \frac{\bar{T}_a + \bar{T}_b}{2} - T_o \quad . \tag{48}$$

2. The element axial force is:

$$F_x = -[P_1 + S_\delta\, \delta] \quad , \tag{49}$$

3. The element shear loads are:

$$V_1 = -P_2 , \tag{51}$$

$$V_2 = -P_3 . \tag{52}$$

4. The torque and moments are:

$$T = -P_4 , \tag{53}$$

$$M_{1a} = -P_6 , \tag{54}$$

$$M_{2a} = P_5 , \tag{55}$$

$$M_{1b} = M_{1a} - V_1 \ell , \tag{56}$$

$$M_{2b} = M_{2a} - V_2 \ell . \tag{57}$$

Phase 2 element stress calculations are as follows:

1. The stresses due to bending are:

$$k_{1a} = \frac{M_{2a} I_{12} - M_{1a} I_2}{I_1 I_2 - I_{12}^2} , \tag{58}$$

$$k_{2a} = \frac{M_{1a} I_{12} - M_{2a} I_1}{I_1 I_2 - I_{12}^2} , \tag{59}$$

$$\sigma_{ca} = k_{1a} c_1 + k_{2a} c_2 , \tag{60}$$

$$\sigma_{da} = k_{1a} d_1 + k_{2a} d_2 , \tag{61}$$

$$\sigma_{fa} = k_{1a} f_1 + k_{2a} f_2 , \tag{62}$$

$$\sigma_{ga} = k_{1a} g_1 + k_{2a} g_2 . \tag{63}$$

For σ_{cb}, σ_{db}, σ_{fb}, σ_{gb} use the above equations interchanging the subscripts for b and a.

Equation 50 is intentionally missing.

The stresses calculated at points c, d, e, and f on the cross section will be modified by the element temperatures T_{ac}, T_{ad}, ... T_{bc}, ... if at least one of the T values is nonzero. At end a:

$$\Delta\sigma_c = -E\alpha(T_{ac} - T'_{1a}\, c_1 - T'_{2a}\, c_2 - \bar{T}_a)$$

$$\Delta\sigma_d = -E\alpha(T_{ad} - T'_{1a}\, d_1 - T'_{2a}\, d_2 - \bar{T}_a)$$

etc.

At end b:

$$\Delta\sigma_c = -E\alpha(T_{bc} - T'_{1b}\, c_1 - T'_{2b}\, c_2 - \bar{T}_b)$$

$$\Delta\sigma_d = -E\alpha(T_{bd} - T'_{1b}\, d_1 - T'_{2b}\, d_2 - \bar{T}_b) \qquad (63a)$$

etc.

(T_a and T_b are the given average temperatures at the ends.) The above stresses are added to the stresses calculated in Equations 60 - 63.

2. The axial stress is:

$$\sigma_{ax} = \frac{F_x}{A} \,. \qquad (64)$$

3. The maxima and minima are:

$$\sigma_{a\,max} = \sigma_{ax} + \max(\sigma_{ca}, \sigma_{da}, \sigma_{fa}, \sigma_{ga}) \,, \qquad (65)$$

$$\sigma_{b\,max} = \sigma_{ax} + \max(\sigma_{cb}, \sigma_{db}, \sigma_{fb}, \sigma_{gb}) \,, \qquad (66)$$

$$\sigma_{a\,min} = \sigma_{ax} + \min(\sigma_{ca}, \sigma_{da}, \sigma_{fa}, \sigma_{ga}) \,, \qquad (67)$$

$$\sigma_{b\,min} = \sigma_{ax} + \min(\sigma_{cb}, \sigma_{db}, \sigma_{fb}, \sigma_{gb}) \,. \qquad (68)$$

4. The margins of safety in tension, $M.S._t$, and compression, $M.S._c$, are as follows:

$$M.S._t = \begin{cases} \min\left(\dfrac{\sigma_t}{\sigma_{a\ max}}, \dfrac{\sigma_t}{\sigma_{b\ max}}\right) - 1 & , \sigma_t > 0 \\ \text{Integer "1"} & , \sigma_t \leq 0 \text{ or } \max\left(\sigma_{a\ max}, \sigma_{b\ max}\right) \leq 0 \end{cases} \tag{69}$$

Define $\sigma'_c = -|\sigma_c|$. Then:

$$M.S._c = \begin{cases} \min\left(\dfrac{\sigma'_c}{\sigma_{a\ min}}, \dfrac{\sigma'_c}{\sigma_{b\ min}}\right) - 1 & , \sigma'_c \neq 0 \\ \text{Integer "1"} & , \sigma'_c = 0 \text{ or } \min\left(\sigma_{a\ min}, \sigma_{b\ min}\right) \geq 0 \end{cases} \tag{70}$$

4.87.2.6 Differential Stiffness Matrix Calculation (Subroutine DBEAM of Module DSMG1)

Many of the equations used in this calculation routine are identical to the stiffness matrix and element force calculations. Refer to sections 4.87.2.2 and 4.87.2.5 for details.

1. Calculate $[T_{eb}]$, $[C_a]$, $[C_b]$, $[E_a]$, $[E_b]$ and $[K]$, the matrices used in the BAR stiffness matrix generation, section 4.87.2.2.

2. Calculate the forces in the element using the equations in section 4.87.2.5.

3. The number 2, 3, 4, 5, 6, 8, 9, 10, 11 and 12^{th} rows and columns of the 12 by 12 differential stiffness matrix are given in Figure 1. The first and seventh rows and columns are zero. The terms are identical to the element forces calculated for output (Equations 51, 52 and 54 through 57 of section 4.87.2.5) with the following notational changes:

$$M_{ay} = M_{2a} \qquad M_{by} = M_{2b}$$

$$M_{az} = M_{1a} \qquad M_{bz} = M_{1b}$$

$$V_y = V_1 \qquad V_z = V_2$$

$$[K_e^d] =$$

$\frac{6F_x}{5\ell}$	0	$\frac{M_{by}}{\ell}$	0	$-\frac{F_x}{10}$	$-\frac{6F_x}{5\ell}$	0	$\frac{M_{ay}}{\ell}$	0	$-\frac{F_x}{10}$
0	$\frac{6F_x}{5\ell}$	$\frac{M_{bz}}{\ell}$	$\frac{F_x}{10}$	0	0	$-\frac{6F_x}{5\ell}$	$\frac{M_{az}}{\ell}$	$\frac{F_x}{10}$	0
$\frac{M_{by}}{\ell}$	$\frac{M_{bz}}{\ell}$	$\frac{JF_x}{\ell^2 A}$	$-\frac{\ell V_y}{6}$	$-\frac{\ell V_z}{6}$	$-\frac{M_{by}}{\ell}$	$-\frac{M_{bz}}{\ell}$	$-\frac{JF_x}{\ell^2 A}$	$\frac{\ell V_y}{6}$	$\frac{\ell V_z}{6}$
0	$\frac{F_x}{10}$	$-\frac{\ell V_y}{6}$	$\frac{2\ell}{15}F_x$	0	0	$-\frac{F_x}{10}$	$\frac{\ell V_y}{6}$	$-\frac{\ell F_x}{30}$	0
$-\frac{F_x}{10}$	0	$-\frac{\ell V_z}{6}$	0	$-\frac{2\ell}{15}F_x$	$\frac{F_x}{10}$	0	$\frac{\ell V_z}{6}$	0	$-\frac{\ell F_x}{30}$
$-\frac{6F_x}{5}$	0	$-\frac{M_{by}}{\ell}$	0	$\frac{F_x}{10}$	$\frac{6F_x}{5\ell}$	0	$-\frac{M_{ay}}{\ell}$	0	$\frac{F_x}{10}$
0	$-\frac{6F_x}{\ell}$	$-\frac{M_{bz}}{\ell}$	$-\frac{F_x}{10}$	0	0	$\frac{6F_x}{5\ell}$	$-\frac{M_{az}}{\ell}$	$-\frac{F_x}{10}$	0
$\frac{M_{ay}}{\ell}$	$\frac{M_{az}}{\ell}$	$-\frac{JF_x}{\ell^2 A}$	$\frac{\ell V_y}{6}$	$\frac{\ell V_z}{6}$	$-\frac{M_{ay}}{\ell}$	$-\frac{M_{az}}{\ell}$	$\frac{JF_x}{\ell^2 A}$	$-\frac{\ell V_y}{6}$	$-\frac{\ell V_z}{6}$
0	$\frac{F_x}{10}$	$\frac{\ell V_y}{6}$	$-\frac{\ell F_x}{30}$	0	0	$-\frac{F_x}{10}$	$-\frac{\ell V_y}{6}$	$\frac{2\ell F_x}{15}$	0
$-\frac{F_x}{10}$	0	$\frac{\ell V_z}{6}$	0	$-\frac{\ell F_x}{30}$	$\frac{F_x}{10}$	0	$-\frac{\ell V_z}{6}$	0	$\frac{2\ell F_x}{15}$

Figure 1. - Differential stiffness matrix for a BAR element, rows and columns 1 and 7 deleted.

4. The effects of "pin joints" are added by applying the elastic stiffness constraints. The elastic stiffness matrix, $[K^e]$, with no pin joints is equivalent to the matrix [k] in Equation 29. If coordinate number j is released by a pin flag the differential stiffness matrix must be modified as follows:

a. If $i \neq j$ and $\ell \neq j$, $i = 1, 2, \ldots, 12$ and $\ell = 1, 2, \ldots, 12$:

$$(K^{d*}_{i\ell})_m = (K^{d*}_{i\ell})_{m-1} - \frac{K^e_{\ell j}\,(K^{d*}_{ji})_{m-1}}{K^e_{jj}} - \frac{K^e_{ji}\,(K^{d*}_{\ell j})_{m-1}}{K^e_{jj}} + \frac{K^e_{\ell j}\,K^e_{ji} + (K^{d*}_{jj})_{m-1}}{(K^e_{jj})^2} \quad (71)$$

where m is the (row) index of the pin joint number, $1 \leq m \leq 12$. For $m = 0$, define

$$(K^{d*}_{i\ell})_0 = (K^d_{i\ell}) \quad . \quad (72)$$

b. If i or $j = \ell$

$$K^{d*}_{ij} = 0 \qquad i = 1, \ldots, 12 \quad , \quad (73)$$

$$K^{d*}_{j\ell} = 0 \qquad j = 1, \ldots, 12 \quad . \quad (74)$$

5. The 12 by 12 matrix $[K^{d*}]$ is now partitioned into 6 by 6 matrices related to each grid point

$$[K^{d*}] = \left[\begin{array}{c|c} K^{d*}_{aa} & K^{d*}_{ab} \\ \hline K^{d*}_{ba} & K^{d*}_{bb} \end{array}\right] \quad . \quad (75)$$

6. If point "p" is the pivot point (p = a or b), the matrices generated in global coordinates are:

$$[K^d_{pa}] = ([T_{eb}]^T[C_p][E_p])^T\,[K^{d*}_{pa}]\,([T_{eb}][C_a][E_a]) \quad , \quad (76)$$

$$[K^d_{pb}] = ([T_{eb}]^T[C_p][E_p])^T\,[K^{d*}_{pb}]\,([T_{eb}]^T[C_b][E_b]) \quad . \quad (77)$$

4.87.2.7 Piecewise Linear Analysis Calculations (Subroutine PSBAR of Module PLA3 and Subroutine PKBAR of Module PLA4)

The additional ECPTNL and ESTNL data block entries for a BAR element are:

ε_o^* - The previously computed axial strain value once removed.

ε^* - The previously computed axial strain value.

E^* - The previously computed modulus of elasticity.

V_1^*, V_2^*, T^*, M_{1a}^*, M_{2a}^* - The previously computed element forces and moments.

All of the above values are initially zero with the exception of E^*, which is initially the original modulus of elasticity present on a MAT1 bulk data card.

For both stress (subroutine PSBAR) and stiffness matrix (subroutine PKBAR) calculations, the following data are generated:

ℓ, $[T_{eb}]$, $[C_a]$, $[C_b]$, $[E_a]$, $[E_b]$, $[k^e_{aa}]$, and $[k^e_{ab}]$ as in Equations 6, 10, 11, 12, 13, 14 and 30 in section 4.87.2.1. Note that: a) $[k^e_{aa}]$ and $[k^e_{ab}]$ are the partitions of the stiffness matrix with pin joint effects taken into account; b) for stress calculations, E^* is used to compute $[k^e_{aa}]$ and $[k^e_{ab}]$; and c) for stiffness matrix calculations E_1 (see Equation 84 below) is used to compute $[k^e_{aa}]$ and $[k^e_{ab}]$.

Using the incremental displacement vectors, $\{\Delta u_a\}$ and $\{\Delta u_b\}$, calculate the incremental strain:

$$\Delta\varepsilon = \frac{1}{\ell}\{T_{eb1}\}^T\left[[C_b][E_b]\{\Delta u_b\} - [C_a][E_a]\{\Delta u_a\}\right], \tag{78}$$

where $\{T_{eb1}\}$ is the first column of $[T_{eb}]$. If coordinate "1" of either P_a or P_b (the pin flags) is "on", the element is treated as linear. This determination is made in the Piecewise Linear

Analysis pre-processor module, PLA1.

Calculate the extensional strains:

$$\Delta\varepsilon^* = \varepsilon^* - \varepsilon_0^* \ , \tag{79}$$

$$\varepsilon_1 = \varepsilon^* + \Delta\varepsilon \ , \tag{80}$$

$$\varepsilon_2 = \varepsilon_1 + \gamma(\Delta\varepsilon) \ , \tag{81}$$

where γ is the ratio of the next load increment to the present load increment.

The stresses

$$\sigma_1 = f(\varepsilon_1), \tag{82}$$

$$\sigma_2 = f(\varepsilon_2), \tag{83}$$

are computed, where f is the tabular stress-strain function. (When $\varepsilon^* = 0$, define $\sigma_1 = E_0\varepsilon_1$, where E_0 is the modulus of elasticity on the MAT1 card)

For stiffness matrix generation the new material properties are:

$$E_1 = \begin{cases} \dfrac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \ , & \text{if } \varepsilon_2 \neq \varepsilon_1 \\ \\ E^* \ , & \text{if } \varepsilon_2 = \varepsilon_1 \end{cases} ; \tag{84}$$

and

$$G_1 = \frac{E_1}{E_0} G_0 \ , \tag{85}$$

where E_0 and G_0 are elastic moduli obtained from the MAT1 bulk data card via subroutine MAT. Note that E_1 is calculated in PSBAR only to predict the next value of E, i.e., to update the ESTNL entry.

For plastic element stresses and forces, the values are calculated in a fashion similar to that found in the phase 2 subroutine, SBAR2, (see section 4.87.2.5) of the SDR2 module. They are:

$$\{\Delta P\} = [k_{aa}][T_{eb}]^T[C_a][E_a]\{\Delta u_a\} + [k_{ab}][T_{eb}]^T[C_b][E_b]\{\Delta u_b\}, \quad (86)$$

$$F_x = A\sigma_1, \quad (87)$$

$$V_1 = -\Delta P_2 + V_1^*, \quad (88)$$

$$V_2 = -\Delta P_3 + V_2^*, \quad (89)$$

$$T = -\Delta P_4 + T^*, \quad (90)$$

$$M_{1a} = -\Delta P_6 + M_{1a}^*, \quad (91)$$

$$M_{2a} = \Delta P_5 + M_{2a}^*, \quad (92)$$

$$M_{1b} = M_{1a} - V_1\ell, \quad (93)$$

$$M_{2b} = M_{2a} - V_2\ell. \quad (94)$$

The stresses due to bending, the axial stress, the minimum and maximum stresses, and the margins of safety are computed as in Equations 58 through 70.

The new ESTNL and ECPTNL entries are:

$$\varepsilon_o^* = \varepsilon^*, \quad (95)$$

$$\varepsilon^* = \varepsilon_1, \quad (96)$$

$$E^* = E_1, \quad (97)$$

$$V_1^* = V_1 \, , \tag{98}$$

$$V_2^* = V_2 \, , \tag{99}$$

$$T^* = T \, , \tag{100}$$

$$M_{1a}^* = M_{1a} \, , \tag{101}$$

$$M_{2a}^* = M_{2a} \, . \tag{102}$$

4.87.2.8 "Consistent" Mass Matrix Calculation (Subroutine MCBAR of Module SMA2)

1. Generate the 12 by 12 matrix:

$$[M^e] = \frac{m}{420}\begin{bmatrix} 175 & 0 & 0 & 0 & 0 & 0 & 35 & 0 & 0 & 0 & 0 & 0 \\ & 156 & 0 & 0 & 0 & 22\ell & 0 & 54 & 0 & 0 & 0 & -13\ell \\ & & 156 & 0 & -22\ell & 0 & 0 & 0 & 54 & 0 & 13\ell & 0 \\ & & & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & 4\ell^2 & 0 & 0 & 0 & -13\ell & 0 & -3\ell^2 & 0 \\ & & & & & 4\ell^2 & 0 & 13\ell & 0 & 0 & 0 & -3\ell^2 \\ & & & \text{SYM} & & & 175 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & 156 & 0 & 0 & 0 & -22\ell \\ & & & & & & & & 156 & 0 & 22\ell & 0 \\ & & & & & & & & & 0 & 0 & 0 \\ & & & & & & & & & & 4\ell^2 & 0 \\ & & & & & & & & & & & 4\ell^2 \end{bmatrix}, \quad (103)$$

where

$$m = (\rho A + \mu)\ell \quad . \quad (104)$$

2. If "pin joints" exist (P_a or P_b nonzero), generate the "unpinned" 12 by 12 stiffness matrix in element coordinates, $[K^e]$, as in Equation 29, section 4.87.2.2.

For each pin joint of index j, perform the operations for i = 1, ..., 12 and ℓ = 1, ..., 12:

$$M^p_{i\ell} = M^e_{i\ell} - \frac{K^e_{\ell j} M^e_{ji}}{K^e_{jj}} - \frac{K^e_{ji} M^e_{\ell j}}{K^e_{jj}} + \frac{K^e_{\ell j} K^e_{ji} M^e_{jj}}{(K^e_{jj})^2} \quad . \quad (105)$$

After each pin joint j operation, replace $[M^e]$ by the "pinned" matrix $[M^p]$.

4. Partition the matrix into 6 by 6 submatrices:

$$[M] = \left[\begin{array}{c|c} M_{aa} & M_{ab} \\ \hline M_{ba} & M_{bb} \end{array}\right] \qquad (106)$$

5. The matrices are converted to global coordinates by the equation:

$$[M^g_{ij}] = \left[[T_{eb}]^T[C_i][E_i]\right]^T[M_{ij}]\left[[T_{eb}]^T[C_j][E_j]\right] \quad , \qquad (107)$$

where i is the pivot point (a or b) and j is used twice (for both a and b).

4.87.2.9 Thermal Analysis Calculations for the BAR Element (Subroutine KBAR of Module SMA1)

If a "stiffness" matrix for heat transfer analysis is to be generated, the first word, HEAT, in CØMMØN data block SMA2HT is .TRUE. The length, ℓ, of the element is calculated with the structure analysis code, described in Section 4.87.2.2. The thermal conductivity coefficient, k, is obtained by calling subroutine HMAT, rather than MAT. The 6x6 matrix partitions are:

For the pivot point i,

$$K_{ii} = \frac{k\,A}{\ell}\left[\begin{array}{ccc|c} 1 & 0 & 0 & \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \\ \hline & 0 & & 0 \end{array}\right]$$

For $j \neq i$,

$$K_{ij} = -\frac{k\,A}{\ell}\left[\begin{array}{ccc|c} 1 & 0 & 0 & \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \\ \hline & 0 & & 0 \end{array}\right]$$

4.87.3 The SHEAR Panel and TWIST Panel Elements

4.87.3.1 Input Data for SHEAR and TWIST Panels

1. The ECPT/EST entries for shear (SHEAR) and twist (TWIST) panel elements are:

Symbol	Description
SIL_i, i=1,2,3,4	Scalar indices for the connected points
N_i, X_i, Y_i, Z_i } i = 1,2,3,4	Local coordinate system number and basic coordinate location for each of the connected points.
Mat I.D.	Material identification number
t	Panel thickness
μ	Nonstructural mass per unit area
t_μ	Temperature for material properties

2. Coordinate system data

Using N_i, X_i, Y_i, Z_i, i = 1,2,3,4 the program constructs $[T_i]$, i = 1,2,3,4, the 3 by 3 global-to-basic transformation matrix for each point.

3. Material data

MAT I.D. and t_μ are used, by utility routine MAT, to produce the following terms from the MPT and DIT data blocks:

Symbol	Description
E	Modulus of elasticity
G	Shear modulus
ν	Poisson's ratio
ρ	Density
α	Thermal expansion coefficient
T_o	Reference temperature
g_e	Structural damping coefficient
σ_t, σ_c, σ_b	Stress limits

4.87.3.2 Definition of Element Geometry

A mean plane is defined as parallel to the two diagonal lines and halfway between them. The projections of the points at the corners of the element onto the plane and the normal to the plane define the element coordinate system. Using standard vector algebra, the steps are:

1. Define:

$$\{V_{01}\} = \begin{Bmatrix} X_1 \\ Y_1 \\ Z_1 \end{Bmatrix}, \quad \{V_{02}\} = \begin{Bmatrix} X_2 \\ Y_2 \\ Z_2 \end{Bmatrix}, \text{ etc.} \tag{1}$$

2. Define diagonal vectors:

$$\{v_{d1}\} = \{V_{03}\} - \{V_{01}\}, \tag{2}$$

$$\{v_{d2}\} = \{V_{04}\} - \{V_{02}\}. \tag{3}$$

3. Define normal vector (x denotes cross product):

$$\{k_n\} = \{v_{d1}\} \times \{v_{d2}\}, \tag{4}$$

$$\{k\} = \frac{\{k_n\}}{|\{k_n\}|}, \tag{5}$$

$$A = \frac{1}{2} |\{k_n\}| \quad \text{(the projected area of the element).} \tag{6}$$

4. Define the vectors along the side of the element (see Figures 2 and 3)

$$\{v_{12}\} = \{V_{02}\} - \{V_{01}\}, \tag{7}$$

$$\{v_{41}\} = \{V_{01}\} - \{V_{04}\}. \tag{8}$$

5. Define transformation matrix $[T_e]$, which transforms element coordinate to basic coordinates, using unit vectors:

$$\{v_{12}^p\} = \{v_{12}\} - (\{v_{12}\}^T \{k\})\{k\} \quad , \tag{9}$$

$$\{i\} = \frac{\{v_{12}^p\}}{|\{v_{12}^p\}|} \quad , \tag{10}$$

$$\{j\} = \{k\} \times \{i\} \quad , \tag{11}$$

$$[T_e] = \begin{bmatrix} i_1 & j_1 \\ i_2 & j_2 \\ i_3 & j_3 \end{bmatrix} \quad . \tag{12}$$

6. Transform the four corner point of the element from basic coordinates to the element system:

$$\{r_1\} = \begin{Bmatrix} x_1 \\ y_1 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \quad , \tag{13}$$

$$\{r_2\} = \begin{Bmatrix} x_2 \\ y_2 \end{Bmatrix} = \begin{Bmatrix} |v_{12}^p| \\ 0 \end{Bmatrix} , \tag{14}$$

$$\{r_3\} = \begin{Bmatrix} x_3 \\ y_3 \end{Bmatrix} = [T_e]^T \{v_{d1}\} \quad , \tag{15}$$

$$\{r_4\} = \begin{Bmatrix} x_4 \\ y_4 \end{Bmatrix} = - [T_e]^T \{v_{41}\} \quad . \tag{16}$$

The four corners of the element are now projected onto the mean plane.

7. The following conditions should be met. Otherwise, the interior angle at the indicated point is not valid.

$$y_3 > 0 \qquad \text{(If not, the interior angle at point 2 > 180}^{\circ}\text{)} \quad , \quad (17)$$

$$x_3 > \frac{y_3}{y_4} x_4 \qquad \text{(If not, the interior angle at point 4 > 180}^{\circ}\text{)} \quad , \quad (18)$$

$$y_4 > 0 \qquad \text{(If not, the interior angle at point 1 > 180}^{\circ}\text{)} \quad , \quad (19)$$

$$x_4 < x_2 - (x_2 - x_3)\frac{y_4}{y_3} \qquad \text{(If not, the interior angle at point 3 > 180}^{\circ}\text{)} \quad . \quad (20)$$

4.87.3.3 Coefficient Generation

The shape of the panel may be a parallelogram, a trapezoid, or a general quadrilateral, and the equations will be different for each case. The slopes of the opposite sides are checked for parallel effects, and the correct routine is used for each possibility.

1. Check for parallel effects:

If

$$\left| \frac{y_3 - y_4}{x_3 - x_4} \right| < \varepsilon, \qquad (21)$$

sides 1 and 3 of the panel are parallel ($\varepsilon = 10^{-1}$).

If

$$\left| \frac{y_4(x_3 - x_2) - y_3 x_4}{x_4(x_3 - x_2) + y_4 y_3} \right| < \varepsilon, \qquad (22)$$

sides 2 and 4 are parallel. If both terms are less than ε, (i.e., the panel is a parallelogram), go to step (4). If both terms are greater than ε, go to step (5). If the one pair of parallel sides is 1 and 3, go to step (2); if the one pair of parallel sides is 2 and 4, go to step (3).

2. In this case the line connecting points 3 and 4 is approximately parallel to the line connecting points 1 and 2. The equations are:

$$y_p = \frac{x_2 y_3 y_4}{y_3 x_4 - y_4 (x_3 - x_2)} \quad , \tag{23}$$

$$p_i = y_p - y_i \quad (i = 1,2,3,4) \quad , \tag{24}$$

$$x_p = \frac{x_2 y_3 x_4}{y_3 x_4 - y_4 (x_3 - x_2)} \quad , \tag{25}$$

$$a = \left(\frac{x_2 - x_p}{y_p} \right) \quad , \tag{26}$$

$$c = \left(\frac{x_1 - x_p}{y_p} \right) \quad , \tag{27}$$

$$Z = \frac{p_1 p_2}{p_3 p_4} \frac{A}{2Gt} \left\{ 1 + \frac{2}{3(1+\nu)} (a^2 + ac + c^2) \right\} \quad . \tag{28}$$

3. In this case the line connecting points 1 and 4 is approximately parallel to the line connecting points 2 and 3. The equations are:

$$d = -\frac{1}{2} \left[\frac{x_4}{y_4} + \frac{x_3 - x_2}{y_3} \right] \quad , \tag{29}$$

$$x_q = x_4 - \frac{x_3 - x_4}{y_3 - y_4} y_4 \quad , \tag{30}$$

$$p_i = [(x_q - x_i) - y_i d] \frac{1}{\sqrt{1 + d^2}} \quad (i = 1,2,3,4) \quad , \tag{31}$$

$$b = \frac{(x_q - x_4)d + y_4}{(x_q - x_4) - y_4 d} \quad , \tag{32}$$

$$Z = \frac{p_1 p_2}{p_3 p_4} \frac{A}{2Gt} \{1 + \frac{2}{3(1+\nu)} (b^2 + bd + d^2)\}. \tag{33}$$

4. In this case the panel approximates a parallelogram. The equations to solve are:

$$p_i = 1, \quad (i = 1,2,3,4), \tag{34}$$

$$d = -\frac{1}{2}\left(\frac{x_4}{y_4} + \frac{x_3 - x_2}{y_3} + \frac{y_3 - y_4}{x_3 - x_4}\right) \quad , \tag{35}$$

$$Z = \frac{A}{2Gt} (1 + \frac{2d^2}{1+\nu}). \tag{36}$$

5. In this case no parallel effects exist. The equations are:

$$x_q = x_4 - \frac{(x_3 - x_4)}{(y_3 - y_4)} y_4 \quad , \tag{37}$$

$$x_p = \frac{x_2 x_4 y_3}{y_3 x_4 - y_4 (x_3 - x_2)} , \tag{38}$$

$$y_p = \frac{x_2 y_3 y_4}{y_3 x_4 - y_4 (x_3 - x_2)} , \tag{39}$$

$$\ell = \sqrt{(x_q - x_p)^2 + y_p^2} , \tag{40}$$

$$d = \frac{x_q - x_p}{y_p} , \tag{41}$$

$$p_i = \frac{y_p}{\ell} [(x_q - x_i) - y_i d] \quad (i = 1,2,3,4) , \tag{42}$$

$$c = \frac{\ell}{p_1} - d , \tag{43}$$

$$b = \frac{\ell}{p_4} - c, \tag{44}$$

$$a = \frac{\ell}{p_2} - d. \tag{45}$$

Let:

$$F = \frac{p_1 p_2 p_3 p_4}{2\ell^2} \{[(a+b) + \frac{2}{3}(a^3+b^3) + \frac{1}{5}(a^5+b^5)] \log_e |a+b|$$

$$+ [(c+d) + \frac{2}{3}(c^3+d^3) + \frac{1}{5}(c^5+d^5)] \log_e |c+d|$$

$$- [(b+c) + \frac{2}{3}(b^3+c^3) + \frac{1}{5}(b^5+c^5)] \log_e |b+c| \qquad (46)$$

$$- [(d+a) + \frac{2}{3}(d^3+a^3) + \frac{1}{5}(d^5+a^5)] \log_e |d+a|$$

$$+ \frac{1}{10}[(a^2-c^2)(b^3-d^3) + (b^2-d^2)(a^3-c^3)]$$

$$- \frac{1}{5}[(a-c)(b^4-d^4) + (b-d)(a^4-c^4)]\} .$$

Then:

$$Z = \frac{p_1 p_2}{p_3 p_4} \frac{1}{2Gt} \left\{A + \frac{4}{1+\nu}[F - \frac{2}{3}A]\right\} . \qquad (47)$$

4.87.3.4 Stiffness Matrix Formulation For a SHEAR Panel (Subroutine KPANEL of Module SMA1)

1. Calculate the lengths of the diagonals:

$$\ell_{13} = \sqrt{x_3^2 + y_3^2} \quad , \tag{48}$$

$$\ell_{24} = \sqrt{(x_4-x_2)^2 + y_4^2} \quad , \tag{49}$$

2. Calculate the unit vectors along the diagonals:

$$u_1 = u_3 = \frac{x_3}{\ell_{13}} \quad , \tag{50}$$

$$v_1 = v_3 = \frac{y_3}{\ell_{13}} \quad , \tag{51}$$

$$u_2 = u_4 = \frac{x_4-x_2}{\ell_{24}} \quad , \tag{52}$$

$$v_2 = v_4 = \frac{y_4}{\ell_{24}} \quad . \tag{53}$$

3. The loads along the diagonals in terms of the average shear stress along side 1 are:

$$A_1 = -\frac{x_2 y_4 \ell_{13}}{2(x_4 y_3 - x_3 y_4)} \quad , \tag{54}$$

$$A_2 = \frac{x_2 y_3 \ell_{24}}{2(x_4 y_3 - x_3 y_4 - x_2(y_3 - y_4))} , \tag{55}$$

$$A_3 = -A_1 , \tag{56}$$

$$A_4 = -A_2 . \tag{57}$$

4. The loads at grid point i in terms of the displacements at grid point j may be expressed in terms of a (3x3) matrix $[k_{ij}]$ where

$$[k_{ij}] = \frac{A_i A_j}{2Z} [T_i]^T [T_e] \begin{Bmatrix} u_i \\ v_i \end{Bmatrix} \{u_j v_j\}^T [T_e]^T [T_j] , \tag{58}$$

$$i = 1, 2, 3, 4 ,$$

$$j = 1, 2, \ldots i .$$

5. The 3x3 matrices are related only to deflections and forces. The terms in the 6x6 matrices, $[K_{ij}]$, corresponding to rotations are zero. Expand the matrices to 6x6:

$$[K_{ij}] = \left[\begin{array}{c:c} k_{ij} & 0 \\ \hdashline 0 & 0 \end{array}\right] . \tag{59}$$

The element structural damping matrix is equal to g_e, the structural damping coefficient, multiplied by the stiffness matrix, $[K_{ij}]$.

4.87.3.5 TWIST Element Stiffness Matrix Generation (Subroutine KPANEL of Module SMA1)

The following data for the SHEAR panel element are used for generation of the element stiffness matrix for the TWIST panel.

$[T_e]$	The 3x2 transformation matrix (Equation 12).
x_2, x_3, x_4, y_3, y_4	The locations of the corners in the element system (Equations 14, 15 and 16).
Z	The energy coefficient (Equation 28, 33, 36, or 47).
$\left.\begin{matrix} u_1 u_2 u_3 u_4 \\ v_1 v_2 v_3 v_4 \end{matrix}\right\}$	Unit vector coefficients at the corners (Equations 50 through 53)
A_1, A_2, A_3, A_4	Load coefficients for the corners (Equations 54 through 57)
$[T_1], [T_2], [T_3], [T_4]$	3x3 global-to-basic transformation matrices

1. Generate the three by three matrices relating the moments at point i to the rotations at point j:

$$[q_{ij}] = \frac{A_i A_j t^2}{24Z} [T_i]^T [T_e] \begin{Bmatrix} -v_i \\ u_i \end{Bmatrix} \{-v_j u_j\}^T [T_e]^T [T_j] . \tag{60}$$

These are generated only for one point i (the pivot point) and j = 1,2,3 and 4.

2. The 3x3 matrices $[q_{ij}]$ are expanded to 6x6 matrices $[K_{ij}]$ having zeros in the translational displacement rows and columns.

$$[K_{ij}] = \begin{bmatrix} 0 & 0 \\ 0 & q_{ij} \end{bmatrix} . \tag{61}$$

4.87.3.6 Mass Matrix Generation (Subroutine MASSTQ of Module SMA2)

The mass at each point is determined by cutting the quadrilateral into four overlapping triangles. Each triangle is defined by three of the four points as follows:

Triangle No.	Connected Points		
K	j1	j2	13
I	4	1	2
II	1	2	3
III	2	3	4
IV	3	4	1

The area of each triangle is determined by the equation :

$$A_K = \frac{1}{2}|(\{V_{oj2}\}-\{V_{oj1}\}) \times (\{V_{oj3}\}-\{V_{oj1}\})| , \tag{62}$$

where $\{V_{oj1}\}$ is the location vector of the first point defining the triangle, $\{V_{oj2}\}$ the second point, and $\{V_{oj3}\}$ the third point.

The mass of each triangle is divided equally among its connected points. The mass at each point is :

$$m_1 = \frac{(\mu + \rho t)}{3} (A_4 + A_1 + A_2) , \tag{63}$$

$$m_2 = \frac{(\mu + \rho t)}{3} (A_1 + A_2 + A_3) , \tag{64}$$

$$m_3 = \frac{(\mu + \rho t)}{3} (A_2 + A_3 + A_4), \tag{65}$$

$$m_4 = \frac{(\mu + \rho t)}{3} (A_3 + A_4 + A_1). \tag{66}$$

For each point a six by six diagonal mass matrix is constructed. The matrix is:

$$[M_{ii}] = \begin{bmatrix} m_i & & & & & \\ & m_i & & & 0 & \\ & & m_i & & & \\ & & & 0 & & \\ & 0 & & & 0 & \\ & & & & & 0 \end{bmatrix} . \qquad (67)$$

4.87.3.7 SHEAR Element Stress and Force Calculations (Subroutines SPANL1 and SPANL2 of Module SDR2)

The stress and force calculations are performed in two phases: phase 1 in SPANL1; phase 2 in SPANL2.

PHASE 1

1. Calculate the 1 by 3 matrices $[S_i]$, i = 1, 2, 3, 4:

$$[S_i] = -\frac{A_i}{2Zt} \{u_i \vdots v_i\} [T_e]^T [T_i], \qquad (68)$$

where A_i, Z, t, u_i, v_i, $[T_e]$ and $[T_i]$ are as given in sections 4.87.3.2 and 4.87.3.3.

2. The [S] terms and the following parameters:

$$A_1, A_2, t, \frac{P_2}{P_1}, \frac{P_1P_2}{P_3^2}, \frac{P_1P_2}{P_4^2},$$

are saved on a scratch file for phase 2 calculations. p_i, where i = 1, 2, 3 and 4 are calculated using the equations in section 4.87.3.3.

PHASE 2

1. The average stress along side 1 is:

$$\bar{s}_1 = \sum_{i=1}^{4} [S_i]\{u_i^t\}. \tag{69}$$

$\{u_i^t\}$ are the translational vectors where:

$$\{u_{gi}\} \Longrightarrow \begin{Bmatrix} u_i^t \\ \hline\hline u_i^r \end{Bmatrix} . \tag{70}$$

2. The stresses on the corners are:

$$\tau_1 = \frac{p_2}{p_1} \bar{s}_1 , \tag{71}$$

$$\tau_2 = \frac{p_1}{p_2} \bar{s}_1 , \tag{72}$$

$$\tau_3 = \frac{p_1 p_2}{p_3^2} \bar{s}_1 , \tag{73}$$

$$\tau_4 = \frac{p_1 p_2}{p_4^2} \bar{s}_1 . \tag{74}$$

3. The average and maximum stresses are defined as:

$$\tau_{avg} = \frac{1}{4} (\tau_1 + \tau_2 + \tau_3 + \tau_4), \tag{75}$$

$$\tau_{max} = \max (|\tau_1|, |\tau_2|, |\tau_3|, |\tau_4|). \tag{76}$$

4. The margin of safety in shear is defined by:

$$M.S._s = \begin{cases} \dfrac{\sigma_s}{|\tau_{max}|} - 1 \text{ , if } \sigma_s > 0 \\ \text{Integer "1", if } \sigma_s \leq 0 \text{ or } \tau_{max} = 0 \end{cases} \tag{77}$$

5. The net loads on the corners in the diagonal direction are:

$$P_{13} = A_1 \bar{s}_1 t \text{ ,} \tag{78}$$

$$P_{24} = A_2 \bar{s}_1 t \text{ .} \tag{79}$$

4.87.3.8 TWIST Element Stress and Force Calculations (Subroutines SPANL1 and SPANL2 of Module SDR2)

The stress and force calculations are performed in two phases, as for the SHEAR panel element.

PHASE 1

1. Calculate for i = 1, 2, 3, 4

$$[S_i] = -\frac{A_i}{4Z} \{-v_i \vdots u_i\} [T_e]^T [T_i]. \tag{80}$$

2. The $[S_i]$ terms and the following data:

$$A_1, A_2, t, \frac{p_2}{p_1}, \frac{p_1 p_2}{p_3^2}, \frac{p_1 p_2}{p_4^2} .$$

are saved on a scratch file for phase 2 calculations.

PHASE 2

1. The mean outer fibre shear stress along side 1 is:

$$\tau_1 = \sum_{i=1}^{4} [S_i] \{u_i^r\}, \tag{81}$$

where $\{u_i^r\}$ are the three rotational displacements:

$$\{u_{gi}\} \Rightarrow \begin{Bmatrix} u_i^t \\ \hline u_i^r \end{Bmatrix} .$$

2. The stresses are :

$$\sigma_1 = \frac{p_2}{p_1} \tau_1, \tag{82}$$

$$\sigma_2 = \frac{\tau_1 p_1}{p_2}, \tag{83}$$

$$\sigma_3 = \frac{p_1 p_2}{p_3^2} \tau_1, \tag{84}$$

$$\sigma_4 = \frac{p_1 p_2}{p_4^2} \tau_1, \tag{85}$$

$$\sigma_{avg} = \frac{1}{4} (\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4), \tag{86}$$

$$\sigma_{max} = \max(|\sigma_1|, |\sigma_2|, |\sigma_3|, |\sigma_4|). \tag{87}$$

3. The margin of safety in shear is defined by :

$$M.S._s = \begin{cases} \dfrac{\sigma_s}{|\sigma_{max}|} - 1 , & \sigma_s > 0 \\ \text{Integer "1"}, & \sigma_s \leq 0 \text{ or } \sigma_{max} = 0 \end{cases} \tag{88}$$

4. The moments are :

$$M_{13} = \frac{A_1 t^2}{6} \tau_1, \tag{89}$$

$$M_{24} = \frac{A_2 t^2}{6} \tau_1 \quad . \tag{90}$$

4.87.3.9 SHEAR Panel Differential Stiffness Calculations (Subroutine DSHEAR of Module DSMG1)

1. Data

The data necessary for analysis are included in the ECPT, CSTM, MPT and UGV data blocks. The following data are generated as in sections 4.87.3.2, 4.87.3.3, and 4.87.3.4 .

a. $[T_i]$, i = 1,2,3,4, the 3x3 transformation matrices between global and basic coordinates, at the four corners of the shear panel.

b. $[T_e]$, the 3x2 transformations between basic and element coordinates.

c. {k}, the unit vector normal to the plane in basic coordinates.

d. u_i, v_i, i = 1,2,3,4, the unit vectors along the diagonals in element coordinates.

e. A_i, i = 1,2,3,4, the load coefficients for the corners.

f. Z, the energy coefficient for the panel.

g. ℓ_{13} and ℓ_{24}, the lengths of the diagonals.

2. Algorithm

a. The load in the diagonal between points 1 and 3 is :

$$F_{13} = -\frac{A_1}{2Z} \sum_{i=1}^{4} A_i \{u_i \vdots v_i\}^T [T_e]^T [T_i] \begin{Bmatrix} x_{1i} \\ x_{2i} \\ x_{3i} \end{Bmatrix} . \tag{91}$$

where $\{x_i\}$ is the vector of the three translations in global coordinates for point (i).

b. The load in the other diagonal is :

$$F_{24} = \frac{A_2}{A_1} F_{13} \cdot \tag{92}$$

c. Construct a perpendicular, which is defined in basic coordinates, to each diagonal vector in the plane of the panel.

$$\{j_1\} = [T_e] \begin{Bmatrix} -v_1 \\ u_1 \end{Bmatrix}, \tag{93}$$

$$\{j_2\} = [T_e] \begin{Bmatrix} -v_2 \\ u_2 \end{Bmatrix}. \tag{94}$$

d. The nonzero partitions of the overall differential stiffness matrix for the displacements are:

$$[k^d_{11}] = F'_{13}[T_1]^T \left[\{j_1\}\{j_1\}^T + \{k\}\{k\}^T\right][T_1], \tag{95}$$

$$[k^d_{13}] = -F'_{13}[T_1]^T \left[\{j_1\}\{j_1\}^T + \{k\}\{k\}^T\right][T_3], \tag{96}$$

$$[k^d_{33}] = F'_{13}[T_3]^T \left[\{j_1\}\{j_1\}^T + \{k\}\{k\}^T\right][T_3], \tag{97}$$

$$[k^d_{31}] = [k^d_{13}]^T, \tag{98}$$

$$[k^d_{22}] = F'_{24}[T_2]^T \left[\{j_2\}\{j_2\}^T + \{k\}\{k\}^T\right][T_2], \tag{99}$$

$$[k^d_{24}] = -F'_{24}[T_2]^T \left[\{j_2\}\{j_2\}^T + \{k\}\{k\}^T\right][T_4], \tag{100}$$

$$[k^d_{44}] = F'_{24}[T_4]^T \left[\{j_2\}\{j_2\}^T + \{k\}\{k\}^T\right] [T_4] , \tag{101}$$

$$[k^d_{42}] = [k^d_{24}]^T , \tag{102}$$

where :

$$F'_{13} = \frac{F_{13}}{\ell_{13}} , \tag{103}$$

$$F'_{24} = \frac{F_{24}}{\ell_{24}} . \tag{104}$$

5. The actual 6x6 partitions are

$$[K^d_{ij}] = \left[\begin{array}{c|c} k^d_{ij} & 0 \\ \hline 0 & 0 \end{array}\right] , \tag{105}$$

and

$$[K^d_{ji}] = [K^d_{ij}]^T . \tag{106}$$

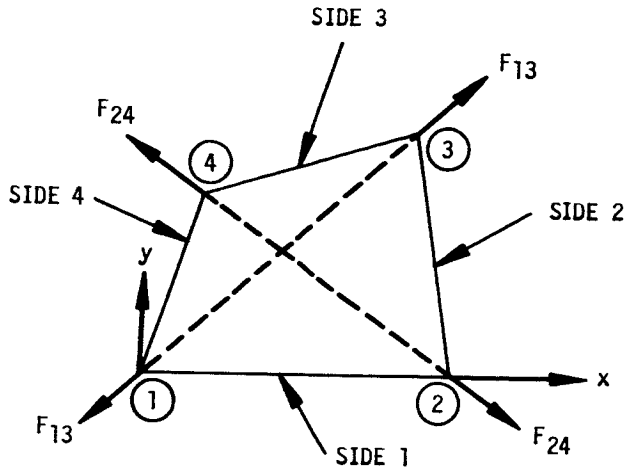


Figure 2. Shear panel element coordinate system and element forces.

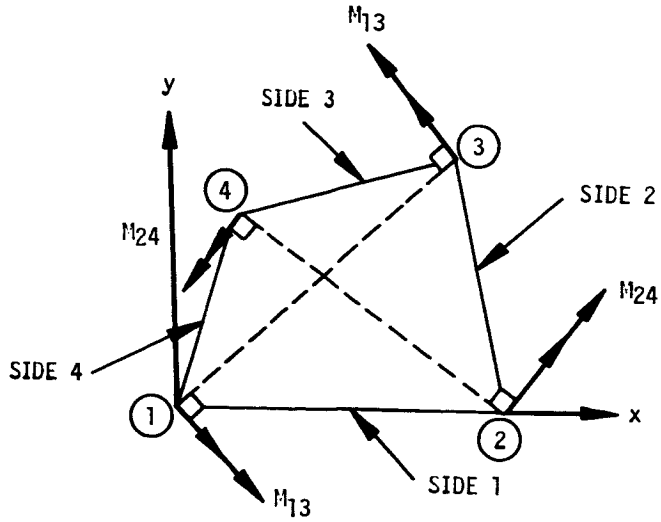


Figure 3. Twist panel element coordinate system and element forces.

4.87.4 TRMEM and QDMEM Elements

4.87.4.1 Input Data for the TRMEM and QDMEM Elements

1. ECPT entries for the TRMEM and QDMEM are:

Symbol		Description
TRMEM	QDMEM	
SIL_1	SIL_1	Scalar indices of the connected grid points.
SIL_2	SIL_2	
SIL_3	SIL_3	
	SIL_4	
N_i	N_i	Local coordinate system numbers and location coordinates in the basic system for the connected grid points.
X_i $i = 1,3$	X_i $i = 1,4$	
Y_i	Y_i	
Z_i	Z_i	
θ		Anisotropic material orientation angle
Mat I.D.		Material identification number
t		Thickness
μ		Nonstructural mass per unit area
t_μ		Temperature for material properties

2. Coordinate system data

The numbers N_i, X_i, Y_i and Z_i are used to calculate the 3 by 3 global-to-basic coordinate transformation matrices $[T_i]$ for points i = 1, 2, 3, and 4.

3. Material data

Symbol	Description
$[G_e]$	3x3 stress-strain matrix
ρ	Mass density
$\alpha_x, \alpha_y, \alpha_{xy}$	Three thermal expansion coefficients
T_o	Reference temperature
g_e	Structural damping coefficient
$\sigma_t, \sigma_c, \sigma_s$	Stress limits for tension, compression and shear

4.87.4.2 Basic Equations For TRMEM

1. The element coordinate system is defined by the following equations (see Figure 4)

$$\{V_{12}\} = \begin{Bmatrix} X_2 - X_1 \\ Y_2 - Y_1 \\ Z_2 - Z_1 \end{Bmatrix} , \tag{1}$$

$$\{V_{13}\} = \begin{Bmatrix} X_3 - X_1 \\ Y_3 - Y_1 \\ Z_3 - Z_1 \end{Bmatrix} , \tag{2}$$

$$\{i\} = \frac{\{V_{12}\}}{|\{V_{12}\}|} , \tag{3}$$

$$\{k\} = \frac{\{i\} \times \{V_{13}\}}{|\{i\} \times \{V_{13}\}|} , \tag{4}$$

$$\{j\} = \{k\} \times \{i\} . \tag{5}$$

2. The displacement transformation matrix from basic coordinates to in-plane coordinates is :

$$[E]^T = \begin{bmatrix} i_1 & i_2 & i_3 \\ j_1 & j_2 & j_3 \end{bmatrix}, \tag{6}$$

3. The coordinates of the points in the element coordinate system are:

$$x_1 = y_1 = y_2 = 0, \tag{7}$$

$$x_2 = |\{V_{12}\}|, \tag{8}$$

$$x_3 = \{V_{13}\}^T \{i\}, \tag{9}$$

$$y_3 = |\{i\} \times \{V_{13}\}|. \tag{10}$$

The area is:

$$A = \frac{1}{2} x_2 y_3. \tag{11}$$

4. The transformations from displacements at the points to strains are:

$$[C_1] = \begin{bmatrix} -\frac{1}{x_2} & 0 \\ 0 & \frac{1}{y_3}\left(\frac{x_3}{x_2} - 1\right) \\ \frac{1}{y_3}\left(\frac{x_3}{x_2} - 1\right) & -\frac{1}{x_2} \end{bmatrix}, \tag{12}$$

$$[C_2] = \begin{bmatrix} \frac{1}{x_2} & 0 \\ 0 & -\frac{x_3}{x_2 y_3} \\ -\frac{x_3}{x_2 y_3} & \frac{1}{x_2} \end{bmatrix}, \tag{13}$$

$$[C_3] = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{y_3} \\ \frac{1}{y_3} & 0 \end{bmatrix}. \tag{14}$$

4.87.4.3 Stiffness Matrix Calculation for TRMEM (Subroutine KTRMEM of Module SMA1)

1. The equation used in the stiffness matrix generation in global coordinates is:

$$[k_{ij}] = At([C_i][E]^T[T_i])^T[G_e]([C_j][E]^T[T_j]), \tag{15}$$

where "i" is the pivot point number, and j = 1, 2, 3 are the three connected points. $[k_{ij}]$ is a 3x3 matrix.

2. For use in the overall structural matrix, the matrices are expanded to 6x6 to form:

$$[K_{ij}] = \left[\begin{array}{c|c} k_{ij} & 0 \\ \hline 0 & 0 \end{array}\right]. \tag{16}$$

4.87.4.4 Mass Matrix Calculation for the TRMEM Element (Subroutine MASSTQ of Module SMA2)

The mass is generated by the following algorithm.

The vectors defining the sides are :

$$\{V_{12}\} = \begin{Bmatrix} X_2 - X_1 \\ Y_2 - Y_1 \\ Z_2 - Z_1 \end{Bmatrix}, \tag{17}$$

$$\{V_{13}\} = \begin{Bmatrix} X_3 - X_1 \\ Y_3 - Y_1 \\ Z_3 - Z_1 \end{Bmatrix}. \tag{18}$$

The area is :

$$A = \frac{1}{2} |\{V_{12}\} \times \{V_{13}\}| . \tag{19}$$

The mass at each point is :

$$m = \frac{A}{3} (\rho t + \mu), \tag{20}$$

which is one-third of the total mass.

For each point the diagonal mass matrix is :

$$[M_{ii}] = \begin{bmatrix} m & & & 0 & & \\ & m & & & 0 & \\ & & m & & & 0 \\ 0 & & & 0 & & \\ & 0 & & & 0 & \\ & & 0 & & & 0 \end{bmatrix}, \quad i = 1,2,3. \tag{21}$$

4.87.4.5 Element Load Calculations For The TRMEM Element (Subroutine TRIMEM of Module SSG1)

Using the loading temperature on the element, $\bar{T}$, given in the GPTT data block, the triangular membrane routine generates force vectors by the equation:

$$\{P_i\} = At[T_i]^T[E]\,[C_i]^T[G_e]\{\alpha\}(\bar{T} - T_o)\ , \quad i = 1,2,3 \qquad (22)$$

where $\{P_i\}$ is a 3x1 vector.

The forces are placed in the PG load vector data block.

4.87.4.6 Element Stress Calculations For The TRMEM Element (Subroutines STRME1 and STQME2 of Module SDR2)

1. Calculations performed in STRME1 (Phase 1 calculations).

   a. Using the formulae given in section 4.87.4.2, calculate the following terms:

$[C_i]$	i = a, b, c	(3x2)
$[T_i]$	i = a, b, c	(3x3)
$[E]$		(3x2)
$[G_e]$		(3x3)

The transformations from displacements to stress are:

$$[S_i] = [G_e][C_i][E]^T[T_i] \cdot \qquad (24)$$

Equation 23 is intentionally missing.

The temperature to stress relation is:

$$\{S_t\} = -[G_e]\{\alpha\} \tag{25}$$

where

$$\{\alpha\} = \alpha \begin{Bmatrix} 1 \\ 1 \\ 0 \end{Bmatrix} , \tag{26}$$

for isotropic materials. $\{\alpha\}$ is input by the user for anisotropic materials and corrected for material angle by $\alpha = [v]\{\alpha_m\}$.

2. Calculations performed by STQME2 (Phase 2 calculations)

The equation for stress is:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \left[\sum_{i=a,b,c} [S_i]\{u_{gi}\} \right] + \{S_t\}[\bar{T} - T_o] , \tag{27}$$

where $\bar{T}$ is the loading temperature obtained from the GPTT data block.

The principal stresses are:

$$\sigma_1 = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2} , \tag{28}$$

$$\sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2} , \tag{29}$$

$$\theta = \frac{1}{2} \arctan \left(\frac{2\sigma_{xy}}{\sigma_x - \sigma_y}\right) \text{ (in degrees)} , \tag{30}$$

where θ is limited to : $-90^o \leq \theta \leq 90^o$

The maximum shear is :

$$\tau = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2} \qquad (31)$$

4.87.4.7 Differential Stiffness Matrix Calculations for the TRMEM Element (Subroutine DTRMEM of Module DSMG1)

1. Input Data.

   ECPT for element

   i - Pivot point scalar index

   $\{u_1\}$, $\{u_2\}$, $\{u_3\}$ - Displacements of pivots on triangle (UGV)

   $\bar{T}$ - Average loading temperature of the grid points of the element (GPTT)

   CSTM - coordinate systems

   MPT - Material properties table

2. Output Data.

   $[K^d_{i1}]$, $[K^d_{i2}]$, $[K^d_{i3}]$ - partitions of the differential stiffness matrix.

3. Solution Algorithm.

   a. The planar stresses in the element, σ_x, σ_y and σ_{xy}, are calculated as in the SDR2 (Stress Data Recovery) module. The following data are saved for use in the differential stiffness calculation :

   $\{i\}$, $\{j\}$, $\{k\}$ - Unit vectors defining the element coordinate system.

   A, t - Area and thickness

   x_2, x_3, y_3 - Locations of the points, element coordinates

   $[T_1]$, $[T_2]$, $[T_3]$ - Global-to-basic coordinate transformations

   σ_x, σ_y, σ_{xy} - Stresses in element system

b. The differential stiffness matrix in terms of the six generalized coordinates (ω_x, ω_y, ω_z, ε_{xx}, ε_{yy}, and ε_{xy}) is:

$$[K_g^d] = At \begin{bmatrix} \sigma_y & -\sigma_{xy} & 0 & 0 & 0 & 0 \\ -\sigma_{xy} & \sigma_x & 0 & 0 & 0 & 0 \\ 0 & 0 & (\sigma_x+\sigma_y) & -\sigma_{xy} & \sigma_{xy} & (\sigma_x-\sigma_y) \\ 0 & 0 & -\sigma_{xy} & 0 & 0 & 0 \\ 0 & 0 & \sigma_{xy} & 0 & 0 & 0 \\ 0 & 0 & (\sigma_x-\sigma_y) & 0 & 0 & 0 \end{bmatrix} \tag{32}$$

If the subroutine is called from the DTRIA or DQUAD routines the following terms are set to zero:

$$[K_{g11}^d] = [K_{g12}^d] = [K_{g21}^d] = [K_{g22}^d] = 0$$

c. The transformation matrices from displacements at the points to generalized coordinates are:

$$[C_1^d] = \begin{bmatrix} 0 & 0 & \gamma_3-\gamma_2 \\ 0 & 0 & \gamma_1 \\ \frac{\gamma_2-\gamma_3}{2} & -\frac{\gamma_1}{2} & 0 \\ -\gamma_1 & 0 & 0 \\ 0 & \gamma_3-\gamma_2 & 0 \\ \frac{\gamma_2-\gamma_3}{2} & -\frac{\gamma_1}{2} & 0 \end{bmatrix} \tag{33}$$

$$[C_2^d] = \begin{bmatrix} 0 & 0 & -\gamma_3 \\ 0 & 0 & -\gamma_1 \\ \frac{\gamma_3}{2} & \frac{\gamma_1}{2} & 0 \\ \gamma_1 & 0 & 0 \\ 0 & -\gamma_3 & 0 \\ \frac{\gamma_3}{2} & \frac{\gamma_1}{2} & 0 \end{bmatrix} \tag{34}$$

$$[C_3^d] = \begin{bmatrix} 0 & 0 & \gamma_2 \\ 0 & 0 & 0 \\ -\frac{\gamma_2}{2} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & \gamma_2 & 0 \\ \frac{\gamma_2}{2} & 0 & 0 \end{bmatrix} \tag{35}$$

where

$$\gamma_1 = \frac{1}{x_2} , \tag{36}$$

$$\gamma_2 = \frac{1}{y_3} , \tag{37}$$

$$\gamma_3 = \frac{x_3}{x_2 y_3} . \tag{38}$$

d. The partitions (3x3) of the differential stiffness matrix in global coordinates are :

$$[K_{ij}] = ([C_i^d] [E^d]^T [T_i])^T [K_\omega^d] [C_j^d] [E^d]^T [T_j] , \tag{39}$$

i = pivot point

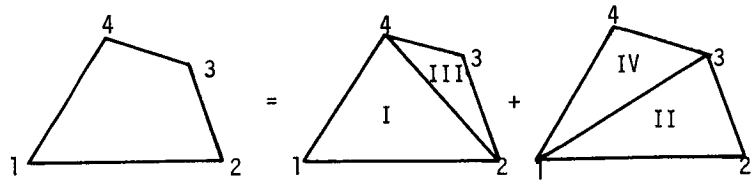
j = 1, 2 and 3

where

$$[E^d]^T = \begin{bmatrix} \{i\}^T \\ \{j\}^T \\ \{k\}^T \end{bmatrix} \quad (3x3) . \tag{40}$$

4.87.4.8 General Calculations for the QDMEM by the QDMEM Driver Routines (Subroutines KQDMEM of Module SMA1, SQDMEl of Module SDR2, DQDMEM of Module DSMG1).

1. The quadrilateral is divided into four triangles as shown in the figure below:



The thickness used for each triangle is one-half that given for the quadrilateral. Since no special calculation time is saved by generating a unique element coordinate system, the basic locations of the points are used to calculate individual coordinate systems for the triangles.

An integer mapping matrix [M] containing the quadrilateral point numbers is used to convert point numbers for the triangles to point numbers for the quadrilateral.

$$[M] = \begin{array}{c} \begin{matrix} \text{Triangle Point No.} & & & \text{Triangle No.} \\ \underline{a} & \underline{b} & \underline{c} & \end{matrix} \\ \begin{bmatrix} 1 & 2 & 4 \\ 2 & 3 & 1 \\ 3 & 4 & 2 \\ 4 & 1 & 3 \end{bmatrix} \begin{matrix} \\ (I) \\ (II) \\ (III) \\ (IV) \end{matrix} \end{array} \qquad (41)$$

The data corresponding to the point numbers in each row of the matrix are transferred to the triangular membrane routine. The pivot grid point i is also transferred.

2. Material orientation for subtriangles.

The material orientation angle for the QDMEM element must be transformed to a set of angles related to the base of each subtriangle. This requires the following steps:

1. The element coordinate system is defined as follows:

$$\{V_i\} = \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} \quad i = 1, 2, 3, 4, \tag{42}$$

$$\{d_{21}\} = \{V_2\} - \{V_1\} \quad , \tag{43}$$

$$\{i\} = \frac{\{d_{21}\}}{|\{d_{21}\}|} \quad , \tag{44}$$

$$\{d_{41}\} = \{V_4\} - \{V_1\} \quad , \tag{45}$$

$$\{k\} = \frac{\{i\} \times \{d_{41}\}}{|\{i\} \times \{d_{41}\}|} \quad , \tag{46}$$

$$\{j\} = \{k\} \times \{i\} \quad . \tag{47}$$

The material is oriented for each triangle as follows:

$$s_1 = \sin(\theta) \, , \tag{48}$$

$$c_1 = \cos(\theta) \, , \tag{49}$$

$$\{p\} = c_1 \{i\} + s_1 \{j\} \, , \tag{50}$$

$$\{V_{II}^t\} = \{V_3\} - \{V_2\} , \tag{51}$$

$$\{V_{III}^t\} = \{V_4\} - \{V_3\} \, , \tag{52}$$

$$\{V_{IV}^t\} = \{V_1\} - \{V_4\} \quad , \tag{53}$$

$$c_i = \frac{\{V_i^t\}^T \{p\}}{|\{V_i^t\}|} = \cos(\theta_i), \quad i = II, III \text{ and } IV \tag{54}$$

$$s_i = \frac{(\{V_i^t\} \times \{p\})^T \{k\}}{|\{V_i^t\}|} = \sin(\theta_i). \tag{55}$$

The values s_i and c_i may be passed to the triangular membrane subroutines in lieu of the angles θ_i.

4.87.4.9 Stiffness Matrix Calculations for the QDMEM.

Three stiffness matrices, which the triangular membrane routine calculates for each sub-triangle, are added to the four matrices which will be output. (Note: only three triangles are needed for each pivot point.) For example, consider the case where point 2 is the pivot grid point. (i.e., the second SIL value in the grid point connection list equals the pivot grid point SIL value). Triangle I is calculated by entering the geometry and property data for the 1, 2 and 4 points on the quadrilateral, with number 2 as the pivot point. The outputs from the stiffness matrix generation routines for the TRMEM are:

$$[K_{21}], [K_{22}], [K_{24}]$$

Data for triangles II and III are also entered, and their corresponding matrix partitions are added. Triangle number IV is not connected to point 2.

4.87.4.10 Element Stress Calculations for the QDMEM (Subroutine SQDME1 and STQME2 of Module SDR2).

The solution for stress in the quadrilateral involves two phases. In the first phase (SQDME1) the triangular membrane partitions are solved for their stress-displacement matrices. These matrices are modified to correspond to the element coordinate system. They

are added together to form four 3x3 matrices relating displacements in global coordinates to element stress. A vector is also calculated which transforms temperature to stress.

The second phase (STQME2) involves the acquisition of the displacement and temperature data and the calculation of the net stress.

The following steps are used to set up an element coordinate system and obtain triangle to element stress transformations.

Phase 1

1. The following quantities are calculated:

$$\{V_i\} = \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} \quad i = 1, 2, 3, 4 , \tag{56}$$

$$\{d_1\} = \{V_3\} - \{V_1\} , \tag{57}$$

$$\{d_2\} = \{V_4\} - \{V_2\} , \tag{58}$$

$$\{k\} = \frac{\{d_1\} \times \{d_2\}}{|\{d_1\} \times \{d_2\}|} , \tag{59}$$

$$\{a_{12}\} = \{V_2\} - \{V_4\} , \tag{60}$$

$$\{a_{23}\} = \{V_3\} - \{V_2\} , \tag{61}$$

$$\{a_{41}\} = \{V_1\} - \{V_4\} , \tag{62}$$

$$\{a_{34}\} = \{V_4\} - \{V_3\} , \tag{63}$$

$$h = \{a_{12}\}^T \{k\} \quad . \tag{64}$$

h is the perpendicular distance between the diagonals. The mean plane of the element lies halfway between the diagonals.

2. The unit vectors along the edges of the four triangles, projected on the mean plane, are calculated from:

$$x_2 = |\{a_{12}\} - h\{k\}| \quad , \tag{65}$$

$$\{i\} = \frac{\{a_{12}\} - h\{k\}}{x_2} \quad , \tag{66}$$

$$\{j\} = \{k\} \times \{j\} \quad , \tag{67}$$

$$[R] = \begin{bmatrix} \{i\}^T \\ \{j\}^T \end{bmatrix} \quad (2x3) \quad , \tag{68}$$

$$\{v_{12}\} = \begin{Bmatrix} 1 \\ 0 \end{Bmatrix} , \tag{69}$$

$$\{v_{ij}\} = [R]\{a_{ij}\} \quad ij = 23, 34, 41 \quad , \tag{70}$$

$$\{w^I\} = \begin{Bmatrix} 1 \\ 0 \end{Bmatrix} , \tag{71}$$

$$\{w^{II}\} = \frac{1}{|\{v_{23}\}|} \{v_{23}\} \quad , \tag{72}$$

$$\{w^{III}\} = \frac{1}{|\{v_{34}\}|} \{v_{34}\} \quad , \tag{73}$$

$$\{w^{IV}\} = \frac{1}{|\{v_{41}\}|} \{v_{41}\} \quad , \tag{74}$$

3. For each triangular membrane, β = I, II, III, IV, of the quadrilateral, the subroutine STRME1 is called to calculate the three stress functions $[S_i]$ where

$$\left\{\begin{matrix}\sigma_1\\ \sigma_2\\ \sigma_{12}\end{matrix}\right\}_{\text{triangle}} = \sum_{i=1}^{3} [S_i]\,\{u_{gdi}\}\,, \tag{75}$$

where $\{u_{gdi}\}$ are the displacements in global coordinates of the points on the triangle. $[S_i^\beta]$ is calculated using the full thickness of the panel for triangle β.

4. The stress functions, Equation 24, are transformed to the element coordinates by the matrix $[T^\beta]$:

$$[S_i^\beta]_{\text{element}} = [T^\beta][S_i^\beta], \tag{76}$$

where

$$[T^\beta] = \begin{bmatrix} w_1^2 & w_2^2 & -2w_1w_2 \\ w_2^2 & w_1^2 & 2w_1w_2 \\ w_1w_2 & -w_1w_2 & w_2^2-w_1^2 \end{bmatrix}, \tag{77}$$

and

$$\left\{\begin{matrix}w_1\\ w_2\end{matrix}\right\} = \{w^\beta\} \tag{78}$$

for triangle β = I, II, III, IV.

5. Using the mapping matrix [M], Equation 41, the matrices are added. The actual equations are:

$$[\bar{S}_1] = \tfrac{1}{4}([S_a^I] + [S_c^{II}] + [S_b^{IV}]) \,, \tag{79}$$

$$[\bar{S}_2] = \tfrac{1}{4}([S_b^I] + [S_a^{II}] + [S_c^{III}]) \,, \tag{80}$$

$$[\bar{S}_3] = \frac{1}{4}([S_b^{II}] + [S_a^{III}] + [S_c^{IV}]) , \quad (81)$$

$$[\bar{S}_4] = \frac{1}{4}([S_c^{I}] + [S_b^{III}] + [S_a^{IV}]) , \quad (82)$$

$$\{\bar{S}_t\} = \frac{1}{4}(\{S_t^{I}\} + \{S_t^{II}\} + \{S_t^{III}\} + \{S_t^{IV}\}). \quad (83)$$

where $[S_i^{\beta}]$ i = a, b, c, are the stress matrices in Equation 76 and $\{S_t^{\beta}\}$ is the vector in Equation 25.

Phase 2

1. In phase 2 the stresses are calculated from:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \{\bar{S}_t\}\bar{t} + \sum_{i=1}^{4} [\bar{S}_i] \{u_{qdi}\} , \quad (84)$$

where

$$\bar{t} = \frac{1}{4} \sum_{i=1}^{4} (t_i - T_o) , \quad (85)$$

and t_i are the loading temperatures at the grid points, obtained from the GPTT data block.

2. The principal stresses and the angles are calculated in exactly the same manner as for the TRMEM element.

4.87.4.11 Mass Matrix Generation for the QDMEM Element (Subroutine MASSTQ of Module SMA2).

The mass is generated by the following algorithm.

The vectors defining the sides and the diagonals are:

$$\{V_{ij}\} = \begin{Bmatrix} X_j - X_i \\ Y_j - Y_i \\ Z_j - Z_i \end{Bmatrix} , \quad ij = 12, 23, 34, 41, 13, 24 \quad (86)$$

The area of the subtriangles defined by the integer mapping matrix [M], Equation 41, is:

$$A_I = \frac{1}{2} \left| \{V_{14}\} \times \{V_{12}\} \right| , \tag{87}$$

$$A_{II} = \frac{1}{2} \left| \{V_{12}\} \times \{V_{23}\} \right| , \tag{88}$$

$$A_{III} = \frac{1}{2} \left| \{V_{23}\} \times \{V_{34}\} \right| , \tag{89}$$

$$A_{IV} = \frac{1}{2} \left| \{V_{34}\} \times \{V_{14}\} \right| . \tag{90}$$

The area of the quadrilateral is:

$$A_q = \frac{1}{2} \left| \{V_{13}\} \times \{V_{24}\} \right| . \tag{91}$$

The mass at each point is:

$$m_1 = \frac{(A_I + A_q)}{3} (\mu + pt) , \tag{92}$$

$$m_2 = \frac{(A_{II} + A_q)}{3} (\mu + pt) , \tag{93}$$

$$m_3 = \frac{(A_{III} + A_q)}{3} (\mu + pt) , \tag{94}$$

$$m_4 = \frac{(A_{IV} + A_q)}{3} (\mu + pt) . \tag{95}$$

For each point, the diagonal mass matrix is:

$$[M_{ii}] = \begin{bmatrix} m_i & 0 & 0 & 0 \\ 0 & m_i & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} , \quad i = 1, 2, 3, 4 . \tag{96}$$

4.87.4.12 Thermal Load Computation For The QDMEM.

The thermal loads are calculated using the triangular membrane routine. The EST data are rearranged to correspond to each of the four subtriangles, and each triangle produces a load in global coordinates.

4.87.4.13 Differential Stiffness Computations For The QDMEM (Subroutines DQDMEM and DTRMEM of Module DSMG1).

The differential stiffness matrices for the QDMEM element are generated by rearranging the ECPT data into four sets of TRMEM data. The TRMEM differential stiffness routine calculates the stresses, generates the differential stiffness matrix partitions in global coordinates and inserts them in the overall matrix.

4.87.4.14 Piecewise Linear Analysis Calculations (Subroutines PSTRM and PSQDM of Module PLA3 and Subroutines PKTRM and PKQDM of Module PLA4)

The additional ECPTNL and ESTNL entries are:

ϵ_o^* - The previously computed strain value once removed.

ϵ^* - The previously computed strain value.

E^* - The previously computed modulus of elasticity.

σ_x^*, σ_y^*, σ_{xy}^* } The previously computed membrane stresses

All of the above values are initially zero with the exception of E^*, which is initially the original modulus of elasticity present on a MAT1 card.

For both PLA3 and PLA4, the element stress matrix calculations are generated in the same manner as Equation 24 of section 4.87.4.6 (Equations 79 through 82 of section 4.87.4.8 for the QDMEM), with the exception that for all DMAP loops (of the Piecewise Linear Analysis Rigid Format) after the first, the 3 by 3 material properties matrix $[G_e]$ is replaced by a stress-dependent 3 by 3 material properties matrix $[G_p]$ defined as follows

$$[G_p] = E_o \begin{bmatrix} 1+s_x^2F & -\nu+s_xs_yF & 2\sigma_{xy}^*s_xF \\ & 1+s_y^2F & 2\sigma_{xy}^*s_yF \\ (\text{sym}) & & 2(1+\nu)+4F\sigma_{xy}^{*2} \end{bmatrix}^{-1} , \qquad (97)$$

where

$$\tau_o = \left[\sigma_x^{*2} - \sigma_x^*\sigma_y^* + \sigma_y^{*2} + 3\sigma_{xy}^{*2}\right]^{1/2} , \qquad (98)$$

$$F = \frac{9(E_o - E^*)}{4\tau_o^2 E^*} , \qquad (99)$$

$$s_x = \frac{2\sigma_x^* - \sigma_y^*}{3} \quad , \tag{100}$$

$$s_y = \frac{2\sigma_y^* - \sigma_x^*}{3} \quad , \tag{101}$$

and E_o and ν are the linear type 1 material properties. If $E^* = 0$, or $\tau_o = 0$, then $[G_p] = [0]$.

Calculate the incremental element stresses:

$$\begin{Bmatrix} \Delta\sigma_x \\ \Delta\sigma_y \\ \Delta\sigma_{xy} \end{Bmatrix} = \left[\sum_{i=a,b,c} [S_i]\{\Delta u_{gi}\} \right] \quad , \tag{102}$$

where $[S_i]$ is given in Equation 24 of section 4.87.4.6, and $\{\Delta u_{gi}\}$ are the 3 by 1 translational displacement vectors.

Define the element stresses for output and for updating the ECPTNL and ESTNL:

$$\sigma_{x1} = \sigma_x^* + \Delta\sigma_x \quad , \tag{103}$$

$$\sigma_{y1} = \sigma_y^* + \Delta\sigma_y \quad , \tag{104}$$

$$\sigma_{xy1} = \sigma_{xy}^* + \Delta\sigma_{xy} \quad . \tag{105}$$

In PLA3, using the element stresses above, the principal stresses are calculated in the same manner as in Equations 28 through 31 in section 4.87.4.6.

Estimate the next elastic coefficients as defined by the following equations:

$$\tau_1 = \left[\sigma_{x1}^2 - \sigma_{x1}\sigma_{y1} + \sigma_{y1}^2 + 3\sigma_{xy1}^2 \right]^{1/2} \quad , \tag{106}$$

$$\varepsilon_1 = f^{-1}(\tau_1) \quad , \tag{107}$$

where f is the tabular stress-strain function. (When τ_1 is outside the range of the function, define $E_1 = 0$, $\varepsilon_1 = \varepsilon^*$, and $\varepsilon^* = \varepsilon_0^*$).

Calculate:

$$\Delta\varepsilon = \varepsilon_1 - \varepsilon^* \quad , \tag{108}$$

$$\Delta\varepsilon^* = \varepsilon^* - \varepsilon_o^* \quad , \tag{109}$$

$$\varepsilon_2 = \varepsilon_1 + \gamma(\Delta\varepsilon) \quad , \tag{110}$$

where γ is a load ratio parameter calculated by the module driver (PLA3 or PLA4).

Calculate:

$$\tau_2 = f(\varepsilon_2) \quad , \tag{111}$$

where f is the tabular stress-strain function.

Then the estimated next modulus of elasticity, E_1, is given by:

$$E_1 = \begin{cases} \dfrac{\tau_2 - \tau_1}{\varepsilon_2 - \varepsilon_1} \text{ , for } \varepsilon_2 \neq \varepsilon_1 \\ 0 \text{ , for } \varepsilon_2 = \varepsilon_1 . \end{cases} \tag{112}$$

The new ESTNL and ECPTNL entries are:

$$\varepsilon_o^* = \varepsilon^* \quad , \tag{113}$$

$$\varepsilon^* = \varepsilon_1 \quad , \tag{114}$$

$$E^* = E_1 \quad , \tag{115}$$

$$\sigma_x^* = \sigma_{x1} \quad , \tag{116}$$

$$\sigma_y^* = \sigma_{y1} \quad , \tag{117}$$

$$\sigma_{xy}^* = \sigma_{xy1} \quad . \tag{118}$$

In module PLA4, the element stiffness matrices are calculated in the same manner as Equations 15 and 16 of section 4.87.4.3 (or as in section 4.87.4.9 for the QDMEM), with the

exception that $[G_e]$ matrix is replaced by the $[G_p]$ matrix (Equation 97). In the calculation for $[G_p]$, E_1 (Equation 112) is used for E*, and the newly calculated membrane stresses (Equations 103, 104 and 105) are used in placed of σ_x^*, σ_y^* and σ_{xy}^* .

4.87.4.15 Thermal Analysis Calculations for the Membrane Elements (Subroutine KTRMEM and KQDMEM of Module SMA1)

If the subroutines are to be used for thermal analysis, the logical word, HEAT, in labeled COMMON SMA1HT is .TRUE. The geometry of the element is processed, as with a structural analysis problem, to produce the parameters x_2, x_3, y_3, A, and t. For thermal analysis, the 2 x 2 material conductivity matrix $[G_e^t]$ is obtained by calling subroutine HMAT. The transformation matrices (2 x 1) between temperatures at the connected grid points and thermal gradients are:

$$[C_1^t] = \begin{bmatrix} -\frac{1}{x_2} \\ \hline \frac{1}{y_3}\left(\frac{x_3}{x_2} - 1\right) \end{bmatrix},$$

$$[C_2^t] = \begin{bmatrix} \frac{1}{x_2} \\ \hline -\frac{x_3}{x_2 y_3} \end{bmatrix},$$

$$[C_3^t] = \begin{bmatrix} 0 \\ \hline \frac{1}{y_3} \end{bmatrix} .$$

The scalar heat conduction terms are:

$$k_{ij}^t = A\ t\ [C_i^t]^T\ [G_e^t]\ [C_j^t] ,$$

where i corresponds to the pivot grid point, and j = 1, 2, and 3.

The 6x6 partitions of the stiffness matrix are:

$$[K_{ij}] = k_{ij} \begin{bmatrix} 1 & 0 & 0 & & \\ 0 & 1 & 0 & & 0 \\ 0 & 0 & 1 & & \\ \multicolumn{3}{c}{0} & & 0 \end{bmatrix}$$

The basic differences which exist in subroutine KQDMEM for thermal analysis are that no transformations between global and element coordinates are performed.

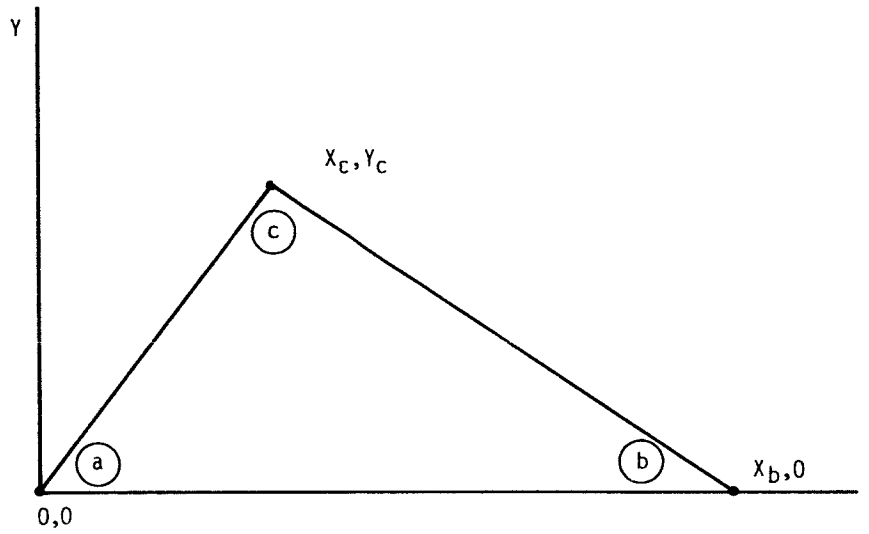


Figure 4. Triangular membrane element.

4.87.5 The TRBSC, TRPLT and QDPLT Elements

4.87.5.1 Input Data for the TRBSC and TRPLT Elements.

1. The ECPT/EST entries for the TRBSC and TRPLT are:

Symbol	Description
SIL_1, SIL_2, SIL_3	Scalar indices for the connected grid points
N_i, X_i, Y_i, Z_i $i = 1, 2, 3$	Reference numbers for local coordinate system and locations in basic coordinates of the three connected grid points
I	Bending moment of inertia per unit width
t	Effective thickness for transverse shear
Mat $Id._b$	Material property identification number for bending
Mat. $Id._s$	Material property identification number for shear
θ	Material orientation angle
μ	Nonstructural mass per area
Z_1, Z_2	Fiber distances for stress calculations
t_μ	Temperature of element for material properties

2. ECPT entries for the QDPLT.

The entries are the same as those for the TRPLT except that four points are used.

3. Coordinate system data

Using N_i, X_i, Y_i, Z_i and the CSTM data block the 3 by 3 global-to-basic coordinate transformation matrices $[T_i]$ are produced for each point i via subroutines TRANSD or TRANSS.

4. Material data

Using the material property identification numbers, the orientation angle, the element temperature and the MPT and DIT data blocks, the following data are calculated:

Symbol		Description
for Mat Id_b	$[G_b]$	3x3 elastic property matrix
	g_e	Structural damping coefficient
for Mat Id_s	G_s	Shear coefficient

For the TRPLT and the QDPLT, the orientation of the material relative to each sub-triangle must be calculated from the geometry and the orientation given for the whole element. The details of this calculation are given in the next section.

4.87.5.2 General Calculation for the TRBSC Element

1. The coordinate system is defined by the three connected points a, b and c. {i}, {j} and {k} are the unit vectors along the x, y and z axis in basic coordinates. X_i, Y_i and Z_i are the location coordinates of the three points, i=a, b, c. (The element coordinate system for the basic bending triangle is shown in Figure 2 of section 5.8 of the Theoretical Manual).

$$\{V_{ab}\} = \begin{Bmatrix} X_b - X_a \\ Y_b - Y_a \\ Z_b - Z_a \end{Bmatrix}, \tag{1}$$

$$\{V_{ac}\} = \begin{Bmatrix} X_c - X_a \\ Y_c - X_a \\ Z_c - Z_a \end{Bmatrix}, \tag{2}$$

The x axis is defined by the unit vector:

$$\{i\} = \frac{\{V_{ab}\}}{|\{V_{ab}\}|} . \tag{3}$$

Calculate:

$$\{k\} = \frac{\{i\} \times \{V_{ac}\}}{|\{i\} \times \{V_{ac}\}|} . \tag{4}$$

The y axis is defined by the unit vector,

$$\{j\} = \{k\} \times \{i\} . \tag{5}$$

2. The locations of the points in element coordinates are:

$$x_a = y_a = y_b = 0 , \tag{6}$$

$$x_b = |\{V_{ab}\}| , \tag{7}$$

$$x_c = \{V_{ac}\}^T \{i\} , \tag{8}$$

$$y_c = \{V_{ac}\}^T \{j\} = |\{i\} \times \{V_{ac}\}| . \tag{9}$$

3. The 3 x 6 transformation matrix from the six displacements in element coordinates to the three degrees of freedom used in the plate is:

$$[E]^T = \begin{bmatrix} k_1 & k_2 & k_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & i_1 & i_2 & i_3 \\ 0 & 0 & 0 & j_1 & j_2 & j_3 \end{bmatrix} . \tag{10}$$

4. The coefficients used for the plate are:

$$[D] = I[G_b] , \tag{11}$$

$$[G_2] = t_s \begin{bmatrix} G_s & 0 \\ 0 & G_s \end{bmatrix} . \tag{12}$$

where $[G_b]$ is the 3 x 3 material matrix for bending and G_s is the coefficient for transverse shear. The area of the triangle, A, the locations of the c.g., $\bar{x}$ and $\bar{y}$, and the radii of gyration about the origin, ρ_x^2, ρ_y^2 and ρ_{xy}^2 are given by:

$$A = \frac{1}{2} x_b y_c \quad , \tag{13}$$

$$\bar{x} = \frac{1}{3} (x_c + x_b) \, , \tag{14}$$

$$\bar{y} = \frac{1}{3} y_c \quad , \tag{15}$$

$$\rho_x^2 = \frac{1}{6} (x_b^2 + x_b \, x_c + x_c^2) \quad , \tag{16}$$

$$\rho_y^2 = \frac{1}{6} y_c^2 \, , \tag{17}$$

$$\rho_{xy}^2 = \frac{y_c}{12} (x_b + 2x_c) \, . \tag{18}$$

5. The stiffness matrix in generalized coordinates {q} is:

$$[K^X] = 4A \begin{bmatrix} D_{11} & D_{13} & D_{12} & 3\bar{x}D_{11} & \bar{x}D_{12}+2\bar{y}D_{13} & 3\bar{y}D_{12} \\ & D_{33} & D_{23} & 3\bar{x}D_{13} & \bar{x}D_{23}+2\bar{y}D_{33} & 3\bar{y}D_{23} \\ & & D_{22} & 3\bar{x}D_{12} & \bar{x}D_{22}+2\bar{y}D_{23} & 3\bar{y}D_{22} \\ & & & 9\rho_x^2 D_{11} & 3\rho_x^2 D_{12}+6\rho_{xy}^2 D_{13} & 9\rho_{xy}^2 D_{12} \\ & & & & \rho_x^2 D_{22}+4\rho_{xy}^2 D_{23}+4\rho_y^2 D_{33} & 3\rho_{xy}^2 D_{22}+6\rho_y^2 D_{23} \\ & & & & & 9\rho_y^2 D_{22} \end{bmatrix} \tag{19}$$

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6. The transformation from generalized coordinates to grid point displacements (relative to point "a" of the triangle) with no transverse shear is:

$$[\bar{H}] = \begin{bmatrix} x_b^2 & 0 & 0 & x_b^3 & 0 & 0 \\ 0 & x_b & 0 & 0 & 0 & 0 \\ -2x_b & 0 & 0 & -3x_b^2 & 0 & 0 \\ x_c^2 & x_c y_c & y_c^2 & x_c^3 & x_c y_c^2 & y_c^3 \\ 0 & x_c & 2y_c & 0 & 2x_c y_c & 3y_c^2 \\ -2x_c & -y_c & 0 & -3x_c^2 & -y_c^2 & 0 \end{bmatrix} \quad (20)$$

where $\{q\} = [\bar{H}]\{u\}$ (no transverse shear)

7. If transverse shear effects are to be calculated ($G_s\ t_s \neq 0$), the following steps are followed:

a. Define

$$[J] = [G_2]^{-1}. \quad (21)$$

b. Calculate the transformation matrix of the shear coordinates:

$$[H_{\gamma q}] = - \left[\begin{array}{c|c|c|c|c|c} 0 & 0 & 0 & 6(J_{11}D_{11}+J_{12}D_{13}) & J_{11}(2D_{12}+4D_{33})+6J_{12}D_{23} & 6(J_{11}D_{23}+J_{12}D_{22}) \\ \hline 0 & 0 & 0 & 6(J_{12}D_{11}+J_{22}D_{13}) & J_{12}(2D_{12}+4D_{33})+6J_{22}D_{23} & 6(J_{12}D_{23}+J_{22}D_{22}) \end{array}\right], \quad (22)$$

where

$$\begin{Bmatrix} \gamma_x \\ \gamma_y \end{Bmatrix} = [H_{\gamma q}] \{q\} . \tag{23}$$

c. The stiffness matrix of the shear terms is added to the bending stiffness matrix.

$$[K^q] = [K^X] + At_s [H_{\gamma q}]^T [G_2] [H_{\gamma q}] . \tag{24}$$

d. The effects of shear deflection on the transformation from general to displacement coordinates is calculated:

$$[H] = [\bar{H}] - \begin{bmatrix} 0 & 0 & 0 & x_b H_{\gamma q_{14}} & x_b H_{\gamma q_{15}} & x_b H_{\gamma q_{16}} \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \begin{matrix} x_c H_{\gamma q_{14}} \\ +y_c H_{\gamma q_{24}} \end{matrix} & \begin{matrix} x_c H_{\gamma q_{15}} \\ +y_c H_{\gamma q_{25}} \end{matrix} & \begin{matrix} x_c H_{\gamma q_{16}} \\ +y_c H_{\gamma q_{26}} \end{matrix} \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} . \tag{25}$$

If no shear exists, $[H] = [\bar{H}]$

8. The matrix [H] is inverted:

$$[H_{qu}] = [H]^{-1} . \tag{26}$$

9. The rigid body effects are given by the matrices $[B_b]$ and $[B_c]$ defined as follows:

$$[B_b] = \begin{bmatrix} 1 & 0 & -x_b \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \tag{27}$$

$$[B_c] = \begin{bmatrix} 1 & y_c & -x_c \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}. \tag{28}$$

10. The 3x3 stiffness matrix partitions in element coordinates are calculated as follows:

$$[K] = [H^{-1}]^T [K^q] [H^{-1}], \tag{29}$$

$$[K] \Longrightarrow \left[\begin{array}{c|c} k_{bb} & k_{bc} \\ \hline k_{cb} & k_{cc} \end{array}\right], \tag{30}$$

$$[k_{ca}] = -[k_{cb}] [B_b] - [k_{cc}] [B_c], \tag{31}$$

$$[k_{ba}] = -[k_{bb}] [B_b] - [k_{bc}] [B_c], \tag{32}$$

$$[k_{aa}] = -[B_b]^T [k_{ba}] - [B_c]^T [k_{ca}], \tag{33}$$

$$[k_{ac}] = [k_{ca}]^T, \tag{34}$$

$$[k_{ab}] = [k_{ba}]^T. \tag{35}$$

4.87.5.3 Stiffness Matrix Calculations for the TRBSC Element (Subroutine KTRBSC of Module SMA1).

1. If the basic triangle is used by itself as a TRBSC element, the stiffness matrices are:

$$[K_{ij}] = \left[\begin{array}{c|c} T_i^T & 0 \\ \hline 0 & T_i^T \end{array}\right] [E] [k_{ij}] [E]^T \left[\begin{array}{c|c} T_j & 0 \\ \hline 0 & T_j \end{array}\right], \tag{36}$$

where

i = a, b and c

j = a, b and c

2. The structural damping matrices are calculated using g_e, the structural damping coefficient, for the referenced bending material. The 6 by 6 damping matrix partitions are:

$$[K^4_{ij}] = g_e [K_{ij}] \quad . \tag{37}$$

4.87.5.4 Stress Calculations for the TRBSC Element.

The stress calculations involve two phases. The first phase is used to calculate the matrix relations between element forces and grid point displacements.

1. The relation between element forces and generalized coordinates is:

$$[k_s] = \begin{bmatrix} 2D_{11} & 2D_{13} & 2D_{12} & 6\bar{x}D_{11} & 2\bar{x}D_{12}+4\bar{y}D_{13} & 6\bar{y}D_{12} \\ 2D_{12} & 2D_{23} & 2D_{22} & 6\bar{x}D_{12} & 2\bar{x}D_{22}+4\bar{y}D_{23} & 6\bar{y}D_{22} \\ 2D_{13} & 2D_{33} & 2D_{23} & 6\bar{x}D_{13} & 2\bar{x}D_{23}+4\bar{y}D_{33} & 6\bar{y}D_{23} \\ 0 & 0 & 0 & -6D_{11} & -2D_{12}+4D_{33} & -6D_{23} \\ 0 & 0 & 0 & -6D_{13} & -6D_{23} & -6D_{22} \end{bmatrix} , \tag{38}$$

where

$$\begin{Bmatrix} M_x \\ M_y \\ M_{xy} \\ V_x \\ V_y \end{Bmatrix} = [K_s] \{q\} \quad . \tag{39}$$

Note: When the basic triangle routine is used for stress recovery in the TRPLT or QDPLT, the values $\bar{x}$ and $\bar{y}$ in the above matrix are replaced by x_c and y_c or x_q and y_q.

2. The matrix [H] is calculated and inverted. The [B] matrix is calculated ([B] is a 6x3 matrix, the $[B_b]$ matrix (Equation 27) comprising the first three rows and the $[B_c]$ matrix, Equation 28, comprising the last three rows). The [E] matrix and the global-to-basic transformation $[T_a]$, $[T_b]$, $[T_c]$ are generated. $[H]^{-1}$ is partitioned.

$$[H]^{-1} = [H_{1b} \mid H_{1c}]. \tag{40}$$

The element force - global displacement matrices are:

$$[S_a] = -[k_s][H]^{-1}[B][E]^T \left[\begin{array}{c|c} T_a & 0 \\ \hline 0 & T_a \end{array}\right], \tag{41}$$

$$[S_b] = [k_s][H_{1b}][E]^T \left[\begin{array}{c|c} T_b & 0 \\ \hline 0 & T_b \end{array}\right], \tag{42}$$

$$[S_c] = [k_s][H_{1c}][E]^T \left[\begin{array}{c|c} T_c & 0 \\ \hline 0 & T_c \end{array}\right]. \tag{43}$$

$$\{S_t\} = [D]\{\alpha\} \tag{43a}$$

where α is the vector of thermal expansion coefficients for the bending material.

3. The second stage of stress calculations involves the use of the displacement vectors $\{u_a\}$, $\{u_b\}$ and $\{u_c\}$. The element forces are:

$$\left\{\begin{array}{c} M_x \\ M_y \\ M_{xy} \\ V_x \\ V_y \end{array}\right\} = \sum_{i=a,b,c} [S_i]\{u_i\} - \{M_e\}, \tag{44}$$

where $\{M_e\}$ is the vector of thermal moments given on a TEMPP2 data field or if the gradient is given:

$$\{M_e\} = -T'\{S_t\} \quad .$$

With no thermal loads the stresses are:

$$\begin{Bmatrix} \sigma_{xi} \\ \sigma_{yi} \\ \sigma_{xyi} \end{Bmatrix} = -\frac{Z_i}{I} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} , \qquad i = 1, 2 \qquad (45)$$

With direct thermal bending moments, $\{M_e\}$, given, the stresses are:

$$\begin{Bmatrix} \sigma_{xi} \\ \sigma_{yi} \\ \sigma_{xyi} \end{Bmatrix} = -\frac{Z_i}{I} \left[\begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} + \{M_e\} \right] - \frac{1}{I}(T_i - \bar{T})\{S_t\} , \qquad (45a)$$

$$i = 1, 2$$

With thermal gradient data, T', the stresses are:

$$\begin{Bmatrix} \sigma_{xi} \\ \sigma_{yi} \end{Bmatrix} t = -\frac{Z_i}{I} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} - \frac{1}{I}(T_i - Z_i T' - \bar{T})\{S_t\} , \qquad (45b)$$

$$i = 1, 2$$

T_i is the given temperature at point i and $\bar{T}$ is the average temperature of the element. If no T_i values are given, Equation (45) is used.

The principal stresses and their orientation are calculated in the same manner as those for the TRMEM element, Section 4.87.4.6.

Thermal loads are generated for this element in the SSG1 module. See Section 4.87.5.12 for the equations.

4.87.5.6 Stiffness Matrix Calculations for the TRPLT Element (Subroutine KTRPLT of Module SMA1).

The NASTRAN bending triangle (triangular plate element, TRPLT) is fabricated from three basic bending triangles. The geometry and notation are shown in Figure 5. The general approach is to calculate the stiffness matrices for all three subtriangles or basic triangles and use the constraint equation of equal slope at the midpoints of the connected edges to calculate a reduced stiffness matrix. Since only the partitions of the stiffness matrix related to one point (the pivot grid point) are used for each calculation, the extra partitions are not used. In the NASTRAN system, the basic bending triangle calculations are in subroutine form, and the variables necessary to call it are: x_b, x_c, y_c, the property and material coefficients, and the transformations for orienting the anisotropic materials. The following steps are used to calculate the overall stiffness matrix for the composite triangle.

1. The element coordinate system is defined by the location of the three grid points in basic coordinates, {x(1)}, {x(2)} and {x(3)}:

$$\{V_2\} = \{x(2)\} - \{x(1)\} , \tag{46}$$

$$\{V_3\} = \{x(3)\} - \{x(1)\} , \tag{47}$$

$$X_2 = |\{V_2\}| , \tag{48}$$

$$\{i\} = \frac{\{V_2\}}{X_2} , \tag{49}$$

$$Y_3 = |\{i\} \times \{V_3\}| , \tag{50}$$

$$\{k\} = \frac{\{i\} \times \{V_3\}}{Y_3} , \tag{51}$$

$$\{j\} = \{k\} \times \{i\} , \tag{52}$$

$$[E] = \left[\begin{array}{c|c|c} \{k\} & 0 & 0 \\ \hline 0 & \{i\} & \{j\} \end{array}\right] \cdot \quad (6 \times 3) \tag{53}$$

The locations of the points in this coordinate system are:

$$\{R(1)\} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} , \tag{54}$$

$$\{R(2)\} = \begin{Bmatrix} X_2 \\ 0 \end{Bmatrix} , \tag{55}$$

$$X_3 = \{V_3\}^T \{i\}, \tag{56}$$

$$\{R(3)\} = \begin{Bmatrix} X_3 \\ Y_3 \end{Bmatrix} , \tag{57}$$

$$\{R(4)\} = \frac{1}{3} \begin{Bmatrix} X_2 + X_3 \\ Y_3 \end{Bmatrix} . \tag{58}$$

2. For use in transferring points to the subtriangles, the integer matrix [M] is formed:

$$[M] = \begin{array}{c} \begin{array}{ccc} \text{Point a} & \text{Point b} & \text{Point c} \end{array} \\ \left[\begin{array}{ccc} 1 & 2 & 4 \\ 2 & 3 & 4 \\ 3 & 1 & 4 \end{array}\right] \end{array} \quad \begin{array}{c} \text{Subtriangle } \beta \\ \text{I} \\ \text{II} \\ \text{III} \end{array} \tag{59}$$

The Roman numerals I, II and III indicate the subtriangle numbers. Points 1, 2 and 3 are the corners of the whole triangle whose centroid is denoted by 4. Points a, b, and c are the corners of the subtriangles. Point c in the subtriangles is always the center point, 4. (see Figure 5).

Note: Steps 3 through 7 are performed for each subtriangle.

3. The location of the three points for each subtriangle, β, is defined by the vectors $\{r_i(a)\}$, $\{r_i(b)\}$, $\{r_i(c)\}$. In terms of the original vectors these are:

$$\left.\begin{aligned} r_i(a) &= R_i(M(\beta,1)) \\ r_i(b) &= R_i(M(\beta,2)) \\ r_i(c) &= R_i(4) \end{aligned}\right\} \qquad i = 1, 2 , \tag{60, 61, 62}$$

where $M(\beta, i)$ is the (β, i) element of the [M] matrix.

4. The variables necessary to calculate a basic bending triangle are x_b, x_c and y_c since the local coordinate system for each subtriangle is chosen such that the "a" point lies on the origin and the "b" point lies on the x axis.

For each triangle the following are calculated:

$$\ell = \sqrt{[r_1(b) - r_1(a)]^2 + [r_2(b) - r_2(a)]^2} \quad \text{(length of base)}, \tag{63}$$

$$w_1 = \frac{1}{\ell} (r_1(b) - r_1(a)), \tag{64}$$

$$w_2 = \frac{1}{\ell} (r_2(b) - r_2(a)) . \tag{65}$$

5. The matrix [T] used for transforming the element coordinates to subtriangle coordinates is formed:

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & w_1 & w_2 \\ 0 & -w_2 & w_1 \end{bmatrix}. \tag{66}$$

The material orientation angle, θ_m, is calculated for each subtriangle. The equations are:

$$\sin(\theta_m) = w_1 \sin(\theta) - w_2 \cos(\theta), \tag{67}$$

$$\cos(\theta_m) = w_1 \cos(\theta) + w_2 \sin(\theta). \tag{68}$$

The displacements in the subtriangle system are equal to [T] times the displacements in the original system (note det [T] is unit length, $x_b = R_1(2)$, $x_c = R_1(4)$ and $y_c = R_2(4)$ for subtriangle I).

6. The parameters x_b, x_c and y_c are then computed:

$$x_b = w_1[r_1(b) - r_1(a)] + w_2[r_2(b) - r_2(a)] , \tag{69}$$

$$x_c = w_1[r_1(c) - r_1(a)] + w_2[r_2(c) - r_2(a)] , \tag{70}$$

$$y_c = -w_2[r_1(c) - r_1(a)] + w_1[r_2(c) - r_2(a)]. \tag{71}$$

7. The stiffness matrices are formed as in the basic bending triangle (Equations 30 through 35) and give:

$$[k_{ia}], [k_{ib}], [k_{ic}], [k_{ca}] [k_{cb}], [k_{cc}] \quad i = \text{pivot grid point.}$$

They relate forces and displacements in the subtriangle coordinate system and are transformed to the overall element coordinate system (i.e., the same system as subtriangle I).

Since the stiffness matrices for each pivot grid point are calculated separately, not all of these partitions are used. For each pivot grid point, i, the following partitions are used:

$$[K_{i1}], [K_{i2}], [K_{i3}] ,$$

and

$$[K_{14}], [K_{24}], [K_{34}], [K_{44}] .$$

The integer mapping matrix [M] is used to determine if and where to add the partitions. The steps used for pivot point i and triangle β are:

a) $[T]^T [k_{ac}] [T]$ is added to $[K_{m,4}]$, $m = M(\beta,1)$

$[T]^T [k_{bc}] [T]$ is added to $[K_{m,4}]$, $m = M(\beta,2)$

$[T]^T [k_{cc}] [T]$ is added to $[K_{4,4}]$

b) If $M(\beta,1) = i$:

$[T]^T [k_{aa}] [T]$ is added to $[K_{ii}]$

$[T]^T [k_{ab}] [T]$ is added to $[K_{i\ell}]$, $\ell = M(\beta,2)$

or if $M(\beta,2) = i$

$[T]^T [k_{bb}] [T]$ is added to $[K_{ii}]$

$[T]^T [k_{ab}]^T [T]$ is added to $[K_{i\ell}]$, $\ell = M(\beta,1)$

c) The above is repeated for each of the three subtriangles.

8. The number 4 point in the middle is a dummy point, and since the displacements at point 4 are functions of the other displacements, it will be removed from the problem by including the calculations for the point 4 displacements in the calculations for the corner displacements, as shown in steps 8a, 8b, 8c and 8d.

a. Calculate the following geometric constants:

$$\ell_1 = \left(x_c^2 + y_c^2 \right)^{1/2} , \tag{72}$$

$$\ell_2 = \left[(x_b - x_c)^2 + y_c^2 \right]^{1/2} , \tag{73}$$

$$s_1 = \frac{x_c}{\ell_1} , \tag{74}$$

$$s_2 = \frac{x_b - x_c}{\ell_2} , \tag{75}$$

$$c_1 = \frac{y_c}{\ell_1} , \tag{76}$$

$$c_2 = \frac{y_c}{\ell_2} \quad . \tag{77}$$

b. The formulas for the locations of the midpoints are:

$$x_1 = \frac{1}{2} x_c \quad , \tag{78}$$

$$y_1 = \frac{1}{2} y_c \quad , \tag{79}$$

$$x_2 = \frac{x_b + x_c}{2} \quad , \tag{80}$$

$$y_2 = \frac{1}{2} y_c \quad . \tag{81}$$

c. The $[H_\psi]$ matrix is calculated as follows:

$$[H_\psi] = \begin{bmatrix} -2x_1 c_1 & (x_1 s_1 - y_1 c_1) & 2y_1 s_1 & -3x_1^2 c_1 & y_1(2x_1 s_1 - y_1 c_1) & 3y_1^2 s_1 \\ 2x_2 c_2 & (x_2 s_2 + y_2 c_2) & 2y_2 s_2 & 3x_2^2 c_2 & y_2(2x_2 s_2 + y_2 c_2) & 3y_2^2 s_2 \end{bmatrix} \tag{82}$$

The slopes in terms of the deflections of points a, b and c are defined by the matrices:

$$[\bar{H}_{\psi b} \mid \bar{H}_{\psi c}] = [H_\psi][H]^{-1} \tag{83}$$

$$[\bar{H}_{\psi a}] = - [H_\psi][H]^{-1} [B] + \begin{bmatrix} 0 & s_1 & c_1 \\ 0 & s_2 & c_2 \end{bmatrix} \tag{84}$$

where $[H]^{-1}$ and $[B]$ are calculated while generating the stiffness matrices. $[H]^{-1}$ is the inverse of the 6x6 matrix in Equation 25, and $[B] = \begin{bmatrix} B_b \\ \hline B_c \end{bmatrix}$ is a 6x3 matrix where $[B_b]$ and $[B_c]$ are calculated in Equations 27 and 28 respectively.

These are transformed to element coordinates by:

$$[H_{\psi\alpha}] = [\bar{H}_{\psi\alpha}] [T] \quad . \tag{85}$$

d. Each row of the matrix corresponds to the slope angle of the mid-point of the sides.

The first row defines the slope of the normal to the line connecting point "a" to the center point. The second row defines the slope of the normal to the line connecting point "b" to the center point. Using the $[H_{\psi\alpha}]$ matrices, four 3 by 3 matrices, $[G_M]$, are formed as follows:

The [M] matrix is now used:

$$[M] = \begin{array}{c} \overbrace{}^{\alpha} \\ \begin{array}{ccc} a & b & c \end{array} \\ \left[\begin{array}{ccc} 1 & 2 & 4 \\ 2 & 3 & 4 \\ 3 & 1 & 4 \end{array}\right] \end{array} \begin{array}{c} \\ \\ \begin{array}{c} I \\ II \\ III \end{array} \end{array} = \beta \ , \qquad (86)$$

For the $[H_{\psi\alpha}]^{\beta}$ matrix, (α = a, b and c; β = I, II or III), the number $M(\beta,\alpha)$ which identifies the matrix $[G_M]$ is found. The three terms in the first row of $[H_{\psi\alpha}]^{\beta}$ are added to the $M(\beta,1)$ row of the $[G_M]$ matrix. The three numbers in the second row of $[H_{\psi\alpha}]^{\beta}$ are added to the $M(\beta,2)$ row of the $[G_M]$ matrix. This procedure is repeated for the three $[H_{\psi\alpha}]^{\beta}$ matrices for each triangle β.

The stiffness matrix partitions of the whole plate are computed from:

$$[K^e_{ij}] = [K_{ij}] - ([G_4]^{-1}[G_i])^T[K_{j4}]^T - [K_{i4}][G_4]^{-1}[G_j]$$
$$+ ([G_4]^{-1}[G_i])^T[K_{44}][G_4]^{-1}[G_j] \qquad \begin{array}{l} \text{for } i = 1, 2, 3 \\ \quad\ j = 1, 2, 3 \end{array} . \qquad (87)$$

where $[K_{ij}]$ are computed as in step 7.

9. Using the locations of the three grid points in basic coordinates, the 3x3 transformation matrices $[T_j]$, j = 1, 2, 3, are calculated. The 6x6 matrices $[C_j]$ are formed as:

$$[C_j] = \left[\begin{array}{c|c} [T_j] & 0 \\ \hline 0 & [T_j] \end{array}\right] \qquad j = 1, 2, 3 \ . \qquad (88)$$

10. The stiffness matrix partitions in global coordinates for pivot point i are computed from:

$$[K^g_{ij}] = [C_i]^T[E][K^e_{ij}][E]^T[C_j] \quad (6x6) , \tag{89}$$

where:

$[K^e_{ij}]$ was calculated in step 8

[E] was calculated in step 1

$[C_i]$, $[C_j]$ were calculated in step 9

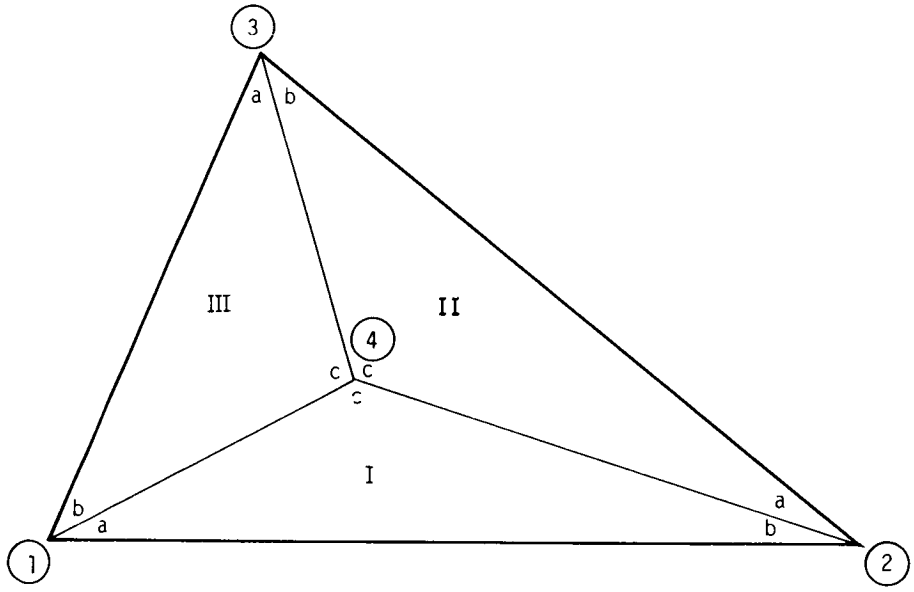


Figure 5. The triangular plate element, TRPLT.

1, 2, 3	=	GIVEN GRID POINTS
4	=	CENTROID OF TRIANGLE
I, II, III	=	BASIC SUBTRIANGLES
a, b, c	=	ORDERED VERTICES OF SUBTRIANGLES

4.87.5.6 Structural Damping Matrices for the TRPLT Element.

The structural damping matrices are:

$$[K^4_{ij}] = g_e[K^g_{ij}], \tag{90}$$

where g_e is the structural damping coefficient for the bending material referenced.

4.87.5.7 Stress and Element Force Calculations for the TRPLT Element (Subroutines STRPL1 and SBSPL2 of Module SDR2).

For stress recovery, the relationship between the center point and the corner points is used to describe the stress functions for each subtriangle. The stresses in each subtriangle at the center point are averaged to provide the final element stress and forces.

1. STRPL1 is used to calculate the phase 1 stress-displacement relations.

The following data are calculated using the same equations as those for the stiffness matrix generation routines.

$[C_i]$ - i = 1, 2, 3 - Global-to-basic transformations

[E] - element to basic coordinate transformation

Values computed for each subtriangle

- x_b, x_c, y_c - subtriangle point locations
- $\sin\theta$, $\cos\theta$ - material orientation
- w_1, w_2 - element-to-subtriangle coordinate transformation
- $[\bar{H}_{\psi a}]$, $[\bar{H}_{\psi b}]$, $[\bar{H}_{\psi c}]$ - normal slope angle relationship matrices

For each subtriangle, β = I, II, III, the following matrices are formed:

$$[T^{\beta}] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & w_1 & w_2 \\ 0 & -w_2 & w_1 \end{bmatrix}, \tag{91}$$

$$[V^{\beta}] = \begin{bmatrix} w_1^2 & w_2^2 & -2w_1w_2 & 0 & 0 \\ w_2^2 & w_1^2 & 2w_1w_2 & 0 & 0 \\ w_1w_2 & -w_1w_2 & w_1^2-w_2^2 & 0 & 0 \\ 0 & 0 & 0 & w_1 & -w_2 \\ 0 & 0 & 0 & w_2 & w_1 \end{bmatrix} \tag{92}$$

For each subtriangle β, three 5x3 transformations are calculated, $[S_{\alpha}^{\beta}]$, a = a, b, c. These are transformed and added to the corresponding matrices for each point with the equation:

$$[S_M^*] = \frac{1}{3} \sum_{\beta} [V^{\beta}][S_{\alpha}^{\beta}][T^{\beta}] \ , \tag{93}$$

where the α, which denotes points on the subtriangle, corresponds to the grid point M on the overall triangle.

$$[H_{\psi\alpha}] = [\bar{H}_{\psi\alpha}] [T] \quad \alpha = a, b, c \ . \tag{94}$$

The $[H_{\psi\alpha}]$ matrices are added to the corresponding $[G_M]$ matrix with the appropriate row interchanges. When the data for all three subtriangles have been generated, the following operations are performed:

$$[S_M^e] = [S_M^*] - [S_4^*][G_4]^{-1}[G_i] \tag{95}$$

for M = 1, 2, 3;

$$[S_M] = [S_M^e][E]^T[C_i] \tag{96}$$

for M = 1, 2, 3 .

2. Phase 2

a) The vector of forces is computed first.

$$\left\{\begin{matrix} M_x \\ M_y \\ M_{xy} \\ V_x \\ V_z \end{matrix}\right\} = \sum_{i=1}^{3} [S_i] \{u_i\} - \{M_t\} \quad , \tag{97}$$

where $\{M_e\}$ is the thermal moment vector. If a thermal gradient is given:

$$\{M_e\} = - \{S_t\}T' \quad .$$

b) With no given temperatures at the stress points, the stresses are then calculated from the equations

$$\left.\begin{aligned} \sigma_{xi} &= \frac{M_x Z_i}{I} \qquad (98) \\ \sigma_{yi} &= \frac{M_y Z_i}{I} \qquad (99) \\ \sigma_{xyi} &= \frac{M_{xy} Z_i}{I} \qquad (100) \end{aligned}\right\} \quad i = 1, 2 \quad .$$

If temperature values T_i at the stress points are given the following equations are used.

$$\left\{\begin{matrix} \sigma_{xi} \\ \sigma_{yi} \\ \sigma_{xyi} \end{matrix}\right\} = - \frac{Z_i}{I} \left[\left\{\begin{matrix} M_x \\ M_y \\ M_{xy} \end{matrix}\right\} + \{M_e\} \right] - \frac{1}{I} (T_i - \bar{T})\{S_t\} \quad , \; i = 1 \text{ or } 2$$

or

$$\begin{Bmatrix} \sigma_{xi} \\ \sigma_{yi} \\ \sigma_{xyi} \end{Bmatrix} = -\frac{Z_i}{I} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} - \frac{1}{I}(T_i - Z_i T' - \bar{T})\{S_t\} \quad , \qquad i = 1 \text{ or } 2$$

where T' is the gradient or $\{M_e\}$ is the thermal moment vector. $\bar{T}$ is the average temperature for the element. The principal stresses and angles are calculated using the same formula as those for the membrane element (see Section 4.87.4.6, Equations 28, 29 and 30).

Thermal loads are generated for this element in the SSG1 module. See Section 4.87 4.87.5.11 for the algorithm.

4.87.5.8 Stiffness Matrix Calculations for the QDPLT Element (Subroutine KQDPLT of Module SMA1)

The quadrilateral plate element uses two sets of overlapping triangles as shown in Figure 6. The logic is the same as that for the quadrilateral membrane except that the order of the points of the triangles is chosen to place the triangle coordinate systems along the diagonals.

1. The following equations are used to calculate the three unit vectors, {i}, {j} and {k}, which define the element coordinate system.

$$\{V_i\} = \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} , \quad i = 1, 2, 3, 4. \tag{101}$$

The diagonals are:

$$\{d_1\} = \{V_3\} - \{V_1\} , \tag{102}$$

$$\{d_2\} = \{V_4\} - \{V_2\} . \tag{103}$$

The area is calculated from:

$$A = \frac{1}{2} |(\{d_1\} \times \{d_2\})| . \tag{104}$$

The normal to the plane is calculated from:

$$\{k\} = \frac{\{d_1\} \times \{d_2\}}{|\{d_1\} \times \{d_2\}|} , \tag{105}$$

$$\{a_1\} = \{V_2\} - \{V_1\} , \tag{106}$$

$$h = \frac{1}{2} \{a_1\}^T \{k\} , \tag{107}$$

The vectors lying in the new plane are computed from:

$$\{i\} = \frac{\{a_1\} - 2h\{k\}}{|\{a_1\} - h\{k\}|} , \tag{108}$$

$$\{j\} = \{k\} \times \{i\} . \tag{109}$$

The nonzero positions of the points in the plane are computed from:

$$X_2 = \{a_i\}^T \{i\} \quad , \tag{110}$$

$$X_3 = \{d_i\}^T \{i\} \quad , \tag{111}$$

$$Y_3 = \{d_i\}^T \{j\} \quad , \tag{112}$$

$$X_4 = X_2 + (\{d_2\}^T \{i\}) \quad , \tag{113}$$

$$Y_4 = \{d_2\}^T \{j\} \quad , \tag{114}$$

$$\{R(i)\} = \begin{Bmatrix} X_i \\ Y_i \end{Bmatrix} \quad . \tag{115}$$

2. Element interior angle tests.

The interior angles of the quadrilateral must be less than 180°. The following checks accomplish this task.

Test		Point with angle greater than 180°
If	$Y_4 < 0$	1
If	$Y_3 < 0$	2
If	$X_4 > X_2 - (X_2 - X_3) \frac{Y_4}{Y_3}$	3
If	$X_3 < \frac{Y_3}{Y_4} X_4$	4

3. The relative data for each subtriangle must be calculated and passed to the matrix calculation subroutine. The integer mapping matrix [M] denotes which points, 1, 2, 3, and 4 of the quadrilateral, are used in the subtriangle. The row position indicates the subtriangle to which the point belongs, and the column position indicates the corresponding point in that subtriangle.

$$[M] = \begin{array}{c} \begin{array}{ccc} \underline{\text{Point a}} & \underline{\text{Point b}} & \underline{\text{Point c}} \end{array} \\ \begin{bmatrix} 2 & 4 & 1 \\ 3 & 1 & 2 \\ 4 & 2 & 3 \\ 1 & 3 & 4 \end{bmatrix} \end{array} \quad \begin{array}{c} \underline{\text{Triangle No.}} \\ \text{I} \\ \text{II} \\ \text{III} \\ \text{IV} \end{array}$$

4. For each triangle the stiffness matrix is calculated in its own coordinate system. This system has its origin at point a, point b lies on the x axis, and point c has a positive y component. $\{R(i)\}$ values are transferred to $\{r(\alpha)\}$ values (α = a, b, c), and the following calculations are performed:

$$\{v(b)\} = \{r(b)\} - \{r(a)\}, \tag{116}$$

$$\{v(c)\} = \{r(c)\} - \{r(a)\}, \tag{117}$$

$$\begin{Bmatrix} w_1 \\ w_2 \end{Bmatrix} = \frac{\{v(b)\}}{|\{v(b)\}|}, \tag{118}$$

$$x_b = |\{v(b)\}|, \tag{119}$$

$$\begin{Bmatrix} x_c \\ y_c \end{Bmatrix} = \begin{bmatrix} w_1 & w_2 \\ -w_2 & w_1 \end{bmatrix} \{v(c)\}. \tag{120}$$

x_b, x_c and y_c are the point locations needed by the subroutine.

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & w_1 & w_2 \\ 0 & -w_2 & w_1 \end{bmatrix}. \tag{121}$$

w_1 is the x component of the new x axis and w_2 is its y component, [T] transforms the z displacement and the two angles from the quadrilateral system to the triangle system.

In order to calculate the material matrices in the basic triangle routine, the material orientation angle, θ_m, is :

$$\sin\theta_m = w_1 \sin\theta - w_2 \cos\theta \ , \tag{122}$$

$$\cos\theta_m = w_1 \cos\theta + w_2 \sin\theta \ . \tag{123}$$

w_1 and w_2 are the cosine and sine of the angle made between the base of the triangle and the material orientation axis.

5. The output of the basic bending triangle routine are the 3x3 matrices:

$$[k_{aa}],\ [k_{ab}],\ [k_{bb}],\ [k_{ac}],\ [k_{bc}],\ [k_{cc}] \ .$$

To transform these to the quadrilateral system the following equation is used:

$$[K^e_{ij}] = \frac{1}{2}[T]^T[k_{ij}][T] \ . \tag{124}$$

These matrices are added to the current positions in the quadrilateral matrix partitions using the [M] matrix in step 3.

6. For each pivot point i the following 3x3 partitions are formed:

$$[k^e_{ij}],\ \text{for } j = 1, 2, 3, 4 \ .$$

7. Using the geometry data, the 3x3 global-to-basic transformations $[T_j]$ are formed for j = 1, 2, 3, 4. These are expanded to the 6x6 matrices $[C_j]$:

$$[C_j] = \left[\begin{array}{c|c} T_j & 0 \\ \hline 0 & T_j \end{array}\right] . \qquad (125)$$

8. The stiffness matrix partitions in global coordinates are found from:

$$[K^g_{ij}] = [C_i]^T[E][k^e_{ij}][E]^T[C_j] , \qquad (126)$$

where [E] is defined in Equation 53.

4.87.5.9 Stress and Element Force Calculations for QDPLT Element (Subroutines SQDPL1 and SBSPL2 of Module SDR2)

1. SQDPL1 calculates the phase 1 stress-displacement relations. A coordinate system matrix [E], the subtriangle base vectors $\{w_1, w_2\}^T$ and the global-to-basic transformation matrices are calculated with the same equations as those used in the plate element stiffness matrix calculations. For each subtriangle, β, the following matrices are formed:

$$[T^\beta] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & w_1 & w_2 \\ 0 & -w_2 & w_1 \end{bmatrix} , \qquad (127)$$

$$[V^\beta] = \begin{bmatrix} w_1^2 & w_2^2 & -2w_1w_2 & 0 & 0 \\ w_2^2 & w_1^2 & 2w_1w_2 & 0 & 0 \\ w_1w_2 & -w_1w_2 & (w_1^2-w_2^2) & 0 & 0 \\ 0 & 0 & 0 & w_1 & -w_2 \\ 0 & 0 & 0 & w_2 & w_1 \end{bmatrix} . \qquad (128)$$

For each subtriangle the stresses must be calculated at the intersection point of the diagonals. In the quadrilateral system:

$$x_5 = \frac{x_2\, x_3\, y_4}{x_3 y_4 + (x_2 - x_4) y_3} , \tag{129}$$

$$y_5 = \frac{y_3}{x_3}\, x_5 . \tag{130}$$

For each subtriangle:

$$\{V_5\} = \{r(a)\} - \begin{Bmatrix} x_5 \\ \\ y_5 \end{Bmatrix} ; \quad x_q = |\{V_5\}|; \quad y_q = 0; \tag{131}$$

where x_q and y_q denote the location of the intersection of the diagonals of the quadrilateral in the subtriangle coordinate system. The stresses are calculated at this point.

$[T^\beta]$ transforms the translation and two rotations in the element system to the subtriangle system. $[V^\beta]$ transforms the three moments and two shears of the subtriangle to the element system. For each subtriangle β, three 5x3 transformations are calculated, $[S^\beta_\alpha]$, α = a, b, c. These are transformed and added to the corresponding matrices for each point with the equation:

$$[S^e_M], = \frac{1}{4} \sum_\beta [V^\beta][S^\beta_\alpha][T^\beta] , \tag{132}$$

where the α, which denotes points on the subtriangle, corresponds to the grid point M on the quadrilateral.

2. Using the basic-to-element and global-to-basic transformations, the stress matrices $[S_M]$ in global coordinates are formed from:

$$[S_M] = [S^e_M][E]^T \begin{bmatrix} [T_i] & 0 \\ 0 & [T_i] \end{bmatrix} . \tag{133}$$

The thermal load vector is:

$$\{S_t\} = [D]\{\alpha\}$$

3. The additional data for phase 2 calculations are

$$I, Z_1, Z_2 \text{ from the ECPT data.}$$

4. Phase 2 (Subroutine SBSPL2)

   The 5 by 6 $[S_M]$ matrices are used in the same manner as the TRPLT elements (see Equations 97 through 100).

4.87.5.10 Lumped Mass Matrix Generation for the TRBSC, TRPLT, and QDPLT Elements (Subroutine MASSTQ of Module SMA2).

The lumped mass matrices are calculated in the same manner as the triangular or quadrilateral membrane except that the material density is not used (see Equations 86 through 96 in section 4.87.4.10). The only contribution to the mass matrix from these elements is the nonstructural mass, μ.

4.87.5.11 Coupled Mass Matrix Calculations for the TRBSC Element (Subroutine MTRBSC of Module SMA2).

The mass properties of the two-dimensional elements are defined by their geometry, the mass density given by the material, the thickness of the element and the nonstructural mass. The normal execution of NASTRAN will result in the calculation of the total mass of the element and distribute it as lumped masses at the connected grid points (subroutine MASSTQ of module SMA2). If the parameter CØUPBAR is set by the user, the elements with bending properties will have their mass distributed according to their elastic properties. This results in element mass matrices with directional properties and coupling terms between points in an element. Since the thickness of the TRBSC element is zero, a coupled mass matrix for this element does not exist. The MTRBSC subroutine is used exclusively by subroutines MTRPLT and MQDPLT.

1. The mass matrix $[\tilde{M}]$ in generalized coordinates is calculated in the following steps.

   a. Integral values I_{ij} used in the mass matrices are calculated from the formulas:

$$A_{0j} = \left[\frac{x_b}{j+1} - \frac{x_b - x_c}{j+2}\right] y_c^{j+1} \quad , \qquad j = 0,1,\ldots 6 \tag{134}$$

$$A_{ij} = \frac{(x_c)^{i+1}\,(y_c)^{j+1}}{(i+1)\,(i+j+2)} + \frac{i x_b}{(i+j+2)} A_{i-1,j} \quad , \qquad \begin{matrix} i = 1,2,\ldots 6 \\ j = 0,1,\ldots 6 \end{matrix} \tag{135}$$

$$B_{ij} = -\frac{(x_c)^{i+1}}{(y_c)^{i+1}\,(i+1)(i+j+2)} (y_c)^{i+j+2} \quad , \qquad \begin{matrix} i = 0,1,\ldots 6 \\ j = 0,1,\ldots 6 \end{matrix} \tag{136}$$

$$I_{ij} = m[A_{ij} + B_{ij}] \quad , \qquad \begin{matrix} i = 0,1,\ldots 6 \\ j = 0,1,\ldots 6 \end{matrix} \tag{137}$$

where m is the nonstructural mass, and where x_b, x_c and y_c are computed in Equations 7, 8, and 9 respectively.

b. Partition $[\tilde{M}]$ into submatrices.

$$[\tilde{M}] \Longrightarrow \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ar} \\ \hline M_{ar}^{T} & M_{rr} \end{array}\right] , \tag{138}$$

where $[\bar{M}_{aa}]$ is a 3 by 3 matrix, $[M_{ar}]$ is a 3 by 6 matrix and $[M_{rr}]$ is a 6 by 6 matrix.

c. The mass matrix $[\bar{M}_{aa}]$ is given by:

$$[\bar{M}_{aa}] = \begin{bmatrix} I_{00} & I_{01} & -I_{10} \\ I_{01} & I_{02} & -I_{11} \\ -I_{10} & -I_{11} & I_{20} \end{bmatrix} . \tag{139}$$

d. The other matrices, $[M_{ar}]$ and $[M_{rr}]$, are less simple. The algebraic expressions for the elements of these matrices are given in Tables 1a and 1b below.

Table 1a. Elements of the 3 by 6 Matrix $[M_{ar}]$.

Notes: $H_{\gamma q_{ij}}$ is contracted to H_{ij}, where $[H_{\gamma q}]$ is computed in Equation 22.

$M_{ar_{ij}}$ is contracted to M_{ik}, where M_{ik} represents an element of $[\tilde{M}]$ given in Equation 138.

$M_{14} = I_{20}$

$M_{15} = I_{11}$

$M_{16} = I_{02}$

$M_{17} = I_{30} + H_{14}I_{10} + H_{24}I_{01}$

Table 1a (con'd). Elements of the 3 by 6 Matrix $[M_{ar}]$.

$$M_{18} = I_{12} + H_{15}I_{10} + H_{25}I_{01}$$

$$M_{19} = I_{03} + H_{16}I_{10} + H_{26}I_{01}$$

$$M_{24} = I_{21}$$

$$M_{25} = I_{12}$$

$$M_{26} = I_{03}$$

$$M_{27} = I_{31} + H_{14}I_{11} + H_{24}I_{02}$$

$$M_{28} = I_{13} + H_{15}I_{11} + H_{24}I_{02}$$

$$M_{29} = I_{04} + H_{16}I_{11} + H_{26}I_{02}$$

$$M_{34} = -I_{30}$$

$$M_{35} = -I_{21}$$

$$M_{36} = -I_{12}$$

$$M_{37} = -I_{40} - H_{14}I_{20} - H_{24}I_{11}$$

$$M_{38} = -I_{22} - H_{15}I_{20} - H_{25}I_{11}$$

$$M_{39} = -I_{13} - H_{16}I_{20} - H_{26}I_{11}$$

Table 1b. Elements of the 6 by 6 Matrix $[M_{rr}]$.

Notes: $H_{\gamma q_{ij}}$ is contracted to H_{ij}; $M_{rr_{ij}}$ is contracted to M_{ik}, where M_{ik} represents an element of $[\tilde{M}]$ given in Equation 138; $M_{ij} = M_{ji}$.

$$M_{44} = I_{40}$$

$$M_{45} = I_{31}$$

$$M_{46} = I_{22}$$

$$M_{47} = I_{50} + H_{14}I_{30} + H_{24}I_{21}$$

$$M_{48} = I_{32} + H_{15}I_{30} + H_{25}I_{21}$$

$$M_{49} = I_{23} + H_{16}I_{30} + H_{26}I_{21}$$

$$M_{55} = I_{22}$$

$$M_{56} = I_{13}$$

$$M_{57} = I_{41} + H_{14}I_{21} + H_{24}I_{12}$$

$$M_{58} = I_{23} + H_{15}I_{21} + H_{25}I_{12}$$

$$M_{59} = I_{14} + H_{16}I_{21} + H_{26}I_{12}$$

$$M_{66} = I_{04}$$

$$M_{67} = I_{32} + H_{14}I_{12} + H_{24}I_{03}$$

$$M_{68} = I_{14} + H_{15}I_{12} + H_{25}I_{03}$$

$$M_{69} = I_{05} + H_{16}I_{12} + H_{26}I_{03}$$

$$M_{77} = I_{60} + 2H_{14}I_{40} + 2H_{24}I_{31} + (H_{14})^2I_{20} + 2H_{14}H_{24}I_{11} + (H_{24})^2I_{02}$$

Table 1b (con'd). Elements of the 6 by 6 Matrix $[M_{rr}]$.

$$M_{78} = I_{42} + H_{15}I_{40} + H_{25}I_{31} + H_{14}I_{22} + H_{14}H_{15}I_{20} + H_{14}H_{25}I_{11} + H_{24}I_{13} + H_{24}H_{15}I_{11} + H_{24}H_{25}I_{02}$$

$$M_{79} = I_{33} + H_{16}I_{40} + H_{26}I_{31} + H_{14}I_{13} + H_{14}H_{16}I_{20} + H_{14}H_{26}I_{11} + H_{24}I_{04} + H_{24}H_{16}I_{11} + H_{24}H_{26}I_{02}$$

$$M_{88} = I_{24} + 2H_{15}I_{22} + 2H_{25}I_{13} + (H_{15})^2I_{20} + 2H_{15}H_{25}I_{11} + (H_{25})^2I_{02}$$

$$M_{89} = I_{15} + H_{16}I_{22} + H_{26}I_{13} + H_{15}I_{13} + H_{15}H_{16}I_{20} + H_{15}H_{26}I_{11} + H_{25}I_{04} + H_{25}H_{16}I_{11} + H_{25}H_{26}I_{02}$$

$$M_{99} = I_{06} + 2H_{16}I_{13} + 2H_{26}I_{04} + (H_{16})^2I_{20} + 2H_{16}H_{26}I_{11} + (H_{26})^2I_{02}$$

2. The mass matrix $[M_{mass}]$ in element coordinates is calculated from the following equation:

$$[M_{mass}] = \left[\begin{array}{c|c} I & 0 \\ \hline -H^{-1}B & H^{-1} \end{array}\right]^T \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ar} \\ \hline M_{ar}^T & M_{rr} \end{array}\right] \left[\begin{array}{c|c} I & 0 \\ \hline -H^{-1}B & H^{-1} \end{array}\right] , \quad (140)$$

where $[I]$ is a 3 x 3 identity matrix, $[H]^{-1}$ is calculated as in Equation 25, $[B] = \left[\begin{array}{c} B_b \\ \hline B_c \end{array}\right]$ is calculated as in Equations 27 and 28.

The calculations are broken down into the following steps where:

$$[M_{mass}] = \left[\begin{array}{c|c|c} M_{aa} & M_{ab} & M_{ac} \\ \hline M_{ba} & M_{bb} & M_{bc} \\ \hline M_{ca} & M_{cb} & M_{cc} \end{array}\right] , \quad (141)$$

and $[M_{ij}]$, i = a, b, c and j = a, b, c are 3 by 3 matrices.

a) Compute:

$$[M] = [H^{-1}]^T [M_{rr}] [H^{-1}] . \quad (142)$$

b) Partition:

$$[M] \Longrightarrow \left[\begin{array}{c|c} M_{bb} & M_{bc} \\ \hline M_{cb} & M_{cc} \end{array}\right] . \quad (143)$$

c) Compute:

$$[M_{ai}] = [M_{ar}] [H^{-1}] . \quad (144)$$

d) Partition:

$$[M_{ai}] \Longrightarrow [\bar{M}_{ab} \mid \bar{M}_{ac}] . \quad (145)$$

e) Calculate:

$$[M_{ab}] = [\bar{M}_{ab}] - [B_b]^T[M_{bb}] - [B_c]^T[M_{cb}] \quad , \tag{146}$$

$$[M_{ac}] = [\bar{M}_{ac}] - [B_b]^T[M_{bc}] - [B_c]^T[M_{cc}] \quad , \tag{147}$$

$$[M_{aa}] = [\bar{M}_{aa}] - [B_b]^T[M_{ab}]^T - [B_c]^T[M_{ac}]^T - [\bar{M}_{ab}][B_b] - [\bar{M}_{ac}][B_c] \quad , \tag{148}$$

$$[M_{ba}] = [M_{ab}]^T \quad , \tag{149}$$

$$[M_{ca}] = [M_{ac}]^T \quad . \tag{150}$$

4.87.5.12 Mass Matrix Calculations for the TRPLT Element (Subroutine MTRPLT of Module SMA2)

1. The general calculations for the mass matrix of the triangular plate element, TRPLT, are the same as those for the stiffness matrix calculations (See Equations 46 through 71).

2. For each subtriangle the output from the basic bending triangle subroutine are the nine 3 x 3 matrices given in Equation 141:

$$\begin{bmatrix} M_{aa} & M_{ab} & M_{ac} \\ M_{ba} & M_{bb} & M_{bc} \\ M_{ca} & M_{cb} & M_{cc} \end{bmatrix} .$$

They relate forces and accelerations in the subtriangle coordinate system and must be transformed to the overall element coordinate system (i.e., the same system as subtriangle I).

The matrix partitions in the subtriangles are added to the correct matrix partition for the whole triangle. For example, for subtriangle number II, $[M_{aa}]$ is transformed and added to $[\bar{M}_{22}]$, $[M_{ab}]$ is transformed and added to $[\bar{M}_{23}]$, $[M_{ac}]$ is transformed and added to $[\bar{M}_{24}]$, $[M_{ba}]$ is transformed and added to $[\bar{M}_{32}]$, etc.

Since the mass matrices for each pivot grid point are calculated separately, not all of these partitions are used. For each pivot grid point, i, the matrices which are used will be:

$$[\bar{M}_{i1}], [\bar{M}_{i2}], [\bar{M}_{i3}] \quad , \quad i = \text{point 1, 2 or 3 of composite triangle}$$

and

$$[\bar{M}_{14}], [\bar{M}_{24}], [\bar{M}_{34}], [\bar{M}_{44}] \quad .$$

3. The number 4 point in the middle is a dummy point and is removed from the problem in the same manner as in the computation of the stiffness matrix (see Equations 72 through 86).

The mass matrix partitions of the whole plate are:

$$[M^e_{ij}] = [\bar{M}_{ij}] - ([G_4]^{-1}[G_i])^T[\bar{M}_{j4}]^T - [\bar{M}_{i4}][G_4]^{-1}[G_j] \qquad (151)$$

$$+ ([G_4]^{-1}[G_i])^T [\bar{M}_{44}] [G_4]^{-1} [G_j] \qquad \begin{matrix} i = 1, 2, 3 \\ j = 1, 2, 3 \end{matrix} \quad .$$

Notice that if i and j were interchanged the matrix would be transposed; this indicates that the whole mass matrix is symmetric.

4. Using the locations of the three grid points in basic coordinates, calculate the 3 x 3 transformation matrices $[T_j]$, j = 1, 2, 3. Form the 6 x 6 matrices:

$$[C_j] = \left[\begin{array}{c|c} T_j & 0 \\ \hline 0 & T_j \end{array}\right] \quad . \qquad (152)$$

5. The 3 x 3 mass matrix partitions are expanded to 6x6 size and transformed to global coordinates using the logic:

$$M_3 = \frac{m}{6} X_2 Y_3 \quad , \qquad (153)$$

where m is the nonstructural mass, and X_2, Y_3 are the x-coordinate and y-coordinate of points 2 and 3 respectively.

$$[\bar{M}^e_{ij}] = \begin{bmatrix} M_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & M_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} & 0 \\ 0 & 0 & M_{21} & M_{22} & M_{23} & 0 \\ 0 & 0 & M_{31} & M_{32} & M_{33} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} , \quad (154)$$

for i = j = 1, 2 or 3; and

$$[\bar{M}^e_{ij}] = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} & 0 \\ 0 & 0 & M_{21} & M_{22} & M_{23} & 0 \\ 0 & 0 & M_{31} & M_{32} & M_{33} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} , \quad (155)$$

for $i \neq j$.

The mass matrix partitions in global coordinates are:

$$[M^g_{ij}] = [C_i]^T[E][\bar{M}^e_{ij}][E]^T[C_j] , \quad (156)$$

where

$$[C_i] = \left[\begin{array}{c|c} T_i & 0 \\ \hline 0 & T_i \end{array}\right] \quad (157)$$

is the global-to-basic transformation matrix,

and

$$[E] = \left[\begin{array}{c|c|c|c|c|c} \{i\} & \{j\} & \{k\} & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & \{i\} & \{j\} & \{k\} \end{array}\right] \qquad (158)$$

is the 6 x 6 element-to-basic transformation matrix.

4.87.5.13 Mass Matrix Calculations for the QDPLT Element (Subroutine MQDPLT of Module SMA2).

1. The general calculations for the mass matrix of the quadrilateral plate element, QDPLT, are the same as those for the stiffness matrix calculations (see Equations 101 through 123).

2. For each subtriangle, the output from the basic bending triangle subroutine are the nine 3 x 3 matrices:

$$\left[\begin{array}{c|c|c} M_{aa} & M_{ab} & M_{ac} \\ \hline M_{ba} & M_{bb} & M_{bc} \\ \hline M_{ca} & M_{cb} & M_{cc} \end{array}\right] .$$

These are transformed to the quadrilateral system by the following equation:

$$[\bar{M}_{ij}] = \frac{1}{2} [T]^T [M_{ij}] [T] \quad , \qquad (159)$$

where [T] is given in Equation 121.

These matrices are added to their corresponding positions in the quadrilateral matrix partitions $[M^e_{ij}]$, in the same manner as that for the stiffness matrix partitions of the quadrilateral (See step 3 of Section 4.87.5.8).

3. For each pivot point i, the following 3 x 3 partitions are formed:

$$[M^e_{ij}], \text{ for } j = 1, 2, 3, 4 \quad .$$

4. The mass at each point in the plane of the element is due to the mass of the attached triangles. The masses of the triangles are:

$$m^{\beta} = \frac{m}{4} x_b^{\beta} y_c^{\beta} \quad , \qquad \beta = \text{I, II, III and IV} \quad , \tag{160}$$

where m is the nonstructural mass, and x_b^{β} and y_c^{β} are the x-coordinate and y-coordinate of points b and c respectively of subtriangle β.

The masses at the points are:

$$m_1 = \frac{1}{3} [m^{I} + m^{II} + m^{IV}] \quad , \tag{161}$$

$$m_2 = \frac{1}{3} [m^{I} + m^{II} + m^{III}] \quad , \tag{162}$$

$$m_3 = \frac{1}{3} [m^{II} + m^{III} + m^{IV}] \quad , \tag{163}$$

$$m_4 = \frac{1}{3} [m^{I} + m^{III} + m^{IV}] \quad . \tag{164}$$

5. The 3 x 3 mass matrix partitions are expanded to 6 x 6 matrices and the in-plane mass effects are added using the logic:

$$m_z^i = \frac{m_i h}{2} \quad , \tag{165}$$

$$I_z^i = \frac{m_i h^2}{4} \quad , \tag{166}$$

$$[\bar{M}^e_{ij}] = \begin{bmatrix} m_i & 0 & 0 & 0 & -m^i_z & 0 \\ 0 & m_i & 0 & m^i_z & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} & 0 \\ 0 & m^i_z & M_{21} & M_{22} + I^i_z & M_{23} & 0 \\ -m^i_z & 0 & M_{31} & M_{32} & M_{33} + I^i_z & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \quad (167)$$

for i = j = 1 or 3; and

$$[\bar{M}^e_{ij}] = \begin{bmatrix} m_i & 0 & 0 & 0 & m^i_z & 0 \\ 0 & m_i & 0 & -m^i_z & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} & 0 \\ 0 & -m^i_z & M_{21} & M_{22} + I^i_z & M_{23} & 0 \\ m^i_z & 0 & M_{31} & M_{32} & M_{33} + I^i_z & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \quad (168)$$

for i = j = 2 or 4; and

$$[\bar{M}^{e}_{ij}] = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & M_{11} & M_{12} & M_{13} & 0 \\ 0 & 0 & M_{21} & M_{22} & M_{23} & 0 \\ 0 & 0 & M_{31} & M_{32} & M_{33} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} , \tag{169}$$

for $i \neq j$.

6. Using the geometry data, the 3 x 3 global-to-basic transformations $[T_j]$ are formed for $j = 1, 2, 3, 4$. These are expanded to 6 x 6 matrices:

$$[C_j] = \left[\begin{array}{c|c} T_j & 0 \\ \hline 0 & T_j \end{array}\right] . \tag{170}$$

7. The 6 x 6 element-to-basic transformation matrix is:

$$[E] = \left[\begin{array}{c|c|c|c|c|c} \{i\} & \{j\} & \{k\} & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & \{i\} & \{j\} & \{k\} \end{array}\right] . \tag{171}$$

8. The 6 x 6 matrices are transformed to global coordinates using the equation:

$$[M^{g}_{ij}] = [C_i]^T [E] [\bar{M}^{e}_{ij}] [E]^T [C_j] . \tag{172}$$

4.87.5.14 Thermal Load Equations for the Bending Elements (Subroutines TRBSC,TRPLT, and ODPLT of Module SSG1).

1. The phase I SDR2 routines for all bending elements generate for connected points g_1, g_2, g_3, (and g_4) the 5x6 matrices $[S_1]$, $[S_2]$, $[S_3]$ (and $[S_4]$). These matrices are generated in the SSG1 module with a minor change in the basic triangle routine.

2. The matrix $[K_s]$ is described on page 4.87-85. In the SDR2 routine the values x and y depend on which element is actually being used. For SSG1 module, calculate the matrix:

$$[K_s^t] = A[K_s(\bar{x},\bar{y})] \quad , \tag{173}$$

the definition of $[K_s]$ is:

$$[K_s] = \begin{bmatrix} DH_{\chi q} \\ \hline G_2 H_{\gamma q} \end{bmatrix} \quad , \tag{174}$$

where A is the area of the basic triangle and $(\bar{x},\bar{y})$ is the center location of the basic triangle. The lower partition will not be used.

3. For each type of element the vector, $\{\chi\}$, is generated where:

$$\{\chi_e\} = -\begin{Bmatrix} \alpha_1 T' \\ \alpha_2 T' \\ \alpha_{12} T' \\ 0 \\ 0 \end{Bmatrix} \qquad \text{or} \qquad \{\chi_e\} = \begin{Bmatrix} [D]^{-1}\{M_e\} \\ \hline 0 \\ 0 \end{Bmatrix} \quad , \tag{175}$$

where T' is given on a TEMPP1 data card or calculated from a TEMPP3 card, α_1, α_2, α_{12} are the material thermal coefficient vector components, [D] is the 3 by 3 material matrix, and $\{M_e\}$ are the thermal moments given on a TEMPP2 card.

4. The 6x1 thermal load vectors in basic coordinates are:

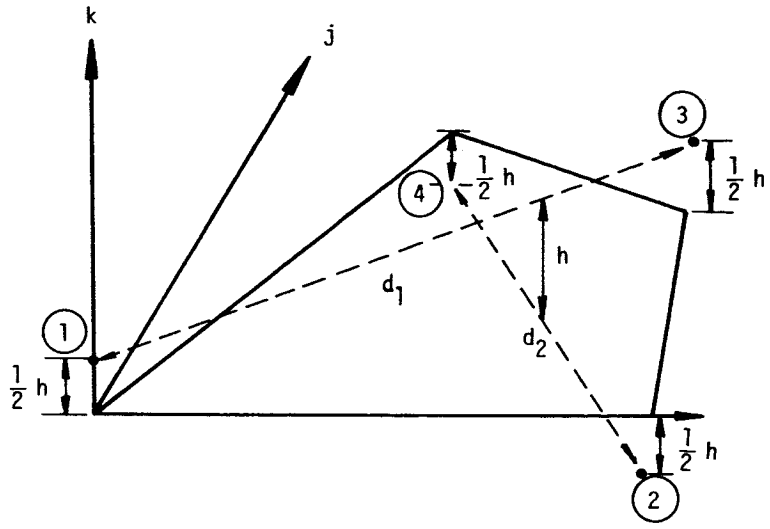
$$\{P_j\} = N[S_j]^T \{\chi_e\} \quad , \qquad j = 1, 2, 3 \text{ (and 4)} \qquad (176)$$

where N = 1: TRBSC

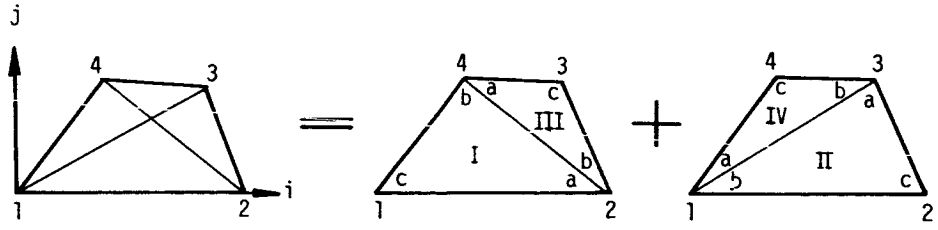
N = 3: TRPLT, TRIA1, TRIA2

N = 2: QDPLT, QUAD1, QUAD2

The $[S_j]^T$ matrix is calculated from the $[K_s]$ matrices of the various basic triangles forming the element. These $[K_s]$ matrices are transformed and combined to produce relations $[S_j]$ between the average element moments and the displacements of the connected grid points, j.



a) Definition of plane



b) Subtriangles

Figure 6. Geometry of the quadrilateral plate element, QDPLT.

4.87.6 The TRIA1, TRIA2, QUAD1 and QUAD2 Elements

These elements have the properties of both membranes and bending plates. The TRIA1 and QUAD1 elements are triangles and quadrilaterals which may use separate thicknesses and materials for membrane, bending and transverse shear action. The TRIA2 and QUAD2 elements are triangles and quadrilaterals which use one thickness and one material to simulate a homogeneous plate with consistent membrane, bending and transverse shear properties.

If these elements use anisotropic materials (defined on a MAT2 bulk data card), the material is oriented with respect to the element coordinate system. The definition of the coordinate system is as follows: the vector from the first point to the second point defines the base or x axis. The z axis is normal to the average plane of the elements, and the third and fourth points have positive y values.

Mass matrices, thermal loads, and differential stiffness matrices for these elements use only the membrane properties.

4.87.6.1 Input Data for the TRIA1, TRIA2, QUAD1 and QUAD2 Elements

1. The ECPT/EST entries for the TRIA1 or QUAD1 elements are:

Symbol	Description
SIL_i, $i = 1,2,3$ or $i = 1,2,3,4$	Scalar indices of the connected grid points.
N_i, X_i, Y_i, Z_i — $i = 1,2,3$ or $i = 1,2,3,4$	Referenced local coordinate system and location in basic coordinates of connected grid points.
θ	Material orientation angle.
MAT ID_m	Material identification number for membrane properties.
t_m	Membrane thickness.
MAT ID_b	Material identification number for bending properties.

Symbol	Description
I	Bending inertia
MAT ID_s	Material identification number for transverse shear properties.
t_s	Transverse shear thickness
μ	Nonstructural mass per area
Z_1, Z_2	Outer fiber distances for stress calculations.
t_μ	Temperature for material properties

2. ECPT Entries for the TRIA2 or QUAD2 Elements.

Symbol		Description
SIL_i	$i = 1,2,3$ or $i = 1,2,3,4$	Scalar indices of connected grid points.
N_i, X_i, Y_i, Z_i	$i = 1,2,3$, or $i = 1,2,3,4$	Referenced local coordinate system and location vector in basic coordinates of connected grid points.
θ		Material orientation angle.
MAT ID		Material identification number
t_m		Element thickness
μ		Nonstructural mass per area.
t_μ		Temperature for material properties

4.87.6.2 Stiffness Matrix Calculations (Subroutine KTRIOD of Module SMA1).

The TRIA1 or QUAD1 element ECPT data are rearranged to correspond to the (TRMEM or QDMEM) membrane ECPT form, and the routine of the TRMEM or QDMEM element is used. The ECPT data are then rearranged to correspond to the ECPT data of a TRPLT or QDPLT element and the respective plate routine is used. Each routine is entirely independent.

The TRIA2 and QUAD2 elements are treated in the same manner except that the arrangement of the ECPT data is different. The type "2" element uses the single material for all three material properties of the type "1" element. The membrane and transverse shear thickness equal the single thickness of the type "2" element. The bending inertia, I_b, for the plate property is:

$$I_b = \frac{t^3}{12} \tag{1}$$

4.87.6.3 Lumped Mass Matrix Generation (Subroutine MASSTQ of Module SMA2)

The bending properties are disregarded for the lumped mass matrix calculations, and the element mass matrices are computed exactly as the ones for the TRMEM and QDMEM elements.

4.87.6.4 Thermal Load Calculations (Subroutine of Module SSG1)

The TRPLT and QDPLT element routines are used to generate loads due to thermal gradients or moments. The TRMEM and QDMEM routines are used to calculate in-plane loads due to uniform thermal expansion.

4.87.6.5 Element Stress and Force Calculations (Subroutines STRQD1 and STRQD2 of Module SDR2)

As with the stiffness matrix calculations, the data are rearranged and the stresses for both the membrane and plate deformations are calculated. The element forces are calculated for the plate only.

1. For the TRIA2 and QUAD2 elements the outer fiber distances Z_1 and Z_2 are:

$$Z_1 = \frac{t}{2} \tag{2}$$

$$Z_2 = -\frac{t}{2} \tag{3}$$

The membrane and plate stresses are added together as follows for Z_1:

$$\begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{\text{composite}} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix}_{\text{membrane}} + \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{\text{bending}}, \tag{4}$$

and for Z_2,

$$\begin{Bmatrix} \sigma_{x2} \\ \sigma_{y2} \\ \sigma_{xy2} \end{Bmatrix}_{\text{composite}} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix}_{\text{membrane}} + \begin{Bmatrix} \sigma_{x2} \\ \sigma_{y2} \\ \sigma_{xy2} \end{Bmatrix}_{\text{bending}} \tag{5}$$

2. The principal stresses and their orientation are calculated from the above results, as in Equations 28, 29 and 30 of section 4.87.4.6.

4.87.6.6 Coupled Mass Matrix Calculations (Subroutine MTRIQD of Module SMA2)

In the lumped mass case these elements are processed using the membrane mass calculation routines (subroutine MASSTQ of module SMA2). When coupled mass is requested, the plate mass calculations will be used instead. The ECPT data are rearranged to the appropriate TRPLT or QDPLT format, and the respective plate routine is used. The mass per area is now calcuated using the material mass density ρ and the thickness t_m for the membrane definition of the element and added to the nonstructural mass:

$$m = \mu + \rho t_m \, , \tag{6}$$

and m is now used instead of μ for the plate calculations.

4.87.6.7 Piecewise Linear Analysis Calculations (Subroutines PSTRI1, PSTRI2, PSQAD1, and PSQAD2 of Module PLA3 and PKTRI1, PKTRI2, PKQAD1 and PKQAD2 of Module PLA4).

The additional ECPTNL and ESTNL entries are:

ε_o^* - The previously computed strain value once removed.

ε^* - The previously computed strain value.

E^* - The previously computed modulus of elasticity.

σ_x^*, σ_y^*, σ_{xy}^* } The previously computed membrane stresses.

M_x^*, M_y^*, M_{xy}^*, V_x^*, V_y^* } The previously computed element forces (ESTNL only).

All of the above values are initially zero with the exception of E^*, which is initially the original modulus of elasticity present on a MAT1 card.

In module PLA3, the incremental element stress matrix is calculated by first rearranging the ESTNL data to correspond to the ESTNL data for a TRMEM or QDMEM, and then the membrane stresses are calculated in the same manner as Equations 103 through 105 of section 4.87.4.14. Then the ESTNL data are rearranged to correspond to the EST data for a TRPLT (or QDPLT) and the incremental bending forces for the TRPLT (or QDPLT) element are calculated in the same manner as in Equation 97 of section 4.87.5.7. However, if the bending material properties are the same as the membrane material properties, then the 3 by 3 bending material properties matrix ($[G_b]$ in Equation 11 of section 4.87.5.2) is replaced by the matrix given in Equation 97 of section 4.87.4.14. In addition the displacement vector $\{u_i\}$ in Equation 44 of section

4.87.5.4 (or Equation 97 of section 4.87.5.7) are replaced by an incremental displacement vector $\{\Delta u_1\}$.

The results are incremental stresses and forces for the membrane and bending properties defined as follows

$$\left.\begin{aligned} \sigma_{x1} &= \sigma_x^* + \Delta\sigma_x \\ \sigma_{y1} &= \sigma_y^* + \Delta\sigma_y \\ \sigma_{xy1} &= \sigma_{xy}^* + \Delta\sigma_{xy} \end{aligned}\right\} \text{ Membrane stresses ,} \qquad (7), (8), (9)$$

$$\left.\begin{aligned} M_{x1} &= M_x^* + \Delta M_x \\ M_{x1} &= M_y^* + \Delta M_y \\ M_{xy1} &= M_{xy}^* + \Delta M_{xy} \\ V_{x1} &= V_x^* + \Delta V_x \\ V_{y1} &= V_y^* + \Delta V_y \end{aligned}\right\} \text{ Bending forces .} \qquad (10), (11), (12), (13), (14)$$

The total bending stresses are calculated using the total bending forces given in Equations 10 through 14 in conjunction with Equations 98 through 100 of section 4.87.5.7.

The membrane and bending stresses are added together as follows for Z_1:

$$\begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{\text{composite}} = \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{\text{membrane}} + \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{\text{bending}} ; \qquad (15)$$

and for Z_2:

$$\begin{Bmatrix} \sigma_{x2} \\ \sigma_{y2} \\ \sigma_{xy2} \end{Bmatrix}_{composite} = \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{membrane} + \begin{Bmatrix} \sigma_{x2} \\ \sigma_{y2} \\ \sigma_{xy2} \end{Bmatrix}_{bending} . \quad (16)$$

The principal stresses and their orientation for output are calculated from the above results, as in Equations 28 through 30 of section 4.87.4.6.

In module PLA4, the bending properties are disregarded, and the ECPTNL data are rearranged to correspond tc the ECPT data for the TRMEM or QDMEM, and the stresses are calculated exactly as the ones for the TRMEM or QDMEM elements (see section 4.87.4.14).

In modules PLA3 and PLA4, after the above stress calculations have been completed, the next elastic coefficients are calculated in the same manner as Equations 106 through 112 of section 4.87.4.14.

The new ESTNL and ECPTNL entries are:

$$\varepsilon_0^* = \varepsilon^* , \quad (17)$$

$$\varepsilon^* = \varepsilon_1 , \quad (18)$$

$$E^* = E_1 , \quad (19)$$

$$\sigma_x^* = \sigma_{x1} , \quad (20)$$

$$\sigma_y^* = \sigma_{y1} , \quad (21)$$

$$\sigma_{xy}^* = \sigma_{xy1} , \quad (22)$$

$$M_x^* = M_{x1} , \quad (23)$$

$$M_y^* = M_{y1} , \quad (24)$$

$$M_{xy} = M_{xy1} , \quad (25)$$

$$V^*_{x1} = V_{x1} \quad , \tag{26}$$

$$V^*_{y1} = V_{y1} \quad , \tag{27}$$

In module PLA4, the ECPTNL data are rearranged, and the element stiffness matrices are calculated in the same manner as for the TRMEM or QDMEM elements in section 4.87.4.14.

4.87.6.8 Differential Stiffness Matrix Calculations for the TRIA1 and TRIA2 Elements (Subroutine DTRIA of Module DSMG1)

This subroutine uses the displacement vectors and thermal load temperature from a static solution to produce a differential stiffness matrix. The DTRMEM subroutine is used to calculate in plane-stresses and in-plane differential stiffness. The triangle is subdivided into three subtriangles and the DTRBSC routine is used to calculate out-of-plane differential stiffness for each of the three subtriangles. The matrices are combined and the center point is removed in the same manner as the KTRPLT subroutine (section 4.87.5.5). The basic steps are as follows:

1. The TRIA2 data from the ECPT is converted to TRIA1 format while in both cases the data is moved to a protected location. The conversion is:

TRIA1 DATA			TRIA2 DATA	
$MATID_m$	$=$ $MATID_b$	$=$ $MATID_s$	$=$ MATID	(28)
t_m	$=$ t_s	$=$ t_m		(29)
I	$=$ $\frac{t_m^3}{12.0}$			(30)

2. The ECPT data are rearranged to the TRMEM format (the same as the TRIA2 format).

3. The material property orientation angles are established and subroutine DTRMEM is called. This routine will insert the in-plane differential stiffness terms in the KDGG matrix and will return the stress values $\bar{\sigma}_x$, $\bar{\sigma}_y$, and $\bar{\tau}_{xy}$.

4. The element coordinate system and geometric coefficients are calculated as follows where the three location vectors are {x(1)}, {x(2)}, and {x(3)}.

$$\{V_2\} = \{x(2)\} - \{x(1)\} \tag{31}$$

$$\{V_3\} = \{x(3)\} - \{x(1)\} \tag{32}$$

$$X_2 = |\{V_2\}| \tag{33}$$

$$\{i\} = \frac{\{V_2\}}{X_2} \tag{34}$$

$$Y_3 = |\{i\} \times \{V_3\}| \tag{35}$$

$$\{k\} = \frac{\{i\} \times \{V_3\}}{Y_3} \tag{36}$$

$$\{j\} = \{k\} \times \{i\} \tag{37}$$

$$X_4 = \frac{X_2 + X_3}{3} \tag{38}$$

$$Y_4 = \frac{Y_3}{3} \tag{39}$$

The locations of the four points in this coordinate system are defined by the matrix [R] where each row defines one point

$$[R] = \begin{bmatrix} 0 & 0 \\ X_2 & 0 \\ X_3 & Y_3 \\ X_4 & Y_4 \end{bmatrix} \tag{40}$$

5. For use in transferring points in the element to points in the subtriangle, the integer mapping matrix [M] is used.

$$[M] = \begin{array}{c} \text{Point a} \quad \text{Point b} \quad \text{Point c} \\ \begin{bmatrix} 1 & 2 & 4 \\ 2 & 3 & 4 \\ 3 & 1 & 4 \end{bmatrix} \end{array} \tag{41}$$

Each row of the matrix corresponds to the three points connected to each subtriangle.

6. A major loop is now performed with one cycle for each of the three subtriangles. Corresponding to points a, b, and c of the M matrix, the location vectors $\{r_a\}$, $\{r_b\}$, and $\{r_c\}$ are extracted from the corresponding rows of the R matrix. For each triangle the

following are calculated:

$$\ell = \sqrt{(r_{b1} - r_{a1})^2 - (r_{b2} - r_{a2})^2} \tag{42}$$

$$W_1 = \frac{1}{\ell}(r_{b1} - r_{a1}) \tag{43}$$

$$W_2 = \frac{1}{\ell}(r_{b2} - r_{a2}) \tag{44}$$

The transformation between subtriangle coordinates to element coordinates is:

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & W_1 & W_2 \\ 0 & -W_2 & W_1 \end{bmatrix} \tag{45}$$

The material orientation data are

$$\left.\begin{aligned} \sin(\theta_m) &= W_1 \sin(\theta) - W_2 \cos(\theta) \\ \cos(\theta_m) &= W_1 \cos(\theta) + W_2 \sin(\theta) \end{aligned}\right\} \tag{46}$$

7. The locations of the three points of each subtriangle are transformed to geometric coefficients x_b, x_c, y_c where

$$x_b = W_1(r_{b1} - r_{a1}) + W_2(r_{b2} - r_{a2}) \tag{47}$$

$$x_c = W_1(r_{c1} - r_{a1}) + W_2(r_{c2} - r_{a2}) \tag{48}$$

$$y_c = -W_2(r_{c1} - r_{a1}) + W_1(r_{c2} - r_{a2}) \tag{49}$$

8. The stresses are transformed to the subtriangle system by the equations:

$$\sigma_x = W_1^2 \bar{\sigma}_x + W_2^2 \bar{\sigma}_y + 2W_1W_2\bar{\tau}_{xy} \tag{50}$$

$$\sigma_y = W_2^2 \bar{\sigma}_x + W_1^2 \bar{\sigma}_y - 2W_1W_2\bar{\tau}_{xy} \tag{51}$$

$$\tau_{xy} = -W_1W_2\bar{\sigma}_x + W_1W_2\bar{\sigma}_y + (W_1^2 - W_2^2)\bar{\tau}_{xy} \tag{52}$$

9. The differential stiffness matrix for each subtriangle is formed in subroutine DTRBSC (Section 4.87.6.10). The input to this routine consists of the ECPT property data; the location parameters x_b, x_c, and y_c; and the in plane stresses σ_x, σ_y and τ_{xy}. The output from this routine consists of the following matrices:

$[K^d_{ij}]$ $\begin{cases} i = \text{pivot point} \\ j = 1, 2, \text{ and/or } 3 \end{cases}$

$[K^d_{j4}]$ $j = 1, 2, \text{ and/or } 3$

$[H]$, $[S]$

10. The above matrices are combined and transformed in exactly the same manner as the triangular plate equations. The differential stiffness matrices replace the elastic stiffness matrices in the equations. See section 4.87.5.5, steps 7 through 10.

4.87.6.9 Differential Stiffness Matrix Calculation for the QUAD1 and QUAD2 Elements (Subroutine DQUAD of Module DSMG1)

The differential stiffness matrix for the QUAD1 and QUAD2 elements is constructed from the matrices produced by four subtriangles. The method used to subdivide the quadrilateral is shown in Figure 6. The stress is calculated for each triangle using the DTRMEM subroutine. The out-of-plane differential stiffness for each triangle is calculated using the DTRBSC subroutine. The element geometry and the manipulation of the matrices is done in the same manner as the elastic stiffness equations for the quadrilateral plates.

The steps followed by the subroutine are:

1. If a QUAD2 element is used, its property data is converted to the QUAD1 equivalent and the ECPT is expanded to the QUAD1 format. The property conversion is:

	QUAD1 DATA		QUAD2 DATA	
$MATID_m$ =	$MATID_6$ =	$MATID_5$ =	MATID	(53)
	t_m =	t_s =	t_m	(54)
		I =	$\frac{t_m^3}{12.0}$	(55)

With both cases the data is stored in a protected location.

2. The element coordinate system and the location of the grid points are calculated as follows:

$$\left.\begin{aligned} \{d_1\} &= \{V_3\} - \{V_1\} \\ \{d_2\} &= \{V_4\} - \{V_2\} \end{aligned}\right\} \tag{56}$$

where $\{V_1\}$, $\{V_2\}$, $\{V_3\}$, and $\{V_4\}$ are the location vectors of the connected grid points.

$$\{k\} = \frac{\{d_1\} \times \{d_2\}}{|\{d_1\} \times \{d_2\}|} \tag{57}$$

$$\{a_1\} = \{V_2\} - \{V_1\} \tag{58}$$

$$h = \{a_1\} \cdot \{k\} \tag{59}$$

$$\{i\} = \frac{\{a_1\} - h\{k\}}{|\{a_1\} - h\{k\}|} \tag{60}$$

$$\{j\} = \{k\} \times \{i\} \tag{61}$$

The locations of the points in the element plane are stored in the [R] matrix where each row corresponds to the x and y location of a point.

$$R_{11} = R_{12} = R_{22} = 0.0 \tag{62}$$

$$R_{21} = X_2 = \{a_1\} \cdot \{i\} \tag{63}$$

$$R_{31} = X_3 = \{d_1\} \cdot \{i\} \tag{64}$$

$$R_{32} = Y_3 = \{d_1\} \cdot \{j\} \tag{65}$$

$$R_{41} = X_4 = X_2 + \{d_2\} \cdot \{i\} \tag{66}$$

$$R_{42} = Y_4 = \{d_2\} \cdot \{j\} \tag{67}$$

3. At this stage the four triangles are processed in a loop. The matrix partition for the element is set to zero and the results for each triangle are added in. The following steps 4 - 8 describe this loop.

4. The three points for each triangle are selected using the mapping matrix M. The data corresponding to these points are put into the ECPT format for a TRMEM element.

5. The geometry of the triangle is calculated using the three rows of the R matrix corresponding to the three points of the triangle a, b, c. These rows correspond to vectors $\{V_a\}$, $\{V_b\}$, and $\{V_c\}$.

$$\{V\} = \{V_b\} - \{V_a\} \tag{68}$$

$$\{V_v\} = \{V_c\} - \{V_a\} \tag{69}$$

$$x_b = |\{V\}| \tag{70}$$

$$\begin{Bmatrix} w_1 \\ w_2 \end{Bmatrix} = \frac{\{V\}}{x_b} \tag{71}$$

$$x_c = W_1 V_{v1} + W_2 V_{v2} \tag{72}$$

$$y_c = -W_2 V_{v1} + W_1 V_{v2} \tag{73}$$

The transformation matrix between element and triangle coordinates is:

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & W_1 & W_2 \\ 0 & -W_2 & W_1 \end{bmatrix} \tag{74}$$

6. The orientation angle θ_m for the subtriangle is computed in case the material is anisotropic.

$$\sin \theta_m = W_1 \sin \theta - W_2 \cos \theta \tag{75}$$

$$\cos \theta_m = W_1 \cos \theta + W_2 \sin \theta \tag{76}$$

7. The triangular membrane subroutine DTRMEM at this point will calculate and insert the in-plane differential stiffness terms and will produce the stress values σ_x, σ_y, and τ_{xy} in the triangle coordinates. The basic triangle subroutine will use the in-plane stresses and the basic locations x_b, x_c, and y_c to produce the out of plane differential stiffness terms. The output of the differential stiffness subroutine, DTRBSC, is the 3 by 3 matrix

partitions $[K_{ia}]$, $[K_{ib}]$, and $[K_{ic}]$, where i is the pivot point. These are transformed to quadrilateral coordinates with the [T] matrix.

$$[K^e_{ij}] = [T]^T [K_{ij}][T] \quad (77)$$

8. The matrices for each triangle are added into the running sum for the quadrilateral and steps 4 - 8 are repeated.

9. The differential stiffness matrix partitions are transformed to global coordinates and inserted into the overall differential stiffness matrix in a manner identical to steps 7 and 8 of section 4.87.5.8.

4.87.6.10 Differential Stiffness Matrix Calculations for the Basic Bending Triangle (Subroutine DTRBSC of Module DSMG1)

Unlike the case of elastic stiffness matrix generation, the basic triangle (TRBSC) may not be used by itself to produce differential stiffness matrix terms. This subroutine, however, is used for the calculation of differential stiffness for the TRIA1, TRIA2, QUAD1, and QUAD2 elements. Its purpose is analogous to the way the KTRBSC subroutine is used in the calculation of elastic stiffness matrices.

The necessary inputs to this subroutine are passed to it via the labeled common blocks DSIAET and DSIADP. The input data used are x_b, x_c, y_c (the basic geometry), σ_x, σ_y, τ_{xy} (the in-plane stresses), and the element property data.

The basic algorithm used by the routine is as follows:

1. The presence of transverse shear is tested and the subroutine selects the method of calculating the element coordinate-to-generalized coordinate transformation matrices $[H_b]$ and $[H_c]$.

2. If no transverse shear flexibility exists, the matrices $[H_b]$ and $[H_c]$ are calculated by the following equations:

$$r = \frac{1}{x_b}$$

$$s = \frac{1}{y_c}$$

$$t = \frac{x_c}{y_c} \qquad (78)$$

$$u = \frac{x_c}{x_b^2 y_c^2} = r^2 st$$

$$[H_b] = \begin{bmatrix} 3r^2 & 0 & r \\ 0 & r & 0 \\ -3r^2t^2 & -rt & -rt^2 \\ -2r^3 & 0 & -r^2 \\ -6ru(x_b-x_c) & -rs & u(3x_c-2x_b) \\ 2rtu(3x_b-2x_c) & rst & 2tu(x_b-x_c) \end{bmatrix}_{(6x3)} \qquad (79)$$

$$[H_c] = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 3s^2 & -s & st \\ 0 & 0 & 0 \\ 0 & 0 & -s^2 \\ -2s^3 & s^2 & 0 \end{bmatrix}_{(6x3)} \qquad (80)$$

3. If both shear material and shear thickness exist, then the $[H_{\gamma q}]$ and $[H]^{-1}$ matrices are generated as with the existing equations for the TRBSC element. See pages 4.87-82, 83. The 6x6 $[H]^{-1}$ matrix, is partitioned as follows:

$$[H]^{-1} \Rightarrow [H_b \vdots H_c] \qquad (81)$$

and is used instead of Equations (79) and (80).

4. In order to form the differential stiffness matrix $[K^{dq}]$, referred to generalized coordinates, the following integral must be evaluated over the triangular area.

$$I_{nm} = h \int_A x^n y^m \, dA \tag{82}$$

The results are:

$$I_{00} = hA = \frac{hx_b y_c}{2} \qquad I_{10} = \frac{hA}{3}(x_b + x_c)$$

$$I_{01} = \frac{hAy_c}{3} \qquad I_{11} = \frac{hAy_c}{12}(x_b + 2x_c)$$

$$I_{02} = \frac{hAy_c^2}{6} \qquad I_{12} = \frac{hAy_c^2}{30}(x_b + 3x_c)$$

$$I_{03} = \frac{hAy_c^3}{10} \qquad I_{13} = \frac{hAy_c^3}{60}(x_b + 4x_c)$$

$$I_{04} = \frac{hAy_c^4}{15}$$

$$I_{20} = \frac{hA}{6}(x_b^2 + x_b x_c + x_c^2) \tag{83}$$

$$I_{21} = \frac{hAy_c}{30}(x_b^2 + 2x_b x_c + 3x_c^2)$$

$$I_{22} = \frac{hAy_c^2}{90}(x_b^2 + 3x_b x_c + 6x_c^2)$$

$$I_{30} = \frac{hA}{10}\left|x_b^3 + x_b^2 x_c + x_b x_c^2 + x_c^3\right|$$

$$I_{31} = \frac{hAy_c}{60}\left|x_b^3 + 2x_b^2 x_c + 3x_b x_c^2 + 4x_c^3\right|$$

$$I_{40} = \frac{hA}{15}\left|x_b^4 + x_b^3 x_c + x_b^2 x_c^2 + x_b x_c^3 + x_c^4\right|$$

5. The elements of the (8x8) differential stiffness matrix $[K^{dq}]$ are listed below. The matrix is symmetric so only the upper triangle terms are given. The superscript $(^{dq})$ is omitted for convenience.

$$
\begin{aligned}
K_{11} &= \sigma_x I_{00} \\
K_{12} &= \tau I_{00} \\
K_{13} &= 2\sigma_x I_{10} \\
K_{14} &= \sigma_x I_{01} + \tau I_{10} \\
K_{15} &= 2\tau I_{01} \\
K_{16} &= 3\sigma_x I_{20} \\
K_{17} &= \sigma_x I_{o2} + 2\tau I_{11} \\
K_{18} &= 3\tau I_{02} \\
K_{22} &= \sigma_y I_{00} \\
K_{23} &= 2\tau I_{10} \\
K_{24} &= \tau I_{01} + \sigma_y I_{10} \\
K_{25} &= 2\sigma_y I_{01} \\
K_{26} &= 3\tau I_{20} \\
K_{27} &= \tau I_{02} + 2\sigma_y I_{11} \\
K_{28} &= 3\sigma_y I_{02} \\
K_{33} &= 4\sigma_x I_{20} \\
K_{34} &= 2(\sigma_x I_{11} + \tau I_{20}) \\
K_{35} &= 4\tau I_{11} \\
K_{36} &= 6\sigma_x I_{30}
\end{aligned}
\tag{84}
$$

$$K_{37} = 2(\sigma_x I_{12} + 2\tau I_{21})$$

$$K_{38} = 6\tau I_{12}$$

$$K_{44} = \sigma_x I_{02} + 2\tau I_{11} + \sigma_y I_{20}$$

$$K_{45} = 2(\tau I_{02} + \sigma_y I_{11})$$

$$K_{46} = 3(\sigma_x I_{21} + \tau I_{30})$$

$$K_{47} = \sigma_x I_{03} + 3\tau I_{12} + 2\sigma_y I_{21}$$

$$K_{48} = 3(\tau I_{03} + \sigma_y I_{12})$$

$$K_{55} = 4\sigma_y I_{02}$$

$$K_{56} = 6\tau I_{21} \qquad (84)$$

$$K_{57} = 2(\tau I_{03} + 2\sigma_y I_{12})$$

$$K_{58} = 6\sigma_y I_{03}$$

$$K_{66} = 9\sigma_x I_{40}$$

$$K_{67} = 3(\sigma_x I_{22} + 2\tau I_{31})$$

$$K_{68} = 9\tau I_{22}$$

$$K_{77} = \sigma_x I_{04} + 4\tau I_{13} + 4\sigma_y I_{22}$$

$$K_{78} = 3(\tau I_{04} + 2\sigma_y I_{13})$$

$$K_{88} = 9\sigma_y I_{04}$$

6. In order to transform the matrix to the displacements of points at the corners of the triangle, the following matrices are generated.

$$[H_a] = [H_b][S_b] - [H_c][S_c] \quad (6x3) \qquad (85)$$

$$[C_a] = \begin{bmatrix} H_q H_a \\ \hline H_a \end{bmatrix} + \begin{bmatrix} 0 & 0 & -1 \\ 0 & 1 & 0 \\ \hline & 0 & \end{bmatrix} \quad (8x3) \qquad (86)$$

$$[C_b] = \begin{bmatrix} H_q H_b \\ \hline H_b \end{bmatrix} \quad (8x3) \qquad (87)$$

$$[C_c] = \begin{bmatrix} H_q H_c \\ \hline H_c \end{bmatrix} \quad (8x3) \qquad (88)$$

7. The output matrix partitions depend on the type of element using this subroutine. If the element type is a QUAD1 or QUAD2 the three output matrix paritions $[K^{de}]$ are:

$$[K^{de}_{ij}] = [C_i]^T [K^{dq}][C_j] \qquad (89)$$

where i is the pivot point and j = a, b, and c.

If the element type is a TRIA1 or TRIA2 the output differential stiffness matrices are calculated using equation 89 above. They are:

$$[K_{ia}] = [C_i]^T [K^{dq}][C_a] \qquad (90)$$

$$[K_{ib}] = [C_i]^T [K^{dq}][C_b] \qquad (91)$$

if i is the pivot point and i = a or i = b.

In addition, for the TRIA1 and TRIA2, elements the following matrices are output:

$$[K^{de}_{ac}] = [C_a]^T [K^{dq}][C_c] \qquad (92)$$

$$[K^{de}_{bc}] = [C_b]^T [K^{dq}][C_c] \qquad (93)$$

$$[K^{de}_{cc}] = [C_c]^T [K^{dq}][C_c] \qquad (94)$$

The matrices $[H]^{-1}$ and [S], previously calculated are also output for the TRIA1 and TRIA2 elements.

4.87.6.11 Thermal Calculations for the Combination Elements (Subroutine KTRIQD of Module SMA1)

If the heat transfer parameter, HEAT, is true, the elements are treated exactly like the membrane elements QDMEM and TRMEM. The bending calculations are bypassed and subroutines KQDMEM or KTRMEM are used for calculation of the conductivity matrix terms.

4.87.7 The ELASi, MASSi and DAMPi Elements

The scalar elements (ELASi, MASSi and DAMPi, i = 1,2,3,4) are connected to scalar components of grid points or to scalar points. The ELASi elements contribute only to: a) the stiffness matrix, $[K^{x}_{gg}]$, for i = 1,2,3,4; and b) to the structural damping matrix, $[K^{4}_{gg}]$, for i = 1,2,3. The MASSi elements contribute only to the mass matrix, $[M_{gg}]$, and the DAMPi elements contribute only to the viscous damping matrix, $[B_{gg}]$.

The scalar elements do not require material or geometric properties in their calculations. Only the ELASi elements are used for stress or force calculations.

4.87.7.1 Input Data for the ELASi, MASSi and DAMPi Elements

The ECPT/EST entries for the scalar elements are:

Symbol	Description	Elements
SIL_1, SIL_2	Scalar indices of connected grid or scalar points	All
c_1, c_2	Component numbers corresponding to SIL_1 and SIL_2.	Types 1 and 2
K	Spring constant	All ELASi elements
g_e	Damping factor	ELAS1, 2 and 3
S	Stress coefficient	
B	Viscous damping coefficient	All DAMPi elements
m	Mass coefficient	All MASSi elements

4.87.7.2 ELASi Stiffness Matrix Generation (Subroutine KELAS of Module SMA1)

1. The two connected scalar indices are i_1 and i_2 given by:

$$i_1 = \begin{cases} SIL_1 + (c_1 - 1), & \text{if Point 1 is a grid point} \\ SIL_1, & \text{if Point 1 is a scalar point} \end{cases}$$

$$i_2 = \begin{cases} SIL_2 + (c_2 - 1), \text{ if Point 2 is a grid point} \\ SIL_2, \text{ if Point 2 is a scalar point} \end{cases}$$

2. The following terms are added to the $[K^x_{gg}]$ matrix:

   +K in position (i_1, i_1) and in position (i_2, i_2),

   -K in position (i_2, i_1) and in position (i_1, i_2).

3. If point 2 is not defined, add +K to position (i_1, i_1).

4. The damping terms are:

$$K^4 = K g_e . \quad (1)$$

These are added to $[K^4_{gg}]$ in the same manner as the stiffness terms were added to $[K^x_{gg}]$.

4.87.7.3 MASSi Mass Matrix Generation (Subroutine MASSD of Module SMA2)

These elements are treated like the ELASi elements except the "m" term is added to the four positions in $[M_{gg}]$.

4.87.7.4 DMAPi Damping Matrix Generation (Subroutine MASSD of Module SMA2)

These elements are treated like the ELASi elements except the "B" term is added to the four positions in $[B_{gg}]$.

4.87.7.5 ELASi Stress and Force Recovery (Subroutines SELAS1 and SELAS2 of Module SDR2)

The element force is:

$$F = K(u_2 - u_1), \quad (2)$$

where u_1 and u_2 are the displacements at scalar index numbers i_1 and i_2.

The element stress is:

$$\sigma = SF. \tag{3}$$

4.87.8 Concentrated Mass Elements CØNM1, CØNM2

Two types of grid point mass data are available. CØNM1 defines the mass matrix directly at the point, with the axes defined by a given local coordinate system. CØNM2 defines the same matrix for a body with a mass and three inertias with a center of gravity offset from the grid point.

4.87.8.1 ECPT Entries for the CØNM1 Mass Element

Symbol	Description
N_m	Local coordinate system number in which the mass matrix is defined.
N_g, X, Y, Z	Local coordinate system number and basic coordinates of the point.
m_{11}	Terms of mass matrix given in row form (out to the diagonal term).
m_{21}, m_{22}	
m_{31},m_{32},m_{33}	
m_{41},m_{42},m_{43},m_{44}	
m_{51},m_{52},m_{53},m_{54},m_{55}	
m_{61},m_{62},m_{63},m_{64},m_{65},m_{66}	

4.87.8.2 Mass Matrix Calculations for the CØNM1 Element (Subroutine MCØNMX of Module SMA2)

1. Using the symmetrical relationships, fill out the remainder of the 6x6 matrix, [m]:

$$m_{ij} = m_{ji} \quad . \tag{1}$$

2. Using the basic coordinates of the point and the local coordinate system definition, the 3x3 transformation matrices $[T_g]$ and $[T_m]$ are generated, and the mass matrix in global coordinates is:

$$[M] = \begin{bmatrix} T_g^T & 0 \\ 0 & T_g^T \end{bmatrix} \begin{bmatrix} T_m & 0 \\ 0 & T_m \end{bmatrix} [m] \begin{bmatrix} T_m^T & 0 \\ 0 & T_m^T \end{bmatrix} \begin{bmatrix} T_g & 0 \\ 0 & T_g \end{bmatrix}, \qquad (2)$$

where $[T_g]$ is the transformation from global-to-basic coordinates at the point, and $[T_m]$ is the transformation from the coordinates defined by the mass local system to the basic coordinate system.

4.87.8.3 ECPT Entries for the CØNM2 Mass Element

Symbol	Description
N_m	Local coordinate system number in which the mass terms are defined.
N_g, X, Y, Z	Local coordinate system number and basic coordinates of the point.
$\overline{m}$	Concentrated mass
x,y,z	Offset of center of gravity in mass coordinate system
I_{11} I_{21}, I_{22} I_{31}, I_{32}, I_{33}	Inertias about the center of gravity given in row order out to the diagonal term

4.87.8.4 Mass Matrix Calculations for the CØNM2 Element (Subroutine MCØNMX of Module SMA2)

1. The transformation from the offset to the grid point is:

$$[D] = \begin{bmatrix} 1 & & & 0 & z & -y \\ & 1 & & -z & 0 & x \\ & & 1 & y & -x & 0 \\ & & & 1 & & \\ & 0 & & & 1 & \\ & & & & & 1 \end{bmatrix}. \qquad (3)$$

2. The mass matrix referenced to the offset point is:

$$[m_o] = \left[\begin{array}{ccc:ccc} \bar{m} & & & & & \\ & \bar{m} & & & 0 & \\ & & \bar{m} & & & \\ \hdashline & & & I_{11} & -I_{21} & -I_{31} \\ & 0 & & -I_{21} & I_{22} & -I_{32} \\ & & & -I_{31} & -I_{32} & I_{33} \end{array}\right] . \quad (4)$$

3. The mass matrix about the grid point along the given coordinates is:

$$[m] = [D]^T[m_o][D]. \quad (5)$$

The actual nonzero terms of matrix [m] are calculated directly from the equations:

$$m_{11} = m_{22} = m_{33} = \bar{m} \quad , \quad (6)$$

$$m_{15} = m_{51} = -m_{24} = -m_{42} = +z\bar{m} \quad , \quad (7)$$

$$m_{16} = m_{61} = -m_{34} = -m_{43} = -y\bar{m} \quad , \quad (8)$$

$$m_{26} = m_{62} = -m_{35} = -m_{53} = x\bar{m} \quad , \quad (9)$$

$$m_{44} = I_{11} + (y^2 + z^2)\bar{m} \quad , \quad (10)$$

$$m_{55} = I_{22} + (x^2 + z^2)\bar{m} \quad , \quad (11)$$

$$m_{66} = I_{33} + (x^2 + y^2)\bar{m} \quad , \quad (12)$$

$$m_{45} = m_{54} = -I_{21} - xy\bar{m} \quad , \quad (13)$$

$$m_{46} = m_{64} = -I_{31} - xz\bar{m} \quad , \tag{14}$$

$$m_{56} = m_{65} = -I_{32} - yz\bar{m} \quad . \tag{15}$$

4. The matrix [m] is transformed back to global coordinates using Equation 2.

4.87.9 The CØNEAX Element

4.87.9.1 Input Data for the CØNEAX Element

1. The ECPT/EST entries for the CØNEAX element are:

Symbol	Description
SIL_a, SIL_b	Scalar indices of the n^{th} harmonic of the connected rings
n	Harmonic index
r_a, r_b	Radii at points a and b
z_a, z_b	Projected distances along the axis
t_m	Membrane thickness
MAT ID_m	Membrane material identification number
I	Bending coefficient
MAT ID_b	Bending material identification number
t_s	Shear thickness
MAT ID_s	Shear material identification number
Z_1, Z_2	Outer fiber distances for stress calculations
$\emptyset_i$, i = 1 to 14	Angles defining points around element
t_μ	Temperature for material properties
μ	Nonstructural mass

4.87.9.2 Stiffness Matrix Calculations (Subroutine KCØNE of Module SMA1).

1. The shell orientation is given by:

$$\ell = \sqrt{(r_b - r_a)^2 + (z_b - z_a)^2}\ , \tag{1}$$

$$\sin\psi = \frac{r_b - r_a}{\ell}\ , \tag{2}$$

$$\cos\psi = \frac{z_b - z_a}{\ell}\ . \tag{3}$$

2. The transformation matrix [E] from element coordinates to ring cylindrical coordinates is:

$$[E] = \begin{bmatrix} 0 & \sin\psi & \cos\psi & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & \cos\psi & -\sin\psi & 0 & 0 \\ 0 & 0 & 0 & 0 & \sin\psi \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & \cos\psi \end{bmatrix} . \quad (4)$$

3. The serial steps for the balance of the stiffness matrix computations unique to the axisymmetric conical shell element are explicitly described in the NASTRAN Theoretical Manual section 5.9.5.7 (Summary of Procedures).

4.87.9.3 Mass Matrix Computation (Subroutine MCØNE of Module SMA2)

$$[M_{ii}] = \begin{bmatrix} m_i & 0 & 0 & 0 & 0 & 0 \\ 0 & m_i & 0 & 0 & 0 & 0 \\ 0 & 0 & m_i & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad i = a \text{ or } b \quad (5)$$

where

$$m_a = \pi\ell\left(\frac{r_b}{6} + \frac{r_a}{3}\right)(\rho t + \mu) \quad . \quad (6)$$

$$m_b = \pi\ell\left(\frac{r_b}{3} + \frac{r_a}{6}\right)(\rho t + \mu)$$

4.87.9.4 Element Load Calculations (Subroutine CØNE of Module SSG1).

The Fourier coefficients of the temperatures are stored in the GPTT data block. The loads are generated by the elements, which reference the connected rings and harmonics indirectly by the grid point scalar indices. The scalar indices are used with the SIL (Scalar Index List) data block to obtain the temperatures. The following steps are used to generate the loads:

1. The data for a logical element are read from the EST data block. The harmonic

number, n, is extracted from the element ID, N_e, by the equation:

$$N_e = 1000N + (n + 1) \quad , \tag{7}$$

where N is the total number of harmonics plus one in the problem.

The temperatures for this particular element and harmonic (T_n^a and T_n^b) are extracted from the GPTT data block. (No default nonzero temperatures are allowed).

2. The following data are generated in the same manner as in the stiffness matrix routine, KØNE:

r_a, r_b, z_a, z_b	-	Ring locations
ℓ	-	Linear distance
$\sin\psi$, $\cos\psi$	-	Inclination functions
[E]	-	Element-to-global transformation matrix (6x5)
t	-	Element thickness
$[E_m]$	-	Material matrix (3x3)
$\alpha_s = \alpha_\phi = \alpha$	-	Temperature coefficient

3. The geometry coefficients, I_{mn}, are calculated as in the stiffness matrix routine by the equation:

$$I_{mn} = \pi \int_0^{\ell} s^m r^{1-n} \, ds = \frac{\pi}{b} \int_{r_a}^{r_b} s^m r^{1-n} \, dr \quad , \tag{8}$$

where $r = a + bs$, $a = r_a$, $b = \frac{r_b - r_a}{\ell}$.

4. The loads are generated in generalized coordinates, $\{P_n^q\}$, with the equations:

$$\{P_{1n}\} = n(I_{01}A_n + I_{11}B_n) \quad , \tag{9}$$

$$\{P_{2n}\} = n(I_{11}A_n + I_{21}B_n) \quad , \tag{10}$$

$$\{P_{3n}\} = \sin\psi\ (I_{01}A_n + I_{11}B_n) \ , \tag{11}$$

$$\{P_{4n}\} = \sin\psi(I_{11}A_n + I_{21}B_n) + I_{00}C_n + I_{10}D_n \ , \tag{12}$$

$$\{P_{5n}\} = \cos\psi(I_{01}A_n + I_{11}B_n) \ , \tag{13}$$

$$\{P_{6n}\} = \cos\psi(I_{11}A_n + I_{21}B_n) \ , \tag{14}$$

$$\{P_{7n}\} = \cos\psi(I_{21}A_n + I_{31}B_n) \ , \tag{15}$$

$$\{P_{8n}\} = \cos\psi(I_{31}A_n + I_{41}B_n) \ , \tag{16}$$

$$\{P_{9n}\} = 0 \ , \tag{17}$$

$$\{P_{10,n}\} = 0 \quad , \tag{18}$$

where

$$A_n = tE_{12}(\alpha_s T_n^a) + tE_{22}(\alpha_\phi T_n^a) \ , \tag{19}$$

$$B_n = \frac{t}{\ell}\ (T_n^b - T_n^a)(E_{12}\alpha_s + E_{22}\alpha_\phi), \tag{20}$$

$$C_n = tE_{11}(\alpha_s T_n^a) + tE_{12}(\alpha_\phi T_n^a) \ , \tag{21}$$

$$D_n = \frac{t}{\ell}\ (T_n^b - T_n^a)(E_{11}\alpha_s + E_{12}\alpha_\phi). \tag{22}$$

5. The transformation from generalized coordinates to element coordinates, $[G_{qu}]$, is calculated if no transverse shear material or thickness is given (i.e., MAT $ID_s = 0$ or $t_s = 0$).

$$[H_{qu}] = [H]^{-1}, \tag{23}$$

where [H] is given explicitly in the stiffness matrix calculations.

6. If transverse shear exists, the shear matrix, [B], is generated. Additional material terms are:

$[D] = I_b[E_b]$, where $[E_b]$ is the bending material 3x3 matrix.

$G_{11} = G$ = Shear coefficient of transverse shear material.

The nonzero terms of [B] are:

$$B_{4,1} = B_{9,1} = \frac{1}{Q}\left[D_{12} n \cos\psi \left(\frac{1}{r_b} - \frac{1}{r_a}\right) - \frac{n}{2}\cos\psi \sin\psi \frac{I_{03}}{\pi}(D_{33} + 2D_{22})\right], \tag{24}$$

$$B_{4,2} = B_{9,2} = \frac{1}{Q}\left[D_{12}\frac{n\ell\cos\psi}{r_b} - \frac{1}{2} n \sin\psi \cos\psi \frac{I_{13}}{\pi}(3D_{33} + D_{22}) + \frac{3}{2} nD_{33}\cos\psi \frac{I_{02}}{\pi}\right], \tag{25}$$

$$B_{4,3} = B_{9,3} = \frac{1}{Q}\left[\frac{1}{2} n^2 D_{33}\cos\psi \frac{I_{03}}{\pi}\right], \tag{26}$$

$$B_{4,4} = B_{9,4} = \frac{1}{Q}\left[\frac{1}{2} n^2 D_{33}\cos\psi \frac{I_{13}}{\pi}\right], \tag{27}$$

$$B_{4,5} = B_{9,5} = \frac{1}{Q}\left[n^2 D_{12}\left(\frac{1}{r_b} - \frac{1}{r_a}\right) - n^2 \sin\psi \frac{I_{03}}{\pi}(2D_{33} + D_{22})\right], \tag{28}$$

$$B_{4,6} + B_{9,6} = \frac{1}{Q}\left[D_{12}\frac{n^2\ell}{r_b} - n^2 \sin\psi \frac{I_{13}}{\pi}(2D_{33} + D_{22}) + \frac{I_{02}}{\pi}(2n^2 D_{33} + \sin^2\psi D_{22})\right], \tag{29}$$

$$B_{4,7} = B_{9,7} = \frac{1}{Q}\left[2D_{11}(r_a - r_b) + D_{12}\frac{n^2\ell^2}{r_b} + \frac{2I_{12}}{\pi}(2n^2 D_{33} + \sin^2\psi D_{22}) - n^2 \sin\psi \frac{I_{23}}{\pi}(2D_{33} + D_{22})\right], \tag{30}$$

$$B_{4,8} = B_{9,8} = \frac{1}{Q}\left[-D_{11}6\ell r_b + D_{12}\frac{n^2\ell^3}{r_b} + \frac{3I_{22}}{\pi}(2n^2D_{33} + \sin^2\psi\, D_{22})\right. \tag{31}$$

$$\left. - n^2\sin\psi\,\frac{I_{33}}{\pi}(2D_{33} + D_{22})\right],$$

$$B_{4,9} = B_{9,9} = \frac{1}{Q}\left[-n\sin\psi\,\frac{I_{02}}{\pi}(D_{22} + D_{33})\right], \tag{32}$$

$$B_{4,10} = B_{9,10} = \frac{1}{Q}\left[n\ell(D_{12} + D_{33}) - n\sin\psi\,\frac{I_{12}}{\pi}(D_{22} + D_{33})\right], \tag{33}$$

where

$$Q = \ell t_s G_{11}\frac{r_a + r_b}{2}\left[1 + \frac{I_{02}}{\pi}\frac{n^2D_{33} + \sin^2\psi\, D_{22}}{\ell t_s G_{11} r_{ar}}\right]. \tag{34}$$

7. The transformation $[\bar{H}]$ transforming displacements in the element coordinate system to displacements in generalized coordinates of the power series is:

$$[\bar{H}] = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
\frac{\cos\psi}{r_a} & 0 & 0 & 0 & \frac{n}{r_a} & 0 & 0 & 0 & 1 & 0 \\
1 & \ell & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & \ell & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & \ell & \ell^2 & \ell^3 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 2\ell & 3\ell^3 & -1 & 0 \\
\frac{\cos\psi}{r_b} & \frac{\ell\cos\psi}{r_b} & 0 & 0 & \frac{n}{r_b} & \frac{n\ell}{r_b} & \frac{n\ell^2}{r_b} & \frac{n\ell^3}{r_b} & 1 & \ell
\end{bmatrix} \tag{35}$$

8. The transformation $[H_{qu}]$ for nonzero transverse shear is:

$$[H_{qu}] = ([\overline{H}] - [B])^{-1} \quad (10x10) \quad . \tag{36}$$

9. $[H_{qu}]$ is partitioned into two 10x5 matrices

$$[H_{qu}] = [H_a \mid H_b] \quad . \tag{37}$$

10. The loads in global coordinates are calculated with:

$$\{P_a\} = [E][H_a]^T\{P_n^q\} \quad , \tag{38}$$

$$\{P_b\} = [E][H_b]^T\{P_n^q\} \quad . \tag{39}$$

4.87.9.5 Element Stress Calculations (Subroutines SCØNE1, SCØNE2, SCØNE3 of Module SDR2)

1. For each element the following quantities are calculated as in section 4.87.9.2:

ℓ, $\sin\psi$, $\cos\psi$, $[E]$, $[H_a]$, $[H_b]$, $[H_{\varepsilon q}]$, $[H_{\psi q}]$, $[H_{\chi q}]$ (using $s = \frac{\ell}{2}$, $r = \frac{r_a + r_b}{2}$).

2. Using the material properties, the following matrices are calculated:

$$[E_m] = \frac{E_1}{(1 - \nu_1^2)} \begin{bmatrix} 1 & -\nu_1 & 0 \\ -\nu_1 & 1 & 0 \\ 0 & 0 & \frac{1 - \nu_1}{2} \end{bmatrix} \quad , \tag{40}$$

$$[D_b] = \frac{E_2 I}{(1 - \nu_2^2)} \begin{bmatrix} 1 & -\nu_2 & 0 \\ -\nu_2 & 1 & 0 \\ 0 & 0 & \frac{1 - \nu_2}{2} \end{bmatrix} , \quad (41)$$

$$[G_s] = \begin{bmatrix} G_3 & 0 \\ 0 & G_3 \end{bmatrix} , \quad (42)$$

where $[E_m]$, $[D_b]$ and $[G_s]$ are computed for membrane, bending and shear materials respectively.

3. The stress matrices are then calculated:

$$[K_s] = \begin{bmatrix} [E_m] & [H_{\varepsilon q}] \\ - - - - - - & \\ [D] & [H_{\chi q}] \\ - - - - - - & \\ t_s[G_s] & [H_{\alpha q}] \end{bmatrix} , \quad (8x10) \quad (43)$$

$$[S_a] = [K_s][H_a][E], (8x6) \quad (44)$$

$$[S_b] = [K_s][H_b][E] , (8x6) . \quad (45)$$

$$St_1 = \alpha_1 E_{11} + \alpha_2 E_{12}$$

$$St_2 = \alpha_1 E_{12} + \alpha_2 E_{12}$$

($\alpha_1 = \alpha_2$ for type 1 materials)

4. Each entry in the EST data block contains data pertaining to the n^{th} harmonic motion of the CØNEAX element. The elements in the EST are ordered by harmonic and CØNEAX I.D. number. All harmonic elements for each CØNEAX are grouped together.

   a. When the harmonic, n, of an element is zero, this indicates it is the first of a group of elements. Storage space is allotted for fourteen 8 by 1 vectors defining the element forces at points. Two UGV vector data blocks must be used to calculate stresses on points. These data blocks correspond to the two subcases "C" and "S" and are solved simultaneously using the same data.

b. Using the $[S_a]$ and $[S_b]$ matrices and the 6 by 1 displacement vectors, $\{u\}$, by their SIL numbers, stress and force vectors are computed.

If $n \neq 0$:

$$\begin{Bmatrix} \bar{\sigma}^c_{sn} \\ \bar{\sigma}^c_{\phi n} \\ \bar{\sigma}^c_{s\phi n} \\ M^c_{sn} \\ M^c_{\phi n} \\ M^c_{s\phi n} \\ V^c_{sn} \\ V^c_{\phi n} \end{Bmatrix} = [S_{an}] \{u^c_{an}\} + [S_{bn}] \{u^c_{bn}\}, \tag{46}$$

$$\begin{Bmatrix} \bar{\sigma}^s_{sn} \\ \bar{\sigma}^s_{\phi n} \\ \bar{\sigma}^s_{s\phi n} \\ M^s_{sn} \\ M^s_{\phi n} \\ M^s_{s\phi n} \\ V^s_{sn} \\ V^s_{\phi n} \end{Bmatrix} = [S_{an}] \{u^s_{an}\} + [S_{bn}] \{u^s_{bn}\}. \tag{47}$$

If n = 0:

$$\left\{\begin{array}{c} \bar{\sigma}_{so} \\ \bar{\sigma}_{\phi o} \\ \bar{\sigma}_{s\phi o} \\ M_{so} \\ M_{\phi o} \\ M_{s\phi o} \\ V_{so} \\ V_{\phi o} \end{array}\right\} = [S_{ao}]\,(\{u^s_{ao}\} + \{u^c_{ao}\}) - [S_{bo}]\,(\{u^s_{bo}\} + \{u^c_{bo}\}). \qquad (48)$$

c. The temperature effects are added using the GPTT data for the two subcases, (T^c_α and T^s_α)

$$(\sigma^{c'}_{sn}) = \sigma^c_{sn} + S_{t1}\,\bar{\bar{T}} \qquad (49)$$

$$(\sigma^{c'}_{n}) = \sigma^c_{\phi n} + S_{t2}\,\bar{T} \qquad (50)$$

$$(\sigma^{c'}_{s\phi n}) = \sigma^c_{s\phi n} \quad . \qquad (51)$$

where

$$\bar{T} = \frac{1}{2}\,(T^n_a + T^n_b) - T_o,\ n = 0$$

$$\bar{T} = \frac{1}{2}\,(T^n_a + T^n_b)^n \quad n \neq 0$$

The same equations are used for the "S" set and when n = 0.

d. The harmonic stresses are calculated by the equations for i = 1,2,3:

$$\sigma^{c}_{sni} = (\sigma^{c'}_{sn}) + \frac{M^{c}_{sn}\, ci}{I} \quad , \tag{52}$$

$$\sigma^{c}_{\phi n} = (\sigma^{c'}_{\phi n}) + \frac{M^{c}_{\phi n}\, ci}{I} \quad , \tag{53}$$

$$\sigma^{c}_{s\phi n} = (\sigma^{c\,'}_{s\phi n}) + \frac{M^{c}_{s\phi n}\, ci}{I} \quad . \tag{54}$$

The equations are repeated for the S set and when n = 0.

e. Principal stresses (σ_1, σ_2, θ, τ_{max} etc.) are calculated as with the TRIA1 or QUAD1 element, except that when $n \neq 0$ the data are calculated for both the S and C sets.

f. The incremental element stresses or forces for the points on the cone are calculated from the following equations for $j = 1,2,\ldots,14$:

For $n \neq 0$:

$$\delta\sigma_{sj} = (\sigma_{sn}^{C'}) \cos(n\phi_j) + (\sigma_{sn}^{S'}) \sin(n\phi_j) , \quad (55)$$

$$\delta\sigma_{\phi j} = (\sigma_{\phi n}^{C'}) \cos(n\phi_j) + (\sigma_{\phi n}^{S'}) \sin(n\phi_j) , \quad (56)$$

$$\delta\sigma_{s\phi j} = (\sigma_{s\phi n}^{C'}) \sin(n\phi_j) - (\sigma_{s\phi n}^{S'}) \cos(n\phi_j) , \quad (57)$$

$$\delta M_{sj} = M_{sn}^{C} \cos(n\phi_j) + M_{sn}^{S} \sin(n\phi_j), \quad (58)$$

$$\delta M_{\phi j} = M_{\phi n}^{C} \cos(n\phi_j) + M_{\phi n}^{S} \sin(n\phi_j) , \quad (59)$$

$$\delta M_{s\phi j} = M_{s\phi n}^{C} \sin(n\phi_j) - M_{s\phi n}^{S} \cos(n\phi_j) , \quad (60)$$

$$\delta V_{si} = V_{sn}^{C} \cos(n\phi_j) + V_{sn}^{S} \sin(n\phi_j), \quad (61)$$

$$\delta V_{\phi j} = V_{\phi n}^{C} \sin(n\phi_j) - V_{\phi n}^{S} \cos(n\phi_j) . \quad (62)$$

g. The incremental stress and force values are added to the running sums for the points. After the last element is calculated (n = N), the forces and stresses for the points are calculated and output. The equations are identical to steps d and e of this section except that 1) the "S" and "C" sets are not used and 2) up to 14 points may be calculated for output for each physical element.

Since the user may leave some spaces blank on the property card for this element, only one of the $\phi_j = 0$ points is used in the calculation.

4.87.9.6 Differential Stiffness Matrix Calculations (Subroutine DCØNE of Module DSMG1)

The data input from the ECPT to the DCØNE subroutine are the same as those given in section 4.87.9.1. Additional data for the generation of the differential stiffness matrix are as follows:

$\{u_a^o\}$, $\{u_b^o\}$ - Displacement vectors of the zero harmonic (extracted from the UGV data block)

T_a^o, T_b^o - Element loading temperatures of the zero harmonic (extracted from the GPTT data block)

The first part of the calculations involves calculation of the element force components. The following steps are performed with harmonic number n = 0.

1. The 10 by 10 transformation matrix $[H_{uq}^o]$ is computed from:

$$[H_{uq}^n] = [\bar{H}_{uq}] + \{H_{u\gamma}\}\{H_{\gamma_s q}\}^T \tag{63}$$

where $[\bar{H}_{uq}]$, a 10 by 10 matrix, and $\{H_{u\gamma}\}$, a column vector, are derived in the NASTRAN Theoretical Manual, section 5.9.5.3, and $\{H_{\gamma_s q}\}^T$, a row vector, is explicitly written out in Equation 85 of section 5.9 of the NASTRAN Theoretical Manual.

2. The 10 generalized displacement quantities q_i are

$$\{q\} = [H_{uq}^o]^{-1} \begin{Bmatrix} [E]^T \{u_a^o\} \\ \hline [E]^T \{u_b^o\} \end{Bmatrix} \tag{64}$$

where $\{u_a^o\}$ and $\{u_b^o\}$ are the 6 by 1 displacement vectors, and [E] is calculated as in Equation 4 of section 4.87.9.2.

3. The strain coefficients are

$$\begin{Bmatrix} \Delta\varepsilon_s \\ \Delta\varepsilon_\phi \\ \Delta\varepsilon_{s\phi} \end{Bmatrix} = \{\alpha\} \frac{(T_b^c - T_a^o)}{\ell} \tag{65}$$

$$\begin{Bmatrix} \varepsilon_s \\ \varepsilon_\phi \\ \varepsilon_{s\phi} \end{Bmatrix} = T_a^o \{\alpha\} \tag{66}$$

where T_a^o and T_b^o are the loading temperatures at the grid points, the $\{\alpha\}$ vector is obtained from the MPT data block via subroutine MAT and ℓ is calculated as in Equation 1 of section 4.87.9.2.

4. The force coefficients are calculated:

$$a_o = t_m G_{12} (\sin \psi \, q_3 + \cos \psi \, q_5) \ , \tag{67}$$

$$a_1 = t_m G_{12} (\sin \psi \, q_4 + \cos \psi \, q_6) \ , \tag{68}$$

$$a_2 = t_m G_{12} \cos \psi \, q_7 \ , \tag{69}$$

$$a_3 = t_m G_{12} \cos \psi \, q_8 \ , \tag{70}$$

$$b_o = t_m G_{22} (\sin \psi \, q_3 + \cos \psi \, q_5) \ , \tag{71}$$

$$b_1 = t_m G_{22} (\sin \psi \, q_4 + \cos \psi \, q_6) \ , \tag{72}$$

$$b_2 = t_m G_{22} \cos \psi \, q_7 \ , \tag{73}$$

$$b_3 = t_m G_{22} \cos \psi \, q_8 \ , \tag{74}$$

$$c_o = t_m G_{11} (q_4 - \varepsilon_s) - t_m G_{12} \varepsilon_\phi \ , \tag{75}$$

$$c_1 = -t_m G_{11} \Delta\varepsilon_s - t_m G_{12} \Delta\varepsilon_\phi \ , \tag{76}$$

$$d_o = t_m G_{12} (q_4 - \varepsilon_s) - t_m G_{22} \varepsilon_\phi \ , \tag{77}$$

$$d_1 = -t_m G_{12} \Delta\varepsilon_s - t_m G_{22} \Delta\varepsilon_\phi \ , \tag{78}$$

where G_{11}, G_{12} and G_{22} are elements of the 3 by 3 symmetric material properties matrix, [G].

5. The geometry coefficients are calculated:

$$I_{mn} = \int_o^{\ell} s^m \, r^{1-n} \, ds \qquad \begin{cases} m = 0, 1, \ldots, 9 \\ n = 0, 1, 2, 3 \end{cases} ; \tag{79}$$

where

$$r = r_a + \left(\frac{r_b - r_a}{\ell} \right) s \quad . \tag{80}$$

An explicit formula for the evaluation of I_{mn} is given in the NASTRAN Theoretical Manual, section 5.9.5.8.

6. The following coefficients for the computation of the differential stiffness matrix are calculated:

$$\begin{aligned} A_{mn} = {} & a_o \, I_{m,\, n+1} + a_1 \, I_{m+1,\, n+1} + a_2 \, I_{m+2,\, n+1} \\ & + a_3 \, I_{m+3,\, n+1} + c_o \, I_{m,\, n} + c_1 \, I_{m+1,\, n} \quad , \end{aligned} \tag{81}$$

$$\begin{aligned} B_{mn} = {} & b_o \, I_{m,\, n+1} + b_1 \, I_{m+1,\, n+1} + b_2 \, I_{m+2,\, n+1} \\ & + b_3 \, I_{m+3,\, n+1} + d_o \, I_{m,\, n} + d_1 \, I_{m+1,\, n} \quad , \end{aligned} \tag{82}$$

$$C_{mn} = A_{mn} + B_{mn} \quad , \tag{83}$$

where m = 0, 1....6; n = 0, 1, 2.

Note: The index n used above is a dummy index and is not the harmonic number.

The second part of the calculations involves generating the differential stiffness matrix. The remaining steps use n as the harmonic number of the element.

1. The nonzero elements of the symmetric differential stiffness matrix $[K^{qd}]$, in generalized coordinates, are given in Table 1c below.

Table 1c. Nonzero Elements of the Differential Stiffness Matrix, $[K^{qd}]$.

$$K_{11}^{qd} = \cos^2\psi B_{02} + \frac{1}{4}\sin^2\psi C_{02}$$

$$K_{12}^{qd} = \cos^2\psi B_{12} + \frac{1}{4}\sin\psi C_{01} + \frac{1}{4}\sin^2\psi C_{12}$$

$$K_{13}^{qd} = \frac{1}{4}n\sin\psi C_{02}$$

$$K_{14}^{qd} = \frac{1}{4}n\sin\psi C_{12}$$

$$K_{15}^{qd} = n\cos\psi B_{02}$$

$$K_{16}^{qd} = n\cos\psi B_{12}$$

$$K_{17}^{qd} = n\cos\psi B_{22}$$

$$K_{18}^{qd} = n\cos\psi B_{32}$$

$$K_{22}^{qd} = \cos^2\psi B_{22} + \frac{1}{4}C_{00} + \frac{1}{2}\sin\psi C_{11} + \frac{1}{4}\sin^2\psi C_{22}$$

$$K_{23}^{qd} = \frac{1}{4}nC_{01} + \frac{1}{4}n\sin\psi C_{12}$$

$$K_{24}^{qd} = \frac{1}{4}nC_{11} + \frac{1}{4}n\sin\psi C_{22}$$

$$K_{25}^{qd} = n\cos\psi B_{12}$$

$$K_{26}^{qd} = n\cos\psi B_{22}$$

$$K_{27}^{qd} = n\cos\psi B_{32}$$

$$K_{28}^{qd} = n\cos\psi B_{42}$$

$$K_{33}^{qd} = \frac{1}{4}n^2C_{02}$$

$$K_{34}^{qd} = \frac{1}{4}n^2C_{12}$$

Table 1c (con'd). Elements of the Differential Stiffness Matrix, $[K^{qd}]$.

$$K^{qd}_{44} = \frac{1}{4} n^2 C_{22}$$

$$K^{qd}_{55} = n^2 B_{02}$$

$$K^{qd}_{56} = n^2 B_{12}$$

$$K^{qd}_{57} = n^2 B_{22}$$

$$K^{qd}_{58} = n^2 B_{32}$$

$$K^{qd}_{66} = A_{00} + n^2 B_{22}$$

$$K^{qd}_{67} = 2A_{10} + n^2 B_{32}$$

$$K^{qd}_{68} = 3A_{20} + n^2 B_{42}$$

$$K^{qd}_{77} = 4A_{20} + n^2 B_{42}$$

$$K^{qd}_{78} = 6A_{30} + n^2 B_{52}$$

$$K^{qd}_{88} = 9A_{40} + n^2 B_{62}$$

The formulas for n = 0 are the same as in Table 1c except that they are all multiplied by 2. The nonzero terms for n = 0 fall into two uncoupled sets which are

(11)	(12)		(66)	(67)	(68)
	(22)			(77)	(78)
					(88)
Effect on Twisting			Effect on Axisymmetric Deformation		

2. The 10 by 10 transformation matrix, $[H^n_{uq}]$, from generalized coordinates to element coordinates, for the n^{th} harmonic is computed as in Equation 63. The matrix is inverted and partitioned into two 10 by 5 matrices:

$$[H^{n}_{uq}]^{-1} \Longrightarrow [H_a \mid H_b] \quad . \tag{84}$$

3. The 6 by 6 differential stiffness matrices in global coordinates are:

$$[K^{d}_{ij}] = [E]\,[H_i]^T\,[K^{qd}]\,[H_j]\,[E]^T \quad , \tag{85}$$

where i = pivot grid point; j = a, b; and [E] is computed as in Equation 4 of section 4.87.9.2.

4.87.10 The TRIARG Element

4.87.10.1 Input Data for the TRIARG Element

1. The ECPT/EST entries for the axisymmetric triangular ring (TRIARG) element are:

Symbol	Descriptions
SIL_1, SIL_2, SIL_3	Scalar index numbers for the three grid points.
γ	Material property orientation angle (degrees)
Mat I.D.	Material property identification number.
N_1, X_1, Y_1, Z_1 N_2, X_2, Y_2, Z_2 N_3, X_3, Y_3, Z_3	Local coordinate system number and location in basic coordinates of the three grid points.
t_μ	Element temperature for material properties.

For this element, Y_i must equal zero for i = 1, 2 and 3 and, we define:

$$\{R_s\} = \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \end{Bmatrix} , \tag{1}$$

$$\{Z_s\} = \begin{Bmatrix} Z_{s1} \\ Z_{s2} \\ Z_{s3} \end{Bmatrix} = \begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{Bmatrix} . \tag{2}$$

2. Coordinate system data

The location (X_i, Y_i, Z_i) and local coordinate system number (N_i) of each grid point are used to calculate the 3 by 3 global-to-basic coordinate system transformation matrices, $[T_i]$, i = 1, 2, 3.

3. Material data

The material property identification number, Mat I.D., and the element temperature for material properties, t_μ, are used to select the following data items. For this element, material properties may be defined on a MAT1 or MAT3 but not a MAT2 bulk data card.

Symbol	Description
E_r, E_θ, E_z	Young's moduli in the radial, tangential and axial directions respectively.
$\nu_{r\theta}, \nu_{\theta z}, \nu_{zr}$	Poisson's ratios in the three directions indicated.
ρ	Mass density
$G_{r\theta}, G_{\theta z}, G_{rz}$	Shear moduli in the three directions indicated.
$\alpha_r, \alpha_\theta, \alpha_z$	Coefficients of thermal expansion in the three directions indicated.
T_o	Thermal expansion reference temperature.
g_e	Structural element damping coefficient.

4.87.10.2 General Geometric Calculations

1. Local coordinate calculations are:

$$Z_{min} = \text{minimum of } (Z_{s1}, Z_{s2}, Z_{s3}), \tag{3}$$

$$\{R_L\} = \{R_s\}, \tag{4}$$

$$\{Z_L\} = \{Z_s\} - \begin{Bmatrix} Z_{min} \\ Z_{min} \\ Z_{min} \end{Bmatrix} . \tag{5}$$

2. The transformation from field coordinates to grid point degrees of freedom is given by (R_{Li} and Z_{Li} are the i^{th} components of $\{R_L\}$ and $\{Z_L\}$ respectively):

$$[\overline{\Gamma}_{\beta q}] = \begin{bmatrix} 1 & R_{L1} & Z_{L1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & R_{L1} & Z_{L1} \\ 1 & R_{L2} & Z_{L2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & R_{L2} & Z_{L2} \\ 1 & R_{L3} & Z_{L3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & R_{L3} & Z_{L3} \end{bmatrix}_{6x6} , \tag{6}$$

$$[\Gamma_{\beta q}] = [\bar{\Gamma}_{\beta q}]^{-1} . \tag{7}$$

3. The transformation matrix from two to three degrees of freedom per point is:

$$[\Gamma_{qs}] = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}_{6x9} . \tag{8}$$

4.87.10.3 Integral Calculations

1. The integrals over the area of the cross-section are of the form:

$$\delta_{ij} = r^i z^j dz dr, \tag{9}$$

for the values:

$$\delta_{-10}, \delta_{-11}, \delta_{00}, \delta_{10}, \delta_{20}, \delta_{30}, \delta_{01}, \delta_{11}, \delta_{21}, \delta_{02}, \delta_{12}, \delta_{-12} .$$

To accomplish this we integrate in two parts:

a. From line $Z = K_{12}r + m_{12}$ to line $Z = K_{13}r + m_{13}$

where

$$K_{ij} = \frac{Z_{Lj} - Z_{Li}}{R_{Lj} - R_{Li}}, \tag{10}$$

and

$$m_{ij} = -\frac{R_{Li}Z_{Lj} - R_{Lj}Z_{Li}}{R_{Lj} - R_{Li}}, \tag{11}$$

and from point R_{L1} to point R_{L3}.

b. From line $Z = K_{12}r + m_{12}$ to $Z = K_{32}r + m_{32}$ and from point R_{L3} to R_{L2}.

For the case where

$$R_{L1} = R_{L2} \text{ or } \left|\frac{R_{L2} - R_{L1}}{R_{L2}}\right| < 10^{-5}$$

we must integrate differently, that is, from line $Z = K_{32}r + m_{32}$ to $Z = K_{13}r + m_{13}$ and from R_{L1} to R_{L3}.

2. After the integrals are computed, a check is made to determine if an excessive amount of round-off error occurred. If round-off was excessive, an approximate integral can be calculated.

These tests are:

If any $\delta_{ij}<0$, then approximation must be used.

If $\sigma_{12} \leq \sigma_{02}$, or $\delta_{-12} \geq \delta_{12}$, or $\delta_{-12} > \delta_{02}$, then approximation must be used.

If $\Delta r \leq \hat{r}$ or $\Delta Z \leq \hat{Z}$, then approximation must be used. The terms Δr, ΔZ, $\hat{r}$ and $\hat{Z}$ are:

$$\Delta r = \max.(|R_{L1} - R_{L2}|, |R_{L2} - R_{L3}|, |R_{L3} - R_{L1}|), \tag{12}$$

$$\hat{r} = [\min.(R_{L1}, R_{L2}, R_{L3})]/10, \tag{13}$$

$$\Delta Z = \max.(|Z_{L1} - Z_{L2}|, |Z_{L2} - Z_{L3}|, |Z_{L3} - Z_{L1}|), \tag{14}$$

$$\hat{Z} = [\min (Z_{L1}, Z_{L2}, Z_{L3})]/10. \tag{15}$$

The approximation is:

$$\sigma_{ij} = (r_a)^i (Z_a)^j A, \tag{16}$$

where

$$r_a = \frac{1}{3}[R_{L1} + R_{L2} + R_{L3}], \tag{17}$$

$$Z_a = \frac{1}{3}[Z_{L1} + Z_{L2} + Z_{L3}], \tag{18}$$

$$A = \frac{1}{2}[R_{L1}(Z_{L2}-Z_{L3}) + R_{L2}(Z_{L3}-Z_{L1}) + R_{L3}(Z_{L1}-Z_{L2})]. \tag{19}$$

3. Form the matrix of integrals:

$$[\tilde{D}] = 2\pi \begin{bmatrix} 0 & \delta_{10} & 0 & 0 & 0 & 0 \\ \delta_{00} & \delta_{10} & \delta_{01} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \delta_{10} \\ 0 & 0 & \delta_{10} & 0 & \delta_{10} & 0 \end{bmatrix}_{4x6} . \tag{20}$$

4.87.10.4 Elastic Constants Matrix Calculations

1. Generate the transformation from material axis to element geometric axis:

$$[T_{eo}] = \begin{bmatrix} \cos^2\gamma & 0 & \sin^2\gamma & \sin\gamma\cos\gamma \\ 0 & 1 & 0 & 0 \\ \sin^2\gamma & 0 & \cos^2\gamma & -\sin\gamma\cos\gamma \\ -2\sin\gamma\cos\gamma & 0 & 2\sin\gamma\cos\gamma & \cos^2\gamma-\sin^2\gamma \end{bmatrix}_{4x4} . \tag{21}$$

2. Generate the matrix of elastic constants for an orthotropic body with respect to cylindrical coordinates:

$$[E_m] = \frac{1}{\Delta} \begin{bmatrix} E_r(1-\nu_{\theta z}\nu_{z\theta}) & & & \\ E_r(\nu_{\theta r}+\nu_{zr}\nu_{\theta z}) & E_\theta(1-\nu_{rz}\nu_{zr}) & \text{(Symmetric)} & \\ E_r(\nu_{zr}+\nu_{\theta r}\nu_{z\theta}) & E_\theta(\nu_{z\theta}+\nu_{r\theta}\nu_{zr}) & E_z(1-\nu_{r\theta}\nu_{\theta r}) & \\ 0 & 0 & 0 & G_{rz}\Delta \end{bmatrix}_{4x4} , \quad (22)$$

where

$$\nu_{\theta r} = \nu_{r\theta} E_\theta/E_r , \quad (23)$$

$$\nu_{z\theta} = \nu_{\theta z} E_z/E_\theta , \quad (24)$$

$$\nu_{rz} = \nu_{zr} E_r/E_z , \quad (25)$$

$$\Delta = 1 - \nu_{r\theta}\nu_{\theta r} - \nu_{\theta z}\nu_{z\theta} - \nu_{zr}\nu_{rz} - \nu_{r\theta}\nu_{\theta z}\nu_{zr} - \nu_{rz}\nu_{\theta r}\nu_{z\theta} . \quad (26)$$

3. Calculate the elastic constants matrix in element geometric axes:

$$[E_g] = [T_{eo}]^T[E_m][T_{eo}] . \quad (27)$$

4.87.10.5 Stiffness Matrix Generation (Subroutine KTRIRG of Module SMA1)

1. Generate the element stiffness matrix in field coordinates:

$$[\tilde{K}] =$$

$$2\pi \begin{bmatrix} E_{22}\delta_{-10} & & & & & \\ (E_{12}+E_{22})\delta_{00} & (E_{11}+2E_{12}+E_{22})\delta_{10} & & & & \\ E_{22}\delta_{-11}+E_{24}\delta_{00} & (E_{12}+E_{22})\delta_{01}+(E_{14}+E_{24})\delta_{10} & E_{22}\delta_{-12}+2E_{24}\delta_{01}+E_{44}\delta_{10} & & & \\ 0 & 0 & 0 & 0 & & \\ E_{24}\delta_{00} & (E_{14}+E_{24})\delta_{10} & E_{24}\delta_{01}+E_{44}\delta_{10} & 0 & E_{44}\delta_{10} & \\ E_{23}\delta_{00} & (E_{13}+E_{23})\delta_{10} & E_{23}\delta_{01}+E_{34}\delta_{10} & 0 & E_{34}\delta_{10} & E_{33}\delta_{10} \end{bmatrix}_{6\times 6} \quad (28)$$

where E_{ij} is an element of $[E_g]$.

2. Transform the element stiffness matrix from field coordinates to grid point degrees of freedom:

$$[\bar{K}] = [\Gamma_{\beta q}]^T[\tilde{K}][\Gamma_{\beta q}]. \quad (29)$$

3. Transform the element stiffness matrix from two to three degrees of freedom per point.

$$[K] = [\Gamma_{qs}]^T[\bar{K}][\Gamma_{qs}]. \quad (30)$$

4. The 3 by 3 partitions $[K^3_{pj}]$ of $[K]$ corresponding to the pivot point p are transformed:

$$[K^3_{pj}] = [T_p]^T[K^3_{pj}][T_j], \quad j = 1,2,3 \quad (31)$$

5. Finally these 3 by 3 partitions are expanded to 6 by 6 partitions:

$$[K_{pj}] = \begin{bmatrix} K_{pj}^{3} & \vdots & 0 \\ \cdots & \vdots & \cdots \\ 0 & \vdots & 0 \end{bmatrix} \tag{32}$$

4.87.10.6 Mass Matrix Calculations (Subroutine MTRIRG of Module SMA2)

1. Generate the consistent mass matrix in field coordinates:

$$[\tilde{M}] = 2\pi \begin{bmatrix} \bar{m}_{11}\delta_{10} & & & & & & \\ \bar{m}_{11}\delta_{20} & \bar{m}_{11}\delta_{30} & & & \text{(Symmetric)} & & \\ \bar{m}_{11}\delta_{11} & \bar{m}_{11}\delta_{21} & m_{11}\delta_{12} & & & & \\ 0 & 0 & 0 & \bar{m}_{22}\delta_{10} & & & \\ 0 & 0 & 0 & \bar{m}_{22}\delta_{20} & \bar{m}_{22}\delta_{30} & & \\ 0 & 0 & 0 & \bar{m}_{22}\delta_{11} & \bar{m}_{22}\delta_{21} & \bar{m}_{22}\delta_{12} & \end{bmatrix}_{6x6} \tag{33}$$

where

$$[\bar{m}] = \begin{bmatrix} \rho & 0 \\ 0 & \rho \end{bmatrix} = \begin{bmatrix} \bar{m}_{11} & 0 \\ 0 & \bar{m}_{22} \end{bmatrix}. \tag{34}$$

2. Transform the mass matrix from field coordinates to grid point degrees of freedom:

$$[\bar{M}] = [\Gamma_{\beta q}]^{T}[\tilde{M}][\Gamma_{\beta q}]. \tag{35}$$

3. Transform the mass matrix from two to three degrees of freedom per point:

$$[M] = [\Gamma_{qs}]^{T}[\bar{M}][\Gamma_{qs}]. \tag{36}$$

4. The 6 by 6 partitions, $[M_{pj}]$, are calculated as in Equations 31 and 32.

4.87.10.7 Thermal Load Calculations (Subroutine TTRIRG of Module SSG1)

1. Form the vector of thermal strains:

$$\{\bar{\alpha}\} = \left(T_{avg} - T_o\right) \begin{Bmatrix} \alpha_r \\ \alpha_\theta \\ \alpha_z \\ 0 \end{Bmatrix} \quad (4x1). \tag{37}$$

where T_{avg} is the average loading temperature at the grid points.

2. Compute thermal load vector in grid point degrees of freedom:

$$\{\bar{F}_T\} = [\Gamma_{\beta q}]^T [\tilde{D}]^T [E_g] \{\alpha\} \quad (6x1). \tag{38}$$

3. Transform thermal load from two to three degrees of freedom per point

$$\{F_T\} = [\Gamma_{qs}]^T \{\bar{F}_T\} \quad (9x1). \tag{39}$$

4. Each partition, $\{F_T^3\}$, of length 3 of $\{F_T\}$ is transformed to global coordinates by

$$\{F_T^3\}_g = [T_i]^T \{F_T^3\} \ . \tag{40}$$

5. These vectors are added to the overall load vector, $\{P_g\}$.

4.87.10.8 Element Force and Stress Calculations (Subroutines STRIR1 and STRIR2 of Module SDR2)

Element stress and force data items are calculated in two phases. The first phase (subroutine STRIR1) calculates the element stiffness and stress matrices. The second phase (subroutine STRIR2) calculates the actual element forces and stresses from the various subcase displacement vectors.

Phase 1 calculations are as follows:

1. Form the element stiffness matrix, [K], as in section 4.87.10.5.

2. Compute the constants:

$$r_o = \frac{1}{3} \sum_{i=1}^{3} R_{Li}, \tag{41}$$

$$z_o = \frac{1}{3} \sum_{i=1}^{3} Z_{Li}. \tag{42}$$

3. Form the $[D_o]$ matrix:

$$[D_o] = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ \frac{1}{r_o} & 1 & \frac{z_o}{r_o} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}_{4x6} . \tag{43}$$

4. Compute the stress matrix

$$[\bar{S}] = [E_g][D_o][\Gamma_{\beta q}]. \tag{44}$$

5. Transform the stress matrix from two to three degrees of freedom per point:

$$[S] = [\bar{S}][\Gamma_{qs}] . \tag{45}$$

6. Transform the stress matrix from basic to local coordinates:

$$[S]_\ell = [S][T_{123}] , \tag{46}$$

where

$$[T_{123}] = \left[\begin{array}{c|c|c} T_1 & 0 & 0 \\ \hline 0 & T_2 & 0 \\ \hline 0 & 0 & T_3 \end{array}\right] . \tag{47}$$

7. Compute the thermal stress vector

$$\{T_s\} = [E_g]\{\bar{\alpha}\} . \tag{48}$$

Phase 2 calculations are as follows:

1. Extract the displacement vector, $\{\Delta\}$, at the three translational components of the grid points from the global displacement vector.

2. Calculate the element forces:

$$\{P\} = [K]\{\Delta\} . \tag{49}$$

3. Calculate the element stresses:

$$\{\sigma\} = [S]_{\ell}\{\Delta\} - T_d\{T_s\} , \tag{50}$$

where

$$T_d = T_{avg} - T_o . \tag{51}$$

4.87.10.9 Thermal Analysis Calculations for the TRIARG and TRAPRG Elements (Subroutine HRING of Module SMA1)

If a heat transfer problem is being solved, this routine is used instead of subroutines KTRIARG and KTRAPR. The following checks are made on the geometry:

$$\left.\begin{array}{l} y = 0 \\ x_i > 0 \end{array}\right\} \; i = 1, 2, 3 \text{ (or 4)}.$$

If these conditions are not met, a fatal error exists. The order of the grid points is also checked. The following equation must be true:

$$(x_s - x_r)(z_t - z_s) - (x_t - x_s)(z_s - z_r) > 0,$$

where the indices r, s, t correspond to three grid points in the element where

$$r, s, t = 1, 2, 3 \text{ for triangles,}$$

$$\text{or} \quad \left.\begin{array}{l} s, t = 1, 2, 3 \\ 2, 3, 4 \\ 3, 4, 1 \\ 4, 1, 2 \end{array}\right\} \text{ for trapezoids.}$$

The conduction matrix for TRIARG is computed by calling for a TRMEM, whose thickness is calculated from

$$t = 2\pi(x_1 + x_2 + x_3)/3.$$

To compute the conduction matrix for TRAPRG, it will be divided into overlapping triangles. The mapping is exactly the same as the mapping of quadrilaterals into triangles. The material orientation angles for the triangles must be computed as was done for QDMEM. The thickness of each of the triangles is given by

$$t = \pi(x_r + x_s + x_t)/3,$$

where r, s, t, are the three vertex indices used from the mapping matrix. The KTRMEM subroutine is then called four times.

4.87.11 The TRAPRG Element

4.87.11.1 Input Data for the TRAPRG Element

1. The ECPT/EST entries for the axisymmetric trapezoidal ring (TRAPRG) element are

Symbol	Description
$SIL_1, SIL_2, SIL_3, SIL_4$	Scalar index numbers for the four grid points.
γ	Material property orientation angle (degrees).
Mat. I.D.	Material property identification number.
N_1, X_1, Y_1, Z_1 N_2, X_2, Y_2, Z_2 N_3, X_3, Y_3, Z_3 N_4, X_4, Y_4, Z_4	Local coordinate system number and location in basic coordinates of the four grid points.
t_μ	Element temperature for material properties

For this element Y_i must equal zero for i = 1, 2, 3 and 4, and we define:

$$\{R_s\} = \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{Bmatrix} , \tag{1}$$

$$Z_s = \begin{Bmatrix} Z_{s1} \\ Z_{s2} \\ Z_{s3} \\ Z_{s4} \end{Bmatrix} = \begin{Bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \end{Bmatrix} . \tag{2}$$

2. Geometry Input

The location (X_i, Y_i, Z_i) and local coordinate system number (N_i) of each grid point are used to calculate the 3 by 3 global-to-basic coordinate system transformation matrices, $[T_i]$, i = 1,2,3,4.

3. Material Property Input

The material property input for the TRAPRG element is the same as that for the TRIARG element (see section 4.87.10.1).

4.87.11.2 General Calculations

1. Local coordinate calculations are:

$$Z_{min} = \text{minimum of } (Z_{s1}, Z_{s2}, Z_{s3}, Z_{s4}), \tag{3}$$

$$\{R_L\} = \{R_s\}, \tag{4}$$

$$\{Z_L\} = \{Z_s\} - \begin{Bmatrix} Z_{min} \\ Z_{min} \\ Z_{min} \\ Z_{min} \end{Bmatrix} . \tag{5}$$

Let R_{Li} and Z_{Li} be the i^{th} component of $\{R_L\}$ and $\{Z_L\}$ respectively. To insure the user has input his grid points in accordance with the restrictions set down in section 2 of the User's Manual, the following tests are made:

If $R_{L1} \geq R_{L2}$ or $R_{L4} \geq R_{L3}$ or $Z_{L4} \leq Z_{L1}$, then the user has violated the restriction that the grid points be ordered in a counterclockwise manner and a user fatal error occurs.

If $|Z_{L1} - Z_{L2}| > .001$ or $|Z_{L3} - Z_{L4}| > .001$, then the restriction that the line joining grid points 1 and 2 and the line joining grid points 3 and 4 be parallel to the r-axis has been violated and a user fatal error occurs.

2. Test for a rectangle. Define:

$$R_{M14} = (R_{L1} + R_{L4})/2, \tag{6}$$

$$R_{M23} = (R_{L2} + R_{L3})/2. \tag{7}$$

If $\left|\frac{R_{L1} - R_{L4}}{R_{M14}}\right| < 0.005$ then $R_{L1} = R_{L4} = R_{M14}$.

If $\left|\frac{R_{L2} - R_{L3}}{R_{M23}}\right| < 0.005$ then $R_{L2} = R_{L3} = R_{M23}$.

If $R_{L1} = R_{L4}$ and $R_{L2} = R_{L3}$, then the element is rectangular.

If $R_{L1} = R_{L4} = 0$, then the element is a core element.

3. Generate the transformation matrix from field coordinates to grid point degrees of freedom:

$$[\bar{H}] = \begin{bmatrix} 1 & R_{L1} & Z_{L1} & R_{L1}Z_{L1} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & R_{L1} & Z_{L1} & R_{L1}Z_{L1} \\ 1 & R_{L2} & Z_{L1} & R_{L2}Z_{L1} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & R_{L2} & R_{L1} & R_{L2}Z_{L1} \\ 1 & R_{L3} & Z_{L4} & R_{L3}Z_{L4} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & R_{L3} & Z_{L4} & R_{L3}Z_{L4} \\ 1 & R_{L4} & Z_{L4} & R_{L4}Z_{L4} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & R_{L4} & Z_{L4} & R_{L4}Z_{L4} \end{bmatrix}_{8x8} . \tag{8}$$

$$[H] = [\bar{H}]^{-1} . \tag{9}$$

4. Generate the transformation matrix from two to three degrees of freedom per point:

$$[\Gamma_{qs}] = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}_{8x12} . \tag{10}$$

5. If the element is a core element, then:

$$h_{1j} = h_{3j} = 0 \qquad j = 1,2,\ldots,8 \ ,$$
$$h_{i1} = h_{i7} = 0 \qquad i = 1,2,\ldots,8 \ . \tag{11}$$

where h_{ij} is an element of [H].

4.87.11.3 Integral Calculations

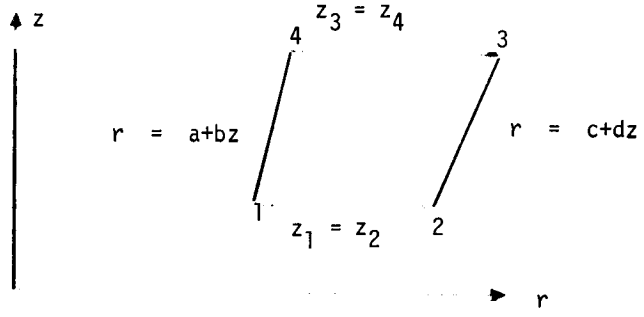
a. Compute the integrals over the cross-section of the trapezoid that are of the form:

$$I_{Pq} = \iint_{rz} r^P z^q \, dr dz \tag{12}$$

for the values:

$I_{-10}, I_{-11}, I_{-12}, I_{00}, I_{01}, I_{02}, I_{10}, I_{11}, I_{12}, I_{20}, I_{21}, I_{22}, I_{30}, I_{31}, I_{32}$.

The limits of integration are chosen depending on the geometric shape of the trapezoid.



If the lines between points 1 and 4 and between points 2 and 3 are defined by the equations

$$r = a + bz, \tag{13}$$

$$r = c + dz, \tag{14}$$

respectively, then:

$$a = R_{L1} - \left(\frac{R_{L4} - R_{L1}}{Z_{L4} - Z_{L1}}\right) Z_{L1}, \tag{15}$$

$$b = \frac{R_{L4} - R_{L1}}{Z_{L4} - Z_{L1}}, \tag{16}$$

$$c = R_{L2} - \left(\frac{R_{L3} - R_{L2}}{Z_{L3} - Z_{L2}}\right) Z_{L2}, \tag{17}$$

$$d = \frac{R_{L3} - R_{L2}}{Z_{L3} - Z_{L2}} . \tag{18}$$

In general, the integration takes the form:

$$I_{Pq} = \int_{z_1}^{z_4} \int_{a+bz}^{c+dz} r^P z^q \, drdz. \tag{19}$$

For the case with the side r = c + dz parallel to the axis of symmetry (the z axis) we have:

$$I_{Pq} = \int_{z_1}^{z_4} \int_{a+bz}^{c} r^P z^q \, drdz. \tag{20}$$

For the case with the side r = a + bz parallel to the axis of symmetry we have:

$$I_{Pq} = \int_{z_1}^{z_4} \int_{a}^{c+dz} r^P z^q \, drdz. \tag{21}$$

And finally for the rectangle, the integration takes the form

$$I_{Pq} = \int_{z_1}^{z_4} \int_{a}^{c} r^P z^q \, dr dz. \tag{22}$$

4.87.11.4 Elastic Constants Matrix Calculation

The elastic constants matrix in element coordinates, $[E_g]$, for the TRAPRG element is calculated identically to the elastic constants matrix for the TRIARG element (see section 4.87.10.4).

4.87.11.5 Stiffness Matrix Generation (Subroutine KTRAPR of Module SMA1)

1. Generate the terms of the symmetric element stiffness matrix in field coordinates as shown in Table 2. Each term must be multiplied by 2π to form $[\tilde{K}]$.

2. Transform the element stiffness matrix from field coordinates to grid point degrees of freedom:

$$[\bar{K}] = [H]^T[\tilde{K}][H]. \tag{23}$$

3. Transform the element stiffness matrix from two to three degrees of freedom per point:

$$[K] = [\Gamma_{qs}]^T[\bar{K}][\Gamma_{qs}]. \tag{24}$$

4. The 3 by 3 partitions $[K_{pj}]$ of $[K]$ corresponding to the pivot point p are transformed:

$$[K^3_{pj}] = [T_p]^T[K^3_{pj}][T_j], \quad j = 1,2,3,4. \tag{25}$$

5. Finally, these 3 by 3 partitions are expanded to 6 by 6 partitions:

$$[K_{pj}] = \begin{bmatrix} K^3_{pj} & 0 \\ 0 & 0 \end{bmatrix}. \tag{26}$$

Table 2. Elements of the 8 by 8 Symmetric Stiffness Matrix for the TRAPRG Element.

	Col. 1	Col. 2	Col. 3	Col. 4
Row 1	$E_{22}I_{-10}$			
Row 2	$(E_{22}+E_{12})I_{00}$	$(E_{11}+2E_{12}+E_{22})I_{10}$		
Row 3	$E_{22}I_{-11}$	$(E_{12}+E_{22})I_{01}$	$E_{22}I_{-12}+E_{44}I_{10}$	
Row 4	$(E_{12}+E_{22})I_{01}$	$(E_{11}+2E_{12}+E_{22})I_{11}$	$(E_{12}+E_{22})I_{02}$ + $E_{44}I_{20}$	$(E_{11}+2E_{12}+E_{22})I_{12}$ + $E_{44}I_{30}$
Row 5	0	0	0	0
Row 6	0	0	$E_{44}I_{10}$	$E_{44}I_{20}$
Row 7	$E_{32}I_{00}$	$(E_{13}+E_{23})I_{10}$	$E_{23}I_{01}$	$(E_{13}+E_{23})I_{11}$
Row 8	$E_{32}I_{10}$	$(E_{31}+E_{32})I_{20}$	$(E_{23}+E_{44})I_{11}$	$(E_{13}+E_{23}+E_{44})I_{21}$

	Col. 5	Col. 6	Col. 7	Col. 8
Row 5	0			
Row 6	0	$E_{44}I_{10}$		
Row 7	0	0	$E_{33}I_{10}$	
Row 8	0	$E_{44}I_{11}$	$E_{33}I_{20}$	$E_{33}I_{30}+E_{44}I_{12}$

4.87.11.6 Mass Matrix Calculation (Subroutine MTRAPR of Module SMA2)

1. Form the coupled mass matrix in field coordinates:

$$[\tilde{M}] = 2\pi \begin{bmatrix} M_1 I_{10} & & & & & & & \\ M_1 I_{20} & M_1 I_{30} & & & \text{Symmetric} & & & \\ M_1 I_{11} & M_1 I_{21} & M_1 I_{12} & & & & & \\ M_1 I_{21} & M_1 I_{31} & M_1 I_{22} & M_1 I_{32} & & & & \\ 0 & 0 & 0 & 0 & M_2 I_{10} & & & \\ 0 & 0 & 0 & 0 & M_2 I_{20} & M_2 I_{30} & & \\ 0 & 0 & 0 & 0 & M_2 I_{11} & M_2 I_{21} & M_2 I_{12} & \\ 0 & 0 & 0 & 0 & M_2 I_{21} & M_2 I_{31} & M_2 I_{22} & M_2 I_{32} \end{bmatrix}_{8x8} . \quad (27)$$

where

$$M_1 = M_2 = \rho . \quad (28)$$

2. Transform the mass matrix to grid point degrees of freedom:

$$[\bar{M}] = [H]^T [\tilde{M}] [H]. \quad (29)$$

3. Transform the mass matrix from two to three degrees of freedom per point:

$$[M] = [\Gamma_{qs}] [\bar{M}] [\Gamma_{qs}]. \quad (30)$$

4. The 6 by 6 partitions, $[M_{pj}]$, are calculated as in Equations 25 and 26.

4.87.11.7 Thermal Load Calculations (Subroutine TTRAPR of Module SSG1)

1. Form the temperature gradient vector:

$$\{\Delta T\} = \{T\} - \begin{Bmatrix} T_o \\ T_o \\ T_o \\ T_o \end{Bmatrix} , \tag{31}$$

where {T} is the vector of loading temperatures at the grid points.

2. Form the thermal expansion coefficient vector:

$$\{\alpha\} = \begin{Bmatrix} \alpha_r \\ \alpha_\theta \\ \alpha_z \\ 0 \end{Bmatrix} . \tag{32}$$

3. Multiply the elastic constants matrix by the thermal expansion coefficient vector:

$$\{AB\} = [E_g]\{\alpha\} . \tag{33}$$

4. Form the [Q] matrix:

$$[Q] = \begin{bmatrix} AB_2I_{00} & AB_2I_{10} & AB_2I_{01} & AB_2I_{11} \\ (AB_1+AB_2)I_{10} & (AB_1+AB_2)I_{20} & (AB_1+AB_2)I_{11} & (AB_1+AB_2)I_{21} \\ AB_2I_{01} & AB_2I_{11} & AB_2I_{02} & AB_2I_{12} \\ (AB_1+AB_2)I_{11} & (AB_1+AB_2)I_{21} & (AB_1+AB_2)I_{12} & (AB_1+AB_2)I_{22} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ AB_3I_{10} & AB_3I_{20} & AB_3I_{11} & AB_3I_{21} \\ AB_3I_{20} & AB_3I_{30} & AB_3I_{21} & AB_3I_{31} \end{bmatrix}_{8x4} . \tag{34}$$

5. Partition the transformation matrix [H] to form [H']:

$$[H'] = [h'_{ij}] \qquad 4x4, \tag{35}$$

where

$$h'_{ij} = h_{ik} \quad \text{for } i = 1,2,4;\ j = 1,2,\ldots,4; \text{ and } k = 2j-1$$

and h_{ik} are the elements of [H].

6. Compute the thermal load in field coordinates:

$$\{\tilde{F}_T\} = 2\pi[Q][H']\{\Delta T\}. \tag{36}$$

7. Transform the thermal load to grid point degrees of freedom:

$$\{\bar{F}_T\} = [H]^T\{\tilde{F}_T\}. \tag{37}$$

8. Transform the thermal load from two to three degrees of freedom per point:

$$\{F_T\} = [\Gamma_{qs}]^T\{\bar{F}_T\}. \tag{38}$$

9. Each partition, $\{F_T^3\}$, of length 3 of $\{F_T\}$ is transformed to global coordinates by:

$$\{F_T^3\}_g = [T_i]^T\{F_T^3\}. \tag{39}$$

10. These vectors are added to the overall load vector, $\{P_g\}$.

4.87.11.8 Element Force and Stress Calculations (Subroutines STRAP1 and STRAP2 of Module SDR2).

Element stress and force data items are calculated in two phases. The first phase (subroutine STRAP1) calculates the element stiffness and stress matrices. The second phase (subroutine STRAP2) calculates the element forces and stresses from the various subcase displacement vectors.

Phase 1 calculations are as follows:

1. Form the element stiffness matrix, [K], as in section 4.87.11.5.

2. Define a fifth "grid point" to be the average of the other four points:

$$R_{L5} = \frac{1}{4}(R_{L1} + R_{L2} + R_{L3} + R_{L4}), \tag{40}$$

$$Z_{L5} = \frac{1}{4}(Z_{L1} + Z_{L2} + Z_{L3} + Z_{L4}). \tag{41}$$

3. Form the matrices $[D^{(1)}],[D^{(2)}],[D^{(3)}],[D^{(4)}],[D^{(5)}]$

where

$$[D^{(i)}] = \begin{bmatrix} 0 & 1 & 0 & Z_{Li} & 0 & 0 & 0 & 0 \\ \frac{1}{R_{Li}} & 1 & \frac{Z_{Li}}{R_{Li}} & Z_{Li} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & R_{Li} \\ 0 & 0 & 1 & R_{Li} & 0 & 1 & 0 & Z_{Li} \end{bmatrix}_{4x8}, \tag{42}$$

where i = 1 to 5 denotes the five grid points.

4. Compute the stress matrices for each of the five grid points in field coordinates:

$$[\tilde{S}^{(i)}] = [E_g][D^{(i)}]. \tag{43}$$

5. Transform each stress matrix to grid point degrees of freedom:

$$[\bar{S}^{(i)}] = [\tilde{S}^{(i)}][H]. \tag{44}$$

6. Transform each stress matrix from two to three degrees of freedom per point:

$$[S^{(i)}] = [\bar{S}^{(i)}][\Gamma_{qs}]. \tag{45}$$

7. Form the master stress matrix:

$$[S] = \begin{bmatrix} S^{(1)} \\ \hline S^{(2)} \\ \hline S^{(3)} \\ \hline S^{(4)} \\ \hline S^{(5)} \end{bmatrix}_{20 \times 12} \tag{46}$$

8. Transform the stress matrix from basic to local coordinates:

$$[S_\ell] = [S][T_{1234}], \tag{47}$$

where

$$[T_{1234}] = \left[\begin{array}{c|c|c|c} T_1 & 0 & 0 & 0 \\ \hline 0 & T_2 & 0 & 0 \\ \hline 0 & 0 & T_3 & 0 \\ \hline 0 & 0 & 0 & T_4 \end{array}\right]. \tag{48}$$

9. Compute the thermal stress vector:

$$\{T_s\} = [E_q]\{\alpha\}. \tag{49}$$

Phase 2 calculations are as follows:

1. Extract the displacement vector, $\{\Delta\}$, at the three translation coordinates of each of the four grid points from the global displacement vector.

2. Calculate the element forces:

$$\{P\} = [K]\{\Delta\} \ . \tag{50}$$

3. Calculate the element stresses:

$$\{\sigma\} = [S_\ell]\{\Delta\} - T_d \{T_s\} \ , \tag{51}$$

where

$$T_d = \begin{cases} T_i - T_o, \text{ if } i \neq 5 \ (T_i \text{ is the temperature at the } i^{th} \text{ point}) \\ T_{avg} - T_o, \text{ if } i = 5 \ (T_{avg} \text{ is the average temperature over the four grid points}) \end{cases} \tag{52}$$

4.87.11.9 Thermal Analysis Calculations for the TRAPRG Element (Subroutine HRING by Module SMA1)

The calculations are described in the preceding description for the TRIARG element; see Section 4.87.10.9.

4.87.12 The TØRDRG Element

4.87.12.1 Input Data for the TØRDRG Element

1. The ECPT/EST entries for the axisymmetric toroidal ring (TØRDRG) element are:

Symbol	Description
SIL_1, SIL_2	Scalar index numbers for the two grid points
α_1, α_2	Angles of curvature at the two grid points (degrees)
γ	Material property orientation angle (currently not used)
H_m, H_f	Membrane and flexure thickness
N_1, X_1, Y_1, Z_1 N_2, X_2, Y_2, Z_2	Local coordinate system number and location in basic coordinates of the grid points.
t_μ	Element temperature for material properties

For this element Y_i must equal zero for i = 1 and 2, and we define:

$$\{R\} = \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} , \tag{1}$$

$$\{Z\} = \begin{Bmatrix} Z_1 \\ Z_2 \end{Bmatrix} . \tag{2}$$

2. Coordinate system data

The location (X_i, Y_i, Z_i) and local coordinate system number (N_i) of each grid point are used to calculate the 3 by 3 global-to-basic coordinate system transformation matrices, $[T_i]$, i = 1, 2.

3. Material data

The material property input for the TØRDRG element is the same as that for TRIARG element (see section 4.87.10.1) with the following notational changes:

$$E_p = E_r, \quad E_T = E_\theta, \quad \nu_{PT} = \nu_{r\theta}$$

$$\{ALF\} = \begin{Bmatrix} \alpha_r \\ \alpha_\theta \end{Bmatrix}$$

4.87.12.2 General Calculations

1. Compute the following constants used in stiffness matrix generation:

$$C = E_p/E_T \ , \tag{3}$$

$$D_M = E_p \, H_m/(C - \nu_{PT}^2) \ , \tag{4}$$

$$D_B = E_p \, H_f^3/(12 \, (C - \nu_{PT}^2)). \tag{5}$$

2. Determine if the element is a toroidal ring, a conical ring, a cylindrical ring, or a shell cap:

   (1) if $\alpha_1 \neq \alpha_2$, then the element is a toroidal ring.

   (2) if $\alpha_1 = \alpha_2 = 90^0$, then the element is a cylindrical ring.

   (3) if $\alpha_1 = \alpha_2 \neq 90^0$, then the element is a conical ring.

   (4) if $\alpha_1 = 0$, then the element is a shell cap.

3. Compute the local coordinate constants for a toroidal element:

$$\phi_\beta = \alpha_2 - \alpha_1 \ , \tag{6}$$

$$R_p = \frac{[(R_2 - R_1)^2 + (Z_2 - Z_1)^2]^{1/2}}{2 \sin (\frac{\phi_\beta}{2})} \ , \tag{7}$$

$$\lambda_1 = \frac{1}{R_p} \ , \tag{8}$$

$$S = (\alpha_2 - \alpha_1)R_p, \tag{9}$$

$$B_\beta = R_1 + R_p\left[\sin\left(\alpha_1 + \frac{\phi_\beta}{2}\right) - \sin(\alpha_1)\right], \tag{10}$$

$$R_T = \frac{B_\beta}{\sin\left(\alpha_1 + \frac{\phi_\beta}{2}\right)}, \tag{11}$$

$$\psi_1 = \cos\left(\alpha_1 + \frac{\phi_\beta}{2}\right), \tag{12}$$

$$\psi_2 = -\frac{\sin\left(\alpha_1 + \frac{\phi_\beta}{2}\right)}{R_p}. \tag{13}$$

4. Compute the local coordinate constants for a conical or cylindrical ring

$$S = [(R_2 - R_1)^2 + (Z_2 - Z_1)^2]^{1/2}, \tag{14}$$

$$B_\beta = R_1 + \frac{S\cos\alpha_1}{2}, \tag{15}$$

$$R_T = \frac{B_\beta}{\sin\alpha_1}, \tag{16}$$

$$R_p = 0, \tag{17}$$

$$\lambda_1 = 0, \tag{18}$$

$$\psi_1 = \cos\alpha_1, \tag{19}$$

$$\psi_2 = 0. \tag{20}$$

5. Generate the transformation matrix from field coordinates to grid point degrees of freedom:

$$[\Gamma_{\beta q}] = \begin{bmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \frac{1}{2} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \frac{-10}{s^3} & \frac{-6}{s^2} & 0 & \frac{-3}{2s} & 0 & 0 & \frac{10}{s^3} & \frac{-4}{s^2} & 0 & \frac{1}{2s} \\
0 & 0 & \frac{15}{s^4} & \frac{8}{s^3} & 0 & \frac{3}{2s^2} & 0 & 0 & \frac{-15}{s^4} & \frac{7}{s^3} & 0 & \frac{-1}{s^2} \\
0 & 0 & \frac{-6}{s^5} & \frac{-3}{s^4} & 0 & \frac{-1}{2s^3} & 0 & 0 & \frac{6}{s^5} & \frac{-3}{s^4} & 0 & \frac{1}{2s^3} \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\frac{-3}{s^2} & 0 & 0 & 0 & \frac{-2}{s} & 0 & \frac{3}{s^2} & 0 & 0 & 0 & \frac{-1}{s} & 0 \\
\frac{2}{s^3} & 0 & 0 & 0 & \frac{1}{s^2} & 0 & \frac{-2}{s^3} & 0 & 0 & 0 & \frac{1}{s^2} & 0
\end{bmatrix}_{10x12} \quad . \quad (21)$$

6. Generate the transformation matrix from local to system coordinates:

$$[\Gamma_{rs}] = \begin{bmatrix} \cos\alpha_1 & 0 & -\sin\alpha_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \sin\alpha_1 & 0 & \cos\alpha_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \cos\alpha_2 & 0 & -\sin\alpha_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sin\alpha_2 & 0 & \cos\alpha_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}_{12x12} . \quad (22)$$

7. Rearrange the transformation matrix $[\Gamma_{\beta q}]$ such that the membrane and flexure terms are reversed.

$$[\bar{\Gamma}_{\beta q}] = \begin{bmatrix} \Gamma_{\beta q}^{(2)} \\ \Gamma_{\beta q}^{(1)} \end{bmatrix}_{10 \times 12} , \quad (23)$$

where $[\Gamma_{\beta q}^{(1)}]$ is the first six rows of $[\Gamma_{\beta q}]$ and $[\Gamma_{\beta q}^{(2)}]$ is the last four rows of $[\Gamma_{\beta q}]$.

4.87.12.3 Integral Calculations

The method used to compute the integrals depends on the geometric shape of the element.

1. Toroidal ring - basic integrals

There are six basic integrals to be computed, of which the first three can best be evaluated by series expansion, but the last three require numerical integration.

$$I_1^{\,j} = R_p^{\,j+1} \int_0^{\phi_\beta} \phi^j d\phi = \frac{R_p^{\,j+1} \phi_\beta^{\,j+1}}{j+1} , \tag{24}$$

$$I_2^{\,j} = R_p^{\,J+1} \int_0^{\phi_\beta} \phi^j \sin\phi d\phi = R_p^{\,j+1} \sum_{i=0}^{\infty} \frac{(-1)^i \phi_\beta^{\,j+1+2i+1}}{(j+1+2i+1)\ (2i+1)!} , \tag{25}$$

$$I_3^{\,j} = R_p^{\,j+1} \int_0^{\phi_\beta} \phi^j \cos\phi d\phi = R_p^{\,j+1} \sum_{i=0}^{\infty} \frac{(-1)^i \phi_\beta^{\,j+1+2i}}{(j+1+2i)\ (2i)!} , \tag{26}$$

$$I_4^{\,j} = R_p^{\,j+1} \int_0^{\phi_\beta} \frac{\phi^j \sin^2\phi}{B}\, d\phi , \tag{27}$$

$$I_5^{\,j} = R_p^{\,j+1} \int_0^{\phi_\beta} \frac{\phi^j 2\sin\phi\cos\phi}{B}\, d\phi , \tag{28}$$

$$I_6^{\,j} = R_p^{\,j+1} \int_0^{\phi_\beta} \frac{\phi^j \cos^2\phi}{B}\, d\phi , \tag{29}$$

where

$$B = R_1 - R_p \sin\alpha_1 + R_p \sin\alpha_1 \cos\phi + R_p \cos\alpha_1 \sin\phi, \tag{30}$$

and $j = 0, 1, \ldots, 10$.

The summations in $I_2^{\,j}$ and $I_3^{\,j}$ are carried out until the truncation error is insignificant.

2. Toroidal ring - required integrals

The actual integrals required can now be defined in terms of basic integrals.

$$\delta_1^{\,j} = (R_1 - R_p\sin\alpha_1)I_1^{\,j} + R_p\cos\alpha_1 I_2^{\,j} + R_p\sin\alpha_1 I_3^{\,j}, \tag{31}$$

$$\delta_2^{\,j} = \cos\alpha_1 I_2^{\,j} + \sin\alpha_1 I_3^{\,j}, \tag{32}$$

$$\delta_3^{\,j} = \cos^2\alpha_1 I_4^{\,j} + \sin\alpha_1\cos\alpha_1 I_5^{\,j} + \sin^2\alpha_1 I_6^{\,j}, \tag{33}$$

$$\delta_4^{\,j} = \cos\alpha_1 I_3^{\,j} - \sin\alpha_1 I_2^{\,j}, \tag{34}$$

$$\delta_5^{\,j} = \sin\alpha_1\cos\alpha_1(I_6^{\,j} - I_4^{\,j}) + \tfrac{1}{2}(1 - 2\sin^2\alpha_1)I_5^{\,j}, \tag{35}$$

$$\delta_6^{\,j} = \cos^2\alpha_1 I_6^{\,j} - \sin\alpha_1\cos\alpha_1 I_5^{\,j} + \sin^2\alpha_1 I_4^{\,j}, \tag{36}$$

$$j = 0,1,\ldots,10$$

3. Conic ring - basic integrals

$$I_1^{\,j} = \int_0^S \xi^j d\xi = \frac{S^{j+1}}{j+1}, \quad j = 0,1,\ldots,10 \tag{37}$$

$$I_2^{\,j} = \int_0^S \left(\frac{\xi^j}{R_1+\xi\cos\alpha_1}\right) d\xi, \quad j = 0,1,\ldots,10 \tag{38}$$

$$I_2^{\,0} = \frac{1}{\cos\alpha_1}\ln\left(\frac{R_1+S\cos\alpha_1}{R_1}\right), \tag{39}$$

$$I_2^{\,1} = \frac{1}{\cos\alpha_1}\left[S - \frac{R_1}{\cos\alpha_1}\ln\left(\frac{R_1+S\cos\alpha_1}{R_1}\right)\right], \tag{40}$$

$$I_2^{\,j} = \frac{S^{j+1}}{R_1}\sum_{i=0}^{\infty}\frac{(-1)^i\left|\frac{S\cos\alpha_1}{R_1}\right|^i}{(j+1+i)}, \quad j = 2,3,\ldots,10. \tag{41}$$

4. Conic ring - required integrals

$$\left.\begin{aligned}
\delta_1^j &= R_1 I_1^j + \psi_1 I_1^{j+1}, && (42)\\
\delta_2^j &= \sin\alpha_1 I_1^j, && (43)\\
\delta_3^j &= \sin^2\alpha_1 I_2^j, && (44)\\
\delta_4^j &= \psi_1 I_1^j, && (45)\\
\delta_5^j &= \sin\alpha_1\, \psi_1 I_2^j, && (46)\\
\delta_6^j &= \psi_1^2 I_2^j, && (47)
\end{aligned}\right\} \quad j = 0,1,\ldots,10$$

5. Cylindrical ring - basic integrals

$$I_1^j = \int_0^S \xi^j d\xi = \frac{S^{j+1}}{j+1}, \qquad j = 0,1,\ldots,10 \qquad (48)$$

$$I_2^j = \int_0^S \frac{\xi^j}{R_1} d\xi = \frac{1}{R_1}\left(\frac{S^{j+1}}{j+1}\right), \quad j = 0,1,\ldots,10 \qquad (49)$$

6. Cylindrical ring - required integrals

$$\left.\begin{aligned}
\delta_1^j &= R_1 I_1^j + \psi_1 I_1^{j+1}, && (50)\\
\delta_2^j &= \sin\alpha_1 I_1^j, && (51)\\
\delta_3^j &= \sin^2\alpha_1 I_2^j, && (52)\\
\delta_4^j &= \delta_5^j = \delta_6^j = 0, && (53)
\end{aligned}\right\} \quad j = 0,1,\ldots,10$$

4.87.12.4 Elastic Constants Matrix Calculations

Form elastic constants matrix

$$[E] = \frac{1}{\left(1 - \frac{E_T}{E_P}\nu_{PT}^2\right)} \begin{bmatrix} E_P & E_T\nu_{PT} \\ E_T\nu_{PT} & E_T \end{bmatrix}_{2x2} \tag{54}$$

4.87.12.5 Stiffness Matrix Calculations (Subroutine KTØRDR of Module SMA1)

1. Define the constants

$$A = R_P , \tag{55}$$

$$V = \nu_{PT} , \tag{56}$$

$$C = E_P/E_T . \tag{57}$$

2. Form the stiffness matrix terms in field coordinates as shown in Tables 3. 4 and 5.

3. Transform the stiffness matrix from field coordinates to grid point degrees of freedom:

$$[\bar{K}] = [\Gamma_{\beta q}]^T[\tilde{K}][\Gamma_{\beta q}]. \tag{58}$$

4. Transform the stiffness matrix from local to system coordinates:

$$[K] = [\Gamma_{rs}]^T[\bar{K}][\Gamma_{rs}]. \tag{59}$$

5. The global-to-basic coordinate system transformation matrices $[T_i]$ are expanded to 6 by 6 matrices:

$$[T_i^6] = \left[\begin{array}{c|c} T_i & 0 \\ \hline 0 & I \end{array}\right] , \quad i = 1,2. \tag{60}$$

Table 3. Columns 1, 2 and 3 of the Symmetric 10 by 10 Stiffness Matrix for the TØRDRG Element.

	Column 1	Column 2	Column 3
Row 1	$D_M(\frac{C}{A^2}\delta_1^0 + \frac{2V}{A}\delta_2^0 + \delta_3^0)$		
Row 2	$D_M(\frac{C}{A^2}\delta_1^1 + \frac{2V}{A}\delta_2^1 + \delta_3^1)$	$D_B\delta_6^0 + D_M(\frac{C}{A^2}\delta_1^2 + \frac{2V}{A}\delta_2^2 + \delta_3^2)$	
Row 3	$D_M(\frac{C}{A^2}\delta_1^2 + \frac{2V}{A}\delta_2^2 + \delta_3^2)$	$D_B(2V\delta_4^0 + 2\delta_6^1) + D_M(\frac{C}{A^2}\delta_1^3 + \frac{2V}{A}\delta_2^3 + \delta_3^3)$	$D_B4(C\delta_1^0 + 2V\delta_4^1 + \delta_6^2 + D_M(\frac{C}{A^2}\delta_1^4 + \frac{2V}{A}\delta_2^4 + \delta_3^4)$
Row 4	$D_M(\frac{C}{A^2}\delta_1^3 + \frac{2V}{A}\delta_2^3 + \delta_3^3)$	$D_B(6V\delta_4^1 + 3\delta_6^2) + D_M(\frac{C}{A^2}\delta_1^4 + 2\frac{V}{A}\delta_2^4 + \delta_3^4)$	$D_B6(2C\delta_1^1 + 3V\delta_4^2 + \delta_6^3) + D_M(\frac{C}{A^2}\delta_1^5 + \frac{2V}{A}\delta_2^5 + \delta_3^5)$
Row 5	$D_M(\frac{C}{A^2}\delta_1^4 + \frac{2V}{A}\delta_2^4 + \delta_3^4)$	$D_B(12V\delta_4^2 + 4\delta_6^3) + D_M(\frac{C}{A^2}\delta_1^5 + \frac{2V}{A}\delta_2^5 + \delta_3^5)$	$D_B2(12C\delta_1^2 + 16V\delta_4^3 + 4\delta_6^4) + D_M(\frac{C}{A^2}\delta_1^6 + \frac{2V}{A}\delta_2^6 \div \delta_3^6)$
Row 6	$D_M(\frac{C}{A^2}\delta_1^5 + \frac{2V}{A}\delta_2^5 + \delta_3^5)$	$D_B(20V\delta_4^3 + 5\delta_6^4) + D_M(\frac{C}{A^2}\delta_1^6 + 2\frac{V}{A}\delta_2^6 + \delta_3^6)$	$D_B10(4C\delta_1^3 + 5V\delta_4^4 + \delta_6^5) + D_M(\frac{C}{A^2}\delta_1^7 + \frac{2V}{A}\delta_2^7 + \delta_3^7)$
Row 7	$D_M(\frac{V}{A}\delta_4^0 + \delta_5^0)$	$D_M(\frac{V}{A}\delta_4^1 + \delta_5^1)$	$D_M(\frac{V}{A}\delta_4^2 + \delta_5^2)$
Row 8	$D_M(\frac{C}{A}\delta_1^0 + \frac{V}{A}\delta_4^1 + V\delta_2^0 + \delta_5^1)$	$D_M(\frac{C}{A}\delta_1^1 + \frac{V}{A}\delta_4^2 + V\delta_2^1 + \delta_5^2)$	$D_M(\frac{C}{A}\delta_1^2 + \frac{V}{A}\delta_4^3 + V\delta_2^2 + \delta_5^3)$
Row 9	$D_M(\frac{2C}{A}\delta_1^1 + \frac{V}{A}\delta_4^2 + 2V\delta_2^1 + \delta_5^2)$	$D_M(2\frac{C}{A}\delta_1^2 + \frac{V}{A}\delta_4^3 + 2V\delta_2^2 + \delta_5^3)$	$D_M(2\frac{C}{A}\delta_1^3 + \frac{V}{A}\delta_4^4 + 2V\delta_2^3 + \delta_5^4$
Row 10	$D_M(\frac{3C}{A}\delta_1^2 + \frac{V}{A}\delta_4^3 + 3V\delta_2^2 + \delta_5^3)$	$D_M(\frac{3C}{A}\delta_1^3 + \frac{V}{A}\delta_4^4 + 3V\delta_1^3 + \delta_5^4)$	$D_M(\frac{3C}{A}\delta_1^4 + \frac{V}{A}\delta_4^5 + 3V\delta_2^4 + \delta_5^5)$

Table 4. Columns 4, 5, and 6 of the Symmetric 10 by 10 Stiffness Matrix for the TØRDRG Element.

	Column 4	Column 5	Column 6
Row 4	$D_B 9(4C\delta_1^2 + 4V\delta_4^3 + \delta_6^4)$ + $D_M(\frac{C}{A^2}\delta_1^6 + \frac{2V}{A}\delta_2^6 + \delta_3^6)$		
Row 5	$D_B 12(6C\delta_1^3 + 5V\delta_4^4 + \delta_6^5)$ + $D_M(\frac{C}{A^2}\delta_1^7 + \frac{2V}{A}\delta_2^7 + \delta_3^7)$	$D_B 16(9C\delta_1^4 + 6V\delta_4^5 + \delta_6^6)$ + $D_M(\frac{C}{A^2}\delta_1^8 + \frac{2V}{A}\delta_2^8 + \delta_3^8)$	
Row 6	$D_B 15(8C\delta_1^4 + 6V\delta_4^5 + \delta_6^6)$ + $D_M(\frac{C}{A^2}\delta_1^8 + \frac{2V}{A}\delta_2^8 + \delta_3^8)$	$D_B 20(12C\delta_1^5 + 7V\delta_4^6 + \delta_6^7)$ + $D_M(\frac{C}{A^2}\delta_1^9 + \frac{2V}{A}\delta_2^9 + \delta_3^9)$	$D_B 25(16C\delta_1^6 + 8V\delta_4^7 + \delta_6^8)$ + $D_M(\frac{C}{A^2}\delta_1^{10} + \frac{2V}{A}\delta_2^{10} + \delta_3^{10})$
Row 7	$D_M(\frac{V}{A}\delta_4^3 + \delta_5^3)$	$D_M(\frac{V}{A}\delta_4^4 + \delta_5^4)$	$D_M(\frac{V}{A}\delta_4^5 + \delta_5^5)$
Row 8	$D_M(\frac{C}{A}\delta_1^3 + \frac{V}{A}\delta_4^4 + V\delta_2^3 + \delta_5^4)$	$D_M(\frac{C}{A}\delta_1^4 + \frac{V}{A}\delta_4^5 + V\delta_2^4 + \delta_5^5)$	$D_M(\frac{C}{A}\delta_1^5 + \frac{V}{A}\delta_4^6 + V\delta_2^5 + \delta_5^6)$
Row 9	$D_M(\frac{2C}{A}\delta_1^4 + \frac{V}{A}\delta_4^5 + 2V\delta_2^4 + \delta_5^5)$	$D_M(\frac{2C}{A}\delta_1^5 + \frac{V}{A}\delta_4^6 + 2V\delta_2^5 + \delta_5^6)$	$D_M(\frac{2C}{A}\delta_1^6 + \frac{V}{A}\delta_4^7 + 2V\delta_2^6 + \delta_5^7)$
Row 10	$D_M(\frac{3C}{A}\delta_1^5 + \frac{V}{A}\delta_4^5 + 3V\delta_2^5 + \delta_5^5)$	$D_M(\frac{3C}{A}\delta_1^6 + \frac{V}{A}\delta_4^7 + 3V\delta_2^6 + \delta_5^7)$	$D_M(\frac{3C}{A}\delta_1^7 + \frac{V}{A}\delta_4^8 + 3V\delta_2^7 + \delta_5^8)$

Table 5. Columns 7, 8, 9, and 10 of the Symmetric 10 by 10 Stiffness Matrix for the TØRDRG Element.

	Col. 7	Col. 8	Col. 9	Col. 10
Row 7	$D_M\delta_6^0$			
Row 8	$D_M(V\delta_4^0 + \delta_6^1)$	$D_M(C\delta_1^0 + 2V\delta_4^1 + \delta_6^2)$		
Row 9	$D_M(2V\delta_4^1 + \delta_6^2)$	$D_M(2C\delta_1^1 + 3V\delta_4^2 + \delta_6^3)$	$D_M(4C\delta_1^2 + 4V\delta_4^3 + \delta_6^4)$	
Row 10	$D_M(3V\delta_4^2 + \delta_6^3)$	$D_M(3C\delta_1^2 4V\delta_4^3 + \delta_6^4)$	$D_M(6C\delta_1^3 + 5V\delta_4^4 + \delta_6^5)$	$D_M(9C\delta_1^4 + 6V\delta_4^5 + \delta_6^6)$

6. The stiffness matrix, [K], is partitioned into 6 by 6 matrices:

$$[K] \Longrightarrow \left[\begin{array}{c|c} K_{11}^{6} & K_{12}^{6} \\ \hline K_{21}^{6} & K_{22}^{6} \end{array}\right] . \tag{61}$$

7. These 6x6 partitions are transformed to local coordinates:

$$[K_{pj}^{6}]_{\ell} = [T_{p}^{6}]^{T}[K_{pj}^{6}][T_{j}^{6}], \tag{62}$$

where j = 1, 2, and p is the pivot point, p = 1 or 2.

4.87.12.6 Mass Matrix Calculations (Subroutine MTØRDR of Module SMA2)

1. Form the mass matrix in field coordinates:

$$[\tilde{M}] = 2\pi\rho H_m \begin{bmatrix} \delta_1^0 & & & & & & & & & \\ \delta_1^1 & \delta_1^2 & & & & & & & & \\ \delta_1^2 & \delta_1^3 & \delta_1^4 & & \text{Symmetric} & & & & & \\ \delta_1^3 & \delta_1^4 & \delta_1^5 & \delta_1^6 & & & & & & \\ 0 & 0 & 0 & 0 & \delta_1^0 & & & & & \\ 0 & 0 & 0 & 0 & \delta_1^1 & \delta_1^2 & & & & \\ 0 & 0 & 0 & 0 & \delta_1^2 & \delta_1^3 & \delta_1^4 & & & \\ 0 & 0 & 0 & 0 & \delta_1^3 & \delta_1^4 & \delta_1^5 & \delta_1^6 & & \\ 0 & 0 & 0 & 0 & \delta_1^4 & \delta_1^5 & \delta_1^6 & \delta_1^7 & \delta_1^8 & \\ 0 & 0 & 0 & 0 & \delta_1^5 & \delta_1^6 & \delta_1^7 & \delta_1^8 & \delta_1^9 & \delta_1^{10} \end{bmatrix}_{10x10} \quad (63)$$

2. Transform the mass matrix to grid point degrees of freedom:

$$[\bar{M}] = [\bar{\Gamma}_{\beta q}]^T[\tilde{M}][\bar{\Gamma}_{\beta q}] \ . \quad (64)$$

3. Transform the mass matrix from local to system coordinates:

$$[M] = [\Gamma_{rs}]^T[\bar{M}][\Gamma_{rs}] \ . \quad (65)$$

4. The mass matrix, [M], is partitioned into 6x6 matrices, and these 6x6 partitions are transformed to local coordinates (see Equations 61 and 62).

4.87.12.7 Thermal Load Calculations (Subroutine TTØRDR of Module SSG1)

1. Compute the temperature gradient constants:

$$\Delta T_1^{(m)} = T_1^{(m)} - T_o \quad , \tag{66}$$

$$\Delta T_2^{(m)} = T_2^{(m)} - T_1^{(m)} \quad , \tag{67}$$

$$\Delta T_1^{(f)} = 0 \quad , \tag{68}$$

$$\Delta T_2^{(f)} = 0 \quad , \tag{69}$$

where $T_i^{(m)}$ are the membrane temperatures at point i.

2. Compute the thermal strain vectors:

$$\{\varepsilon_T^{(0)}\} = \Delta T_i^{(m)}\{ALF\} \quad , \tag{70}$$

$$\{\varepsilon_T^{(1)}\} = \Delta T_2^{(m)}\{ALF\} \quad , \tag{71}$$

$$\{H_T^{(0)}\} = \Delta T_1^{(f)}\{ALF\} \quad , \tag{72}$$

$$\{H_T^{(1)}\} = \Delta T_2^{(f)}\{ALF\} \quad , \tag{73}$$

where {ALF} is a vector of length two; the first component is α_r and the second α_θ.

3. Form the matrices of integrals

$$[\tilde{F}_{ME}^{(0)}] = 2\pi H_m \begin{bmatrix} 0 & \delta_1^0 & 2\delta_1^1 & 3\delta_1^2 & \lambda_1\delta_1^0 & \lambda_1\delta_1^1 & \lambda_1\delta_1^2 & \lambda_1\delta_1^3 & \lambda_1\delta_1^4 & \lambda_1\delta_1^5 \\ \delta_4^0 & \delta_4^1 & \delta_4^2 & \delta_4^3 & \delta_2^0 & \delta_2^1 & \delta_2^2 & \delta_2^3 & \delta_2^4 & \delta_2^5 \end{bmatrix}_{2x10} \tag{74}$$

$$[\tilde{F}_{ME}^{(1)}] = \frac{2\pi H_m}{S} \begin{bmatrix} 0 & \delta_1^1 & 2\delta_1^2 & 3\delta_1^3 & \lambda_1\delta_1^1 & \lambda_1\delta_1^2 & \lambda_1\delta_1^3 & \lambda_1\delta_1^4 & \lambda_1\delta_1^5 & \lambda_1\delta_1^6 \\ \delta_4^1 & \delta_4^2 & \delta_4^3 & \delta_4^4 & \delta_2^1 & \delta_2^2 & \delta_2^3 & \delta_2^4 & \delta_2^5 & \delta_2^6 \end{bmatrix}_{2x10} \tag{75}$$

$$[\tilde{F}_{FE}^{(0)}] = \frac{2\pi H_f^3}{12} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & -2\delta_1^0 & -6\delta_1^1 & -12\delta_1^2 & -20\delta_1^3 \\ 0 & 0 & 0 & 0 & 0 & -\delta_4^0 & -2\delta_4^1 & -3\delta_4^2 & -4\delta_4^3 & -5\delta_4^4 \end{bmatrix}_{2x10} \tag{76}$$

$$[\tilde{F}_{FE}^{(1)}] = \frac{2\pi H_f^3}{12s} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & -2\delta_1^1 & -6\delta_1^2 & -12\delta_1^3 & -20\delta_1^4 \\ 0 & 0 & 0 & 0 & 0 & -\delta_4^1 & -2\delta_4^2 & -3\delta_4^3 & -4\delta_4^4 & -5\delta_4^5 \end{bmatrix}_{2x10} \tag{77}$$

4. Compute the thermal load vector in field coordinates

$$\{\tilde{F}_T\} = [\tilde{F}_{ME}^{(0)}]^T[E]\{\epsilon_T^{(0)}\} + [\tilde{F}_{ME}^{(1)}]^T[E]\{\epsilon_T^{(1)}\} + [\tilde{F}_{FE}^{(0)}]^T[E]\{H_T^{(0)}\} + [\tilde{F}_{FE}^{(1)}]^T[E]\{H_T^{(0)}\} . \tag{78}$$

5. Transform the thermal load vector to grid point degrees of freedom:

$$\{\bar{F}_T\} = [\Gamma_{\beta q}]^T\{\tilde{F}_T\} . \tag{79}$$

6. Transform the thermal load vector from local to system coordinates:

$$\{F_T\} = [\Gamma_{rs}]^T\{\bar{F}_T\} . \tag{80}$$

7. Transform the thermal load vector to basic coordinates:

$$\{F_T\}_b = [T_{12}]^T\{F_T\}, \tag{81}$$

where

$$[T_{12}] = \begin{bmatrix} T_1 & 0 & 0 & 0 \\ 0 & I & 0 & 0 \\ 0 & 0 & T_2 & 0 \\ 0 & 0 & 0 & I \end{bmatrix} , \qquad (82)$$

and $[T_i]$ and $[I]$ are 3 by 3 matrices.

8. These vectors are added to the overall load vector, $\{P_g\}$.

4.87.12.8 Element Force and Stress Calculations (Subroutines STØRD1 and STØRD2 of Module SDR1)

Element stress and force data are calculated in two phases. The first phase (subroutine STØRD1) calculates the element stiffness and stress matrices. The second phase (subroutine STØRD2) calculates the element forces and stresses from the various subcase displacement vectors. Stresses are evaluated at both ends and at the mid-span of the element.

Phase 1 calculations are as follows:

1. Form the element stiffness matrix, [K], as in section 4.87.12.5.

2. Set up the coordinates of the three stress points:

$$\{X\} = \begin{Bmatrix} 0 \\ \frac{S}{2} \\ S \end{Bmatrix} . \qquad (83)$$

3. Compute the constants λ_2, λ_3, λ_4 as a function of the stress points coordinates.

   a. If the element is a toroidal ring, then:

$$\lambda_2^{(i)} = \frac{\cos\left(\alpha_1 + \frac{X(i)}{R_p}\right)}{R_1 - R_p\left[\sin\alpha_1 - \sin\left(\alpha_1 + \frac{X(i)}{R_p}\right)\right]} , \qquad (84)$$

$$\lambda_3^{(i)} = \frac{\sin\left(\alpha_1 + \frac{X(i)}{R_p}\right)}{R_1 - R_p[\sin\alpha_1 - \sin\left(\alpha_1 + \frac{X(i)}{R_p}\right)]} \quad i = 1,2,3, \tag{85}$$

$$\lambda_4^{(i)} = -\lambda_3^{(i)}/R_p \ . \tag{86}$$

b. If the element is a cylindrical or conical ring, then:

$$\lambda_2^{(i)} = \frac{\cos\alpha_1}{R_1 + X(i)\cos\alpha_1} \ , \tag{87}$$

$$\lambda_3^{(i)} = \frac{\cos\alpha_1}{R_1 + X(i)\cos\alpha_1} \quad i = 1,2,3, \tag{88}$$

$$\lambda_4^{(i)} = 0 \ . \tag{89}$$

c. If the element is a shell cap, then:

$$\lambda_2^{(i)} = \frac{\cos\left(\alpha_1 + \frac{X(i)}{R_p}\right)}{R_1 - R_p\left[\sin\alpha_1 - \sin\left(\alpha_1 + \frac{X(i)}{R_p}\right)\right]} \quad i = 1,2,3 \ , \tag{90}$$

$$\lambda_3^{(i)} = 1/R_p \ , \tag{91}$$

$$\lambda_4^{(i)} = -1/(R_p^2) \ . \tag{92}$$

4. Compute the stress matrix in field coordinates for the three stress points as shown in Tables 6 and 7. Note that the factors H and $H^3/12$ have been omitted for $[\tilde{S}_1^{(i)}]$ and $[\tilde{S}_2^{(i)}]$ respectively.

If the element is a shell cap, then modify $[\tilde{S}^{(i)}]$ by:

$$\tilde{S}_{12} = E_{12} - E_{11} \ , \tag{93}$$

$$\tilde{S}_{22} = E_{22} + E_{12} \ , \tag{94}$$

$$\tilde{S}_{37} = -2\ (E_{12} + E_{11}) \ , \tag{95}$$

$$\tilde{S}_{47} = 2\ (E_{22} + E_{12}) \ , \tag{96}$$

$$\tilde{S}_{58} = 3(E_{22} - 4\ E_{11}) \ . \tag{97}$$

5. Form the master stress matrix in field coordinates:

$$[\tilde{S}] = \begin{bmatrix} \tilde{S}^{(1)} \\ \hline \tilde{S}^{(2)} \\ \hline \tilde{S}^{(3)} \end{bmatrix} \quad 15 \times 10 \ . \tag{98}$$

Table 6. Terms in Columns 1 Through 6 of the 2 by 10 $[\tilde{S}_1^{(i)}]$ Matrix and the 3 by 10 $[\tilde{S}_2^{(i)}]$ Matrix.

The $[\tilde{S}_1^{(i)}]$ Matrix

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
$\lambda_2^{(i)}E_{12}$	E_{11} $+\lambda_2^{(i)}E_{12}X(i)$	$2E_{11}X(i)$ $+\lambda_2^{(i)}E_{12}X^2(i)$	$3E_{11}X^2(i)$ $+\lambda_2^{(i)}E_{12}X^3(i)$	$\lambda_1^{(i)}E_{11}$ $+\lambda_3^{(i)}E_{12}$	$(\lambda_1^{(i)}E_{11}$ $+\lambda_3^{(i)}E_{12})X(i)$
$\lambda_2^{(i)}E_{22}$	E_{12} $+\lambda_2^{(i)}E_{22}X(i)$	$2E_{12}X^2(i)$ $+\lambda_2^{(i)}E_{22}X^2(i)$	$3E_{12}X^2(i)$ $+\lambda_2^{(i)}E_{22}X^3(i)$	$\lambda_1^{(i)}E_{12}$ $+\lambda_3^{(i)}E_{22}$	$(\lambda_1^{(i)}E_{12}$ $+\lambda_3^{(i)}E_{22})X(i)$

The $[\tilde{S}_2^{(i)}]$ Matrix

0	0	0	0	0	$-\lambda_2^{(i)}E_{12}$
0	0	0	0	0	$\lambda_2^{(i)}E_{22}$
0	0	0	0	0	$g^{(i)}$

where $g^{(i)} = (\lambda_2^{(i)})^2 E_{22} - \lambda_4^{(i)}E_{12}$ and

$$[\tilde{S}^{(i)}] = \begin{bmatrix} \tilde{S}_1^{(i)} \\ \hline \tilde{S}_2^{(i)} \end{bmatrix}_{5\times10}$$

Table 7. Terms in Columns 7 Through 10 of the 2 by 10 $[\tilde{S}_1^{(i)}]$ Matrix and the 3 by 10 $[\tilde{S}_2^{(i)}]$ Matrix.

The $[\tilde{S}_1^{(i)}]$ Matrix

	Col. 1	Col. 2	Col. 3	Col. 4
Row 1	$(\lambda_1^{(i)}E_{11}$	$(\lambda_1^{(i)}E_{11}$	$(\lambda_1^{(i)}E_{11}$	$(\lambda_1^{(i)}E_{11}$
	$+ \lambda_3^{(i)}E_{12}X^2(i)$	$+ \lambda_3^{(i)}E_{12})X^3(i)$	$+ \lambda_3^{(i)}E_{12})X^4(i)$	$+ \lambda_3^{(i)}E_{12})X^5(i)$
Row 2	$(\lambda_1^{(i)}E_{12}$	$(\lambda_1^{(i)}E_{12}$	$(\lambda_1^{(i)}E_{12}$	$(\lambda_1^{(i)}E_{12}$
	$+ \lambda_3^{(i)}E_{22})X^2(i)$	$+ \lambda_3^{(i)}E_{22})X^3(i)$	$+ \lambda_3^{(i)}E_{22})X^4(i)$	$+ \lambda_3^{(i)}E_{22})X^5(i)$

The $[\tilde{S}_2^{(i)}]$ Matrix

Row 1	$-2\lambda_2^{(i)}E_{12})X(i)$	$- 3\lambda_2^{(i)}E_{12}X^2(i)$	$- 4\lambda_2^{(i)}E_{12}X^3(i)$	$- 5\lambda_2^{(i)}E_{12}X^4(i)$
	$- 2E_{11}$	$- 6E_{11}X(i)$	$- 12E_{11}X^2(i)$	$- 20E_{11}X^3(i)$
Row 2	$2\lambda_2^{(i)}E_{22}X(i)$	$3\lambda_2^{(i)}E_{12}X^2(i)$	$4\lambda_2^{(i)}E_{22}X^3(i)$	$5\lambda_2^{(i)}E_{22}X^4(i)$
	$+ 2E_{12}$	$+ 6E_{12}X(i)$	$+ 12E_{12}X^2(i)$	$+ 20E_{12}X^3(i)$
Row 3	$2g^{(i)}X(i)$	$3g^{(i)}X^2(i)$	$4g^{(i)}X^3(i)$	$5g^{(i)}X^4(i)$
	$- 2\lambda_2^{(i)}E_{11}$	$- 6\lambda_2^{(i)}E_{11}X(i)$	$- 12\lambda_2^{(i)}E_{11}X^2(i)$	$- 20\lambda_2^{(i)}E_{11}X^3(i)$
		$- 6E_{11}$	$- 24E_{11}X(i)$	$- 60E_{11}X^2(i)$

where $g^{(i)} = (\lambda_2^{(i)})^2 E_{22} - \lambda_4^{(i)}E_{12}$ and

$$[\tilde{S}^{(i)}] \quad \left[\begin{array}{c} \tilde{S}_1^{(i)} \\ \hline \tilde{S}_2^{(i)} \end{array}\right]$$

6. Transform the stress matrix to grid point degrees of freedom

$$[\bar{S}] = [\tilde{S}][\Gamma_{\beta q}] . \tag{99}$$

7. Transform the stress matrix from local to system coordinates

$$[S] = [\bar{S}]\,[\Gamma_{rs}] . \tag{100}$$

8. Transform the stress matrix to global coordinates

$$[S]_g = [S]\,[T_{12}] . \tag{101}$$

9. Compute the thermal stress vector for the three stress points:

$$\{T_s^{(i)}\} = \begin{Bmatrix} \Delta T_1^{(m)} H_m (E_{11}\alpha_1 + E_{12}\alpha_2) + \Delta T_2^{(m)} H_m \frac{Xi}{S} (E_{11}\alpha_1 + E_{12}\alpha_2) \\ \Delta T_1^{(m)} H_m (E_{21}\alpha_1 + E_{22}\alpha_2) + \Delta T_2^{(m)} H_m \frac{Xi}{S} (E_{21}\alpha_1 + E_{22}\alpha_2) \\ \Delta T_1^{(f)} \frac{H_f^3}{12} (E_{11}\alpha_1 + E_{12}\alpha_2) + \Delta T_2^{(f)} \frac{H_f^3 Xi}{12S} (E_{11}\alpha_1 + E_{12}\alpha_2) \\ -\Delta T_1^{(f)} \frac{H_f^3}{12} (E_{21}\alpha_1 + E_{22}\alpha_2) - \Delta T_2^{(f)} \frac{H_f^3 Xi}{12S} (E_{21}\alpha_1 + E_{22}\alpha_2) \\ \Delta T_1^{(f)} \frac{H_f^3}{12} \lambda_2^{(i)} [(E_{11} - E_{12})\alpha_1 + (E_{12} - E_{22})\alpha_2] \\ \quad + \Delta T_2^{(f)} \frac{H^3}{12S} \Big\{ \lambda_2^{(i)} Xi [(E_{11} - E_{12})\alpha_1 \\ \quad + (E_{12} - E_{22})\alpha_2] + [E_{11}\alpha_1 + E_{12}\alpha_2] \Big\} \end{Bmatrix} \quad (5 \times 1) \tag{102}$$

where $\Delta T_1^{(m)}$, $\Delta T_2^{(m)}$, $\Delta T_1^{(f)}$ and $\Delta T_2^{(f)}$ are as given in Equations 66 through 69.

10. Form the master thermal stress vector

$$\{T_s\} = \begin{Bmatrix} T_s^{(1)} \\ \hline T_s^{(2)} \\ \hline T_s^{(3)} \end{Bmatrix} . \tag{103}$$

Phase 2 calculations are as follows:

1. Extract the displacement vector, $\{\Delta\}$, at the two grid points from the global displacement vector.

2. Calculate the element forces:

$$\{P\} = [K]\{\Delta\} . \tag{104}$$

3. Calculate the element stresses without regard to thermal loading:

$$\{\sigma'\} = [S]_g \{\Delta\} \quad (12 \times 1) . \tag{105}$$

4. If there is no thermal loading, then

$$\{\sigma\} = \{\sigma'\} . \tag{106}$$

5. If there is thermal loading, then

$$\sigma_j = \sigma'_j - (T_1 - T_o) T_{S_j} - (T_2 - T_1) T_{S_{j+15}} . \tag{107}$$

for j = 1 and 2 and

$$\sigma_j = \sigma'_j . \tag{108}$$

for j = 3, 4, 5.

4.87.13 The VISC Element

The viscous element, VISC, has the same properties as the RØD element (see section 4.87.1) except that instead of generating a contribution to the stiffness matrix, the element generates a contribution to the damping matrix, $[B_{gg}]$.

4.87.13.1 Input Data for the VISC Element

1. The ECPT/EST entries for the VISC are:

Symbol	Description
SIL_a, SIL_b	Scalar indices for grid points a and b
N_a, X_a, Y_a, Z_a N_b, X_b, Y_b, Z_b	Local coordinate system number and basic coordinates of grid points.
C_1	Extensional damping coefficient
C_2	Torsional damping coefficient

Given N_a, X_a, Y_a, Z_a, N_b, X_b, Y_b and Z_b and the CSTM (Coordinate System Transformation Matrices) data block, the 3 by 3 transformation matrices, $[T_a]$ and $[T_b]$, are calculated using utility routine TRANSD (see section 3.4.37).

4.87.13.2 Damping Matrix Calculations (Subroutine BVISC of Module SMA2)

1. Generate {n} as in Equation 2, section 4.87.1.2, and generate the transformation matrices $[T_a]$ and $[T_b]$.

2. Calculate:

$$[b_t] = C_1 \begin{bmatrix} n_1^2 & n_1n_2 & n_1n_3 \\ n_1n_2 & n_2^2 & n_2n_3 \\ n_1n_3 & n_2n_3 & n_3^2 \end{bmatrix}, \qquad (1)$$

$$[b_r] = C_2 \begin{bmatrix} n_1^2 & n_1n_2 & n_1n_3 \\ n_1n_2 & n_2^2 & n_2n_3 \\ n_1n_3 & n_2n_3 & n_3^2 \end{bmatrix} . \quad (2)$$

3. The 6x6 damping matrices are:

$$[B_{aa}] = \left[\begin{array}{c|c} T_a^T b_t T_a & 0 \\ \hline 0 & T_a^T b_r T_a \end{array}\right] , \quad (3)$$

$$[B_{ab}] = -\left[\begin{array}{c|c} T_a^T b_t T_b & 0 \\ \hline 0 & T_a^T b_r T_b \end{array}\right] , \quad (4)$$

$$[B_{bb}] = \left[\begin{array}{c|c} T_b^T b_t T_b & 0 \\ \hline 0 & T_b^T b_r T_b \end{array}\right] , \quad (5)$$

$$[B_{ba}] = -\left[\begin{array}{c|c} T_b^T b_t T_a & 0 \\ \hline 0 & T_b^T b_r T_a \end{array}\right] . \quad (6)$$

4. These matrices are added to $[B_{gg}]$.

4.87.14 Integral Calculations for the TRIARG, TRAPRG Elements

Integrals of the form

$$I_{pq} = \int_{R_j}^{R_i} \int_{Z_{mn}}^{Z_{k\ell}} r^p z^q \, dz dr \quad . \tag{1}$$

must be calculated for the TRIARG and TRAPRG elements (see sections 4.87.10.3 and 4.87.11.3). The integration may be performed for any integer values of p and q. The area of integration is defined by the two lines $r = R_i$ and $r = R_j$, and by the two lines $z = b_{k\ell} r + a_{k\ell}$ and $z = b_{mn} R + a_{mn}$.

This integration is performed by the integration "driver" subroutine, FØRTRAN function DKI in module SMA1, FØRTRAN function DMI in module SMA2, and FØRTRAN function AI in module SDR2.

The following input data are necessary for these routines:

- p - an integer that defines the power of the r variable.
- q - an integer that defines the power of the z variable.
- {R} - a vector of the r coordinates of all points used to describe the area of integration.
- {Z} - a vector of the z coordinates of all points used to describe the area of integration.
- k,ℓ - the subcripts of R, Z defining one of the lines of the limit of integration (i.e., the line between points (r_k, z_k) and (r_ℓ, z_ℓ)).
- m,n - the subscripts of R, Z defining the second line on the limit of integration.
- i,j - the subscripts of R defining the other two lines on the limit of integration.

In the following paragraphs FØRTRAN names of functions auxiliary to DKI are given. The corresponding FØRTRAN function names auxiliary to functions DMI and AI can be found in sections 4.28.8 and 4.46.8 respectively.

The following slopes and y-intercepts are calculated in functions DKK and DKM

$$a_{k\ell} = \frac{R_\ell Z_k - R_k Z_\ell}{R_\ell - R_k} , \tag{2}$$

$$b_{k\ell} = \frac{Z_\ell - Z_k}{R_\ell - R_k} , \tag{3}$$

$$a_{mn} = \frac{R_n Z_m - R_m Z_n}{R_n - R_m} , \tag{4}$$

$$b_{mn} = \frac{Z_n - Z_m}{R_n - R_m} . \tag{5}$$

A test for a vanishing area of integration is made: if $R_i = R_j$, then $I_{pq} = 0$; if $a_{k\ell} = a_{mn}$ and $b_{k\ell} = b_{mn}$, then $I_{pq} = 0$.

The formulas for evaluation of the integrals are dependent upon the values of p and q as given in the following sections.

4.87.14.1 Integral Calculation for $q \geq 0$ and any p. (Function DKINT)

Define the function

$$f_1(x,y) = \frac{1}{q+1} \sum_{t=0}^{q+1} C\, x^t\, y^{q+1-t} D \quad , \tag{6}$$

where

$$C = \begin{cases} \prod_{s=1}^{t} \dfrac{q+1-s+1}{s} & \text{for } t \neq 0 \quad , \\ 1 & \text{for } t = 0 \quad , \end{cases} \tag{7}$$

$$D = \begin{cases} \left[\dfrac{R_j^{(q+1+p+1-t)} - R_i^{(q+1+p+1-t)}}{q+1+p+1-t}\right] & \text{for } (q+1+p+1-t) \neq 0 \\ \ln\,(R_j/R_i) & \text{for } (q+1+p+1-t) = 0 \end{cases} . \tag{8}$$

C and D are calculated in functions DKEF and DKJ respectively.

The integral is

$$I_{pq} = f_1(a_{mn},b_{mn}) - f_1(a_{k\ell},b_{k\ell}) \quad . \tag{9}$$

4.87.14.2 Integral Calculation for $p \geq 0$ and $q < -1$ (Function DK89)

$$f_2(\alpha,x,y) = \frac{1}{y^{p+1}} \sum_{s=0}^{p} p!(-x)^s\, D \quad , \tag{10}$$

where

$$D = \begin{cases} \dfrac{(x+yR_\alpha)^{p+1+q+1-s}}{(p-s)!s!(p+1+q+1-s)} & \text{for } (p+1+q+1-s) \neq 0 \\ \dfrac{\ln|x+yR_\alpha|}{(p+1+q+1)!(-q-2)!} & \text{for } (p+1+q+1-s) = 0 \end{cases} , \tag{11}$$

and α = i or j.

The integral is

$$I_{pq} = \frac{1}{2+q}\left[f_2(i,a_{k\ell},b_{k\ell}) - f_2(i,a_{mn}\ b_{mn})\right.$$

$$\left. - f_2(j,a_{k\ell},b_{k\ell}) + f_2(j,a_{mn},b_{mn})\right] \quad . \tag{12}$$

4.87.14.3 Integral Calculation for p< 0 and q< - 1 (Function DK100)

Define the function

$$f_3(\alpha,x,y) = \frac{-1}{x^{(-p-q-2)}} \sum_{s=0}^{-p-q-3} (-p-q-3)\ !\ D \quad , \tag{13}$$

where

$$D = \begin{cases} \dfrac{(x+yR_\alpha)^{(-p-1-s)}\ (-y)^s}{(-p-q-3-s)!s!(-p-1-s)R_\alpha^{(-p-1-s)}} & \text{for } (-p-1-s) \neq 0 \\ \dfrac{(-y)^{-p-1}\ \ln\left(\left|\dfrac{x+yR_\alpha}{R_\alpha}\right|\right)}{(-p-1)!(-q-2)!} & \text{for } (-p-1-s) = 0 \end{cases} \quad , \tag{14}$$

and α = i or j.

The integral is

$$I_{pq} = \frac{1}{2+q}\left[f_3(i,a_{k\ell},b_{k\ell}) - f_3(i,a_{mn},b_{mn})\right.$$

$$\left. - f_3(i,a_{k\ell},b_{k\ell}) + f_3(i,a_{mn},b_{mn})\right] \quad . \tag{15}$$

4.87.14.4 Integral Calculations for p > - 1 and q = -1 (Function DKJAB)

Define the function

$$f_4(\alpha,x,y) = \frac{R_\alpha^{p+1}\ln(|x+yR_\alpha|)}{p+1} - \frac{y}{p+1} f_2(\alpha,x,y) , \tag{16}$$

where f_2 is given in Equation 10.

The integral is

$$I_{pq} = f_4(i,a_{k\ell},b_{k\ell}) - f_4(i,a_{mn},b_{mn}) - f_4(j,a_{k\ell},b_{k\ell}) - f_4(j,a_{mn},b_{mn}) \tag{17}$$

4.87.14.5 Integral Calculations for p < - 1 and q = -1 (Function DK219)

Define the function

$$f_5(\alpha,x,y) = -\frac{\ln(|x+yR_\alpha|)}{(-p-1)R_\alpha^{(-p-1)}} + \frac{y}{(-p-1)} f_3(\alpha,x,y) , \tag{18}$$

where f_3 is given in Equation 13.

The integral is

$$I_{pq} = f_5(i,a_{k\ell},b_{k\ell}) - f_5(i,a_{mn},b_{mn}) - f_5(j,a_{k\ell},b_{k\ell}) - f_5(j,a_{mn},b_{mn}) \tag{19}$$

4.87.14.6 Integral Calculations for p = -1 and q = -1 (Function DK211)

Define the function

$$f_6(\alpha,x,y) = \begin{cases} 0, & \text{for } yR_\alpha = x \\ \frac{1}{2}[\ln(|2\,y\,R_\alpha|)]^2, & \text{for } (yR_\alpha)^2 = x^2 \text{ and } yR_\alpha \neq x \\ \ln|x|\,\ln|R_\alpha| - \sum_{t=1}^{\infty} \frac{1}{t^2}\left[\frac{-yR_\alpha}{x}\right]^t, & \text{for } (yR_\alpha)^2 < x^2 \\ \frac{1}{2}[\ln(|yR_\alpha|)]^2 + \sum_{t=1}^{\infty} \frac{1}{t^2}\left[\frac{-x}{yR_\alpha}\right]^t, & \text{for } (yR_\alpha)^2 < x^2 \end{cases} \quad (20)$$

The summation term is calculated until its value becomes less than 1.0×10^{-6}.

The integral is

$$I_{pq} = f_6(i,a_{k\ell},b_{k\ell}) - f_6(i,a_{mn},b_{mn}) - f_6(i,a_{k\ell},b_{k\ell}) - f_6(i,a_{mn},b_{mn}) \quad (21)$$

4.87.15 The FLUID2, FLUID3, FLUID4, AXIF2, AXIF3, AXIF4, and MFREE Elements

4.87.15.1 Input Data for the Fluid Elements

1. The ECPT/EST entries for the FLUID2 element are:

Symbol	Description
SIL_1, SIL_2	Scalar indices for the connected scalar points
$N_i = 0, r_i, z_i, 0$ $i = 1, 2$	Reference number for the basic coordinate system and locations in the fluid coordinate systems.
ρ	Fluid density
B	Fluid bulk modulus
n	Harmonic number

2. The ECPT/EST entries for the FLUID3 and FLUID4 elements are identical except that three and four points are used respectively.

3. The ECPT/EST entries for the MFREE element are identical to the FLUID2 element except that a weight factor, γ, is used instead of ρ and B.

4. No other material or coordinate system data is necessary.

5. The AXIF elements are identical to the FLUID elements at this stage.

4.87.15.2 Matrix Calculations for the FLUID2 Element (Subroutine KFLUD2 of Module SMA1 and Subroutine MFLUD2 of Module SMA2)

The FLUID2 element is intended to model a fluid in the region adjacent to and including the axis of symmetry. The volume is defined by two circular ring points in the fluid. The shape is that of a disc having a conical or cylindrical outer boundary.

1. The integral parameters, for the stiffness matrix, $I_{2n,0}$, $I_{2n,1}$, $I_{2n,2}$, and $I_{2n+2,0}$ are calculated according to the following equations:

$$\left.\begin{aligned} I_{2n,0} &= I_{2n,1} = I_{2n,2} = 0 \quad , \\ I_{2n+2,0} &= \frac{1}{6}(z_2 - z_1)(r_2^2 + r_1 r_2 + r_1^2) \end{aligned}\right\} \quad n = 0 \quad . \qquad (1)$$

If $\left|\frac{r_2-r_1}{z_2-z_1}\right| < 10^{-6}$:

$$\left.\begin{aligned} I_{2n,0} &= \left[\frac{r_1+r_2}{2}\right]^{2n}\left(\frac{z_2-z_1}{2n}\right) \\ I_{2n,1} &= \frac{I_{2n,0}}{2}(z_2+z_1) \\ I_{2n,2} &= \frac{I_{2n,0}}{3}(z_2^2+z_1z_2+z_1^2) \\ I_{2n+2,0} &= I_{2n,0}\left(\frac{2n}{2n+2}\right)r_1^2 \end{aligned}\right\} \quad n > 0 . \qquad (2)$$

If $\left|\frac{r_2-r_1}{z_2-z_1}\right| > 10^{-6}$:

$$D = \frac{z_2-z_1}{r_2-r_1} \qquad (3)$$

$$\left.\begin{aligned} I_{2n,0} &= \frac{D}{2n(2n+1)}\left(r_2^{2n+1}-r_1^{2n+1}\right) \\ I_{2n,1} &= \frac{D}{2n(2n+1)}\left[r^{2n+1}z_2 - r_1^{2n+1}z_1 - \left(\frac{D}{2n+2}\right)\left(r_2^{2n+2}-r_1^{2n+2}\right)\right] \\ I_{2n,2} &= \frac{D}{2n(2n+1)}\left\{r_2^{2n+1}z_2^2 - r_1^{2n+1}z_1^2 - \left(\frac{2D}{2n+2}\right)\left[r_2^{2n+2}z_2 - r_1^{2n+2}z_1 - \frac{D}{2n+3}\left(r_2^{2n+3}-r_1^{2n+3}\right)\right]\right\} \\ I_{2n+2,0} &= \frac{D}{(2n+2)(2n+3)}\left[r_2^{2n+3}-r_1^{2n+3}\right] . \end{aligned}\right\} \quad (4) \quad n > 0$$

2. The integral parameters for the mass matrix, $I_{2n+2,0}$, $I_{2n+2,1}$, and $I_{2n+2,2}$ are calculated with the same equations as above except the value k = 2n+2 is substituted for k = 2n.

3. The transformation matrix $[H^n_{qp}]$ is defined as:

$$[H^n_{pq}] = \frac{1}{z_2 - z_1} \begin{bmatrix} \frac{z_2}{r_1^n} & -\frac{z_1}{r_2^n} \\ -\frac{1}{r_1^n} & \frac{1}{r_2^n} \end{bmatrix} . \quad (5)$$

4. The stiffness matrix is:

$$[K^n_p] = \frac{\pi}{\rho} [H^n_{pq}]^T \begin{bmatrix} (2n^2\ I_{2n,0}) & (2n^2\ I_{2n,1}) \\ (2n^2\ I_{2n,1}) & (2n^2\ I_{2n,2} + I_{2n+2,0}) \end{bmatrix} [H^n_{pq}] \quad (6)$$

$n > 0$

Note: if n = 0, a factor of 2 is used.

5. The mass matrix is:

$$[M^n_p] = \frac{\pi}{B} [H^n_{pq}]^T \begin{bmatrix} I_{2n+2,0} & I_{2n+2,1} \\ I_{2n+2,1} & I_{2n+2,2} \end{bmatrix} [H^n_{pq}] , \quad n > 0 . \quad (7)$$

Note: if n = 0 a factor of 2 is used.

6. Various tests are performed for the element.

If $|z_2 - z_1| = 0$, the calculations are skipped,

if $r_1 = 0$ or $r_2 = 0$, a fatal error exists,

if $\rho = 0$, a fatal error exists,

if B = 0, the mass calculations are skipped.

4.87.15.3 Matrix Calculations for the FLUID3 Element (Subroutines KFLUD3 of Module SMA1 and Subroutine MFLUD3 of Module SMA2)

The FLUID3 element is used to model a volume of fluid defined by three connected fluid ring points.

1. The three connected points are arranged in the order such that the area factor, R, is positive. The area factor is defined by the equation:

$$R = (r_2 - r_1)(z_3 - z_1) - (r_3 - r_1)(z_2 - z_1) \; . \qquad (8)$$

2. The transformation matrix, $[H_{pq}]$, is calculated as:

$$[H_{pq}] = \frac{1}{R}\begin{bmatrix} (r_2z_3 - r_3z_2) & (r_3z_1 - r_1z_3) & (r_1z_2 - r_2z_1) \\ (z_2 - z_3) & (z_3 - z_1) & (z_1 - z_2) \\ (r_3 - r_2) & (r_1 - r_3) & (r_2 - r_1) \end{bmatrix} \; . \qquad (9)$$

3. The integral parameters, $I_{k\ell}$, for the stiffness matrix are the sum of the integrals, $G_{k\ell}$, for each of the three sides. The points defining each side are:

SIDE	POINTS - a,b
1	1, 2
2	2, 3
3	3, 1

The following parameters are used to generate the integrals, $G_{k\ell}$:

$$\left.\begin{aligned} \Delta r &= r_b - r_a \\ \Delta z &= z_b - z_a \\ \beta &= z_a - r_a \frac{\Delta z}{\Delta r} \end{aligned}\right\} \; . \qquad (10)$$

The integrals for each side are:

$$
\left.
\begin{aligned}
G_{00} &= \beta \log \frac{r_a}{r_b} - \Delta z \\
G_{10} &= -\beta\Delta r + \frac{\Delta z}{2\Delta r}(r_a^2 - r_b^2) \\
G_{20} &= \frac{1}{2}\beta(r_a^2 - r_b^2) + \frac{\Delta z}{3\Delta r}(r_a^3 - r_b^3) \\
G_{01} &= \frac{1}{2}\beta^2 \log \frac{r_a}{r_b} - \beta\Delta z + \frac{1}{4}\frac{\Delta z^2}{\Delta r^2}(r_a^2 - r_b^2) \\
G_{11} &= -\frac{1}{2}\beta^2 \Delta r + \frac{1}{2}\beta \frac{\Delta z}{\Delta r}(r_a^2 - r_b^2) + \frac{1}{6}\left(\frac{\Delta z}{\Delta r}\right)^2 (r_a^3 - r_b^3) \\
G_{02} &= \frac{1}{3}\beta^3 \log \frac{r_a}{r_b} - \beta^2\Delta z + \frac{1}{2}\beta\left(\frac{\Delta z}{\Delta r}\right)^2 (r_a^2 - r_b^2) + \frac{1}{9}\left(\frac{\Delta z}{\Delta r}\right)^3 (r_a^3 - r_b^3)
\end{aligned}
\right\} \quad (11)
$$

4. The stiffness matrix is:

$$
[K_p^n] = \frac{\pi}{\rho}[H_{pq}]^T \begin{bmatrix} n^2 I_{00} & n^2 I_{10} & n^2 I_{01} \\ n^2 I_{10} & (n^2+1) I_{20} & n^2 I_{11} \\ n^2 I_{01} & n^2 I_{11} & (n^2 I_{02} + I_{20}) \end{bmatrix} [H_{pq}] . \quad (12)
$$

The matrix terms are multiplied by two if n = 0.

5. The mass matrix terms are simply:

$$
M_{ij}^n = \frac{\pi A}{60B}(r_1 + r_2 + r_3 + r_i + r_j)\, c_{ij} , \quad (13)
$$

where

$$
c_{ij} = 2 , \qquad i = j,
$$

$$
c_{ij} = 1 , \qquad i \neq j,
$$

and

$$
A = \frac{R}{2} \text{ is the area.}
$$

6. The tests performed are:

   if $r_i = 0$ a fatal error exists,

   if $R = 0$ the routine exits,

   if $\rho = 0$ a fatal error exists,

   if $B = 0$ the mass routine exits.

4.87.15.4 Matrix Generation for the FLUID4 Element (Subroutine KFLUD4 in Module SMA1 and Subroutine MFLUD4 in Module SMA2)

This element describes an axisymmetric volume of fluid defined by four fluid ring points. It is actually solved by subdividing the quadrilateral cross section into four triangles and calling the appropriate FLUID3 subroutine for each of the triangles. The parameters ρ and B are multiplied by two in order to account for the overlapping volumes and reduce the matrix terms.

1. A test is made in the stiffness routine to check the interior angles which must be less than 180°. For each of the four triangles, the area factor K is calculated which will be positive if the order of the points is counterclockwise. If K is negative for one or three out of the four triangles, a fatal error exists.

2. The triangles and their three connected points are:

Triangle	Connected Points		
	a	b	c
I	1	2	3
II	1	2	4
III	1	3	4
IV	2	3	4

(14)

   The ECPT data is moved to a temporary storage space and the original ECPT is used for the data for each triangle.

3. Since matrix terms are only created if one of the connected points is the "pivot point", a test is made and the FLUID3 subroutine is not called if the "pivot point" is not one of the three points.

4.87.15.5 Matrix Calculations for the MFREE Element (Subroutine MFREE in Module SMA2)

The data for this element is generated by subroutine IFP4 from the free surface information and is not available as a user-input element. The element describes the effect of gravity on a surface in between two fluid ring points. In a special case, the surface is interior to a circle defined by one fluid ring point.

1. If the two connected points are identical ($SIL_1 = SIL_2$), the special case exists and the equations are:

$$\left.\begin{aligned} M_{ii} &= \frac{\pi r^2}{2\gamma(2n+2)} \quad , \quad n > 0 \\ M_{ii} &= \frac{\pi r^2}{2\gamma} \quad , \quad n = 0 \end{aligned}\right\} \tag{15}$$

A factor of two is included in the denominator because the terms will be calculated twice.

2. If the connected points are unique, the equation for the mass matrix is:

$$[M_p^n] = \frac{\pi(r_2 - r_1)}{12\,\gamma}\begin{bmatrix} 3r_1 + r_2 & r_1 + r_2 \\ r_1 + r_2 & 3r_2 + r_1 \end{bmatrix} \quad , \quad n > 0. \tag{16}$$

The values are multiplied by two for n = 0.

4.87.15.6 Stress Calculations for the AXIF Elements, Phase 1.

The SDR2 calculations for these elements are actually the calculations of the velocity of the fluid passing through a fluid element.

The data placed on the ESTB file are:

1. Id_e - Element Id
2. SIL_1, SIL_2, (SIL_3, SIL_4) - Scalar indices of connected points
3. $[S_v]$ - the velocity-pressure matrix

The $[S_v]$ matrix for the CAXIF2 element is a four by two matrix given as follows:

$$[S_v] = \begin{bmatrix} S_c^2 \\ \hline S_e^2 \end{bmatrix} \tag{17}$$

where

$$\begin{Bmatrix} V_{rc} \\ V_{zc} \\ V_{se} \\ V_{\phi e} \end{Bmatrix} = [S_v] \begin{Bmatrix} p_1 \\ p_2 \end{Bmatrix} \tag{18}$$

V_{rc} and V_{zc} are velocities at r = 0, V_{se} and $V_{\phi e}$ are velocities at the midpoint of the outer edge, along the edge and circumferential.

The two by two matrix $[S_c]$, for the center, is:

$$[S_c^2] = \frac{1}{\rho} \begin{bmatrix} 0 & 0 \\ \frac{1}{z_2 - z_1} & \frac{-1}{z_2 - z_1} \end{bmatrix} \quad n = 0 \tag{19}$$

$$[S_c^2] = \frac{1}{\rho} \begin{bmatrix} \frac{-1}{r_1 + r_2} & \frac{-1}{r_1 + r_2} \\ 0 & 0 \end{bmatrix} \quad n = 1 \tag{20}$$

$$[S_c^2] = [0] \qquad n > 1 \tag{21}$$

The two by two $[S_c^2]$ matrix, for the outer edge is:

$$[S_e^2] = -\frac{(\bar{r})^{n-1}}{\rho \ell} \begin{bmatrix} n\Delta r & (n\bar{z}\Delta r + \bar{r}\Delta z) \\ n\ell & n\bar{z}\ell \end{bmatrix} [H_{qp}^n] \tag{22}$$

where

$$\left.\begin{aligned} \Delta r &= r_2 - r_1 \ , \\ \Delta z &= z_2 - z_1 \ , \\ \bar{r} &= \frac{1}{2}(r_2 + r_1) \ , \\ \bar{z} &= \frac{1}{2}(z_2 + z_1) \ , \\ \ell &= \sqrt{\Delta r^2 + \Delta z^2} \ , \\ [H^n_{qp}] &= \frac{1}{\Delta z}\begin{bmatrix} \frac{z_2}{r_1^n} & -\frac{z_1}{r_2^n} \\ \\ \frac{-1}{r_1^n} & \frac{1}{r_2^n} \end{bmatrix} \end{aligned}\right\} \quad (23)$$

The nine by three $[S^t_v]$ matrix for the CAXIF3 element is calculated with the following equations

$$[S_v] = \begin{bmatrix} [S^t_c] \\ \hline [S^t_e] \end{bmatrix} \quad (24)$$

The three by three $[S^t_c]$ matrix relates three pressures to the three velocities in the basic coordinate system V_r, V_ϕ, V_z.

$$[S^t_e] = -\frac{1}{\rho}\begin{bmatrix} 0 & 1 & 0 \\ \frac{n}{r_c} & n & \frac{nz_c}{r_c} \\ 0 & 0 & 1 \end{bmatrix}[H^n_{qp}] \quad (25)$$

where $[H^n_{qp}]$ is a three by three transformation matrix between pressures and generalized coordinates defined in Section 4.87.15.3.

The six by three matrix, $[S^t_e]$, which defines the velocities at each edge, tangential and circumferential, is:

$$[S_e^t] = \frac{1}{\rho}\begin{bmatrix} \frac{1}{\ell_{12}} & -\frac{1}{\ell_{12}} & 0 \\ \frac{n}{r_1+r_2} & \frac{n}{r_1+r_2} & 0 \\ 0 & \frac{1}{\ell_{23}} & -\frac{1}{\ell_{23}} \\ 0 & \frac{n}{r_2+r_3} & \frac{n}{r_2+r_3} \\ -\frac{1}{\ell_{13}} & 0 & \frac{1}{\ell_{13}} \\ \frac{n}{r_1+r_3} & 0 & \frac{n}{r_1+r_3} \end{bmatrix} \qquad (26)$$

where $\ell_{ij} = \sqrt{(r_j - r_i)^2 + (z_j - z_i)^2}$

The CAXIF4 element is composed of four overlapping triangles. For each triangle I, II, III or IV the connected points 1, 2, 3, 4 are allocated as follows:

Triangles	Connected points a, b, c
I	1 2 3
II	1 2 4
III	1 3 4
IV	2 3 4

For each triangle calculate the 3x3 $[S_c^t]$ matrix from Equation 9 and add each column to one of four columns corresponding to the connected point. The results are divided by 4 to provide an average $[S_c^q]$ matrix for the quadrilateral.

The $[S_e^q]$ matrix for the quadrilateral is:

$$[S_e^q] = -\frac{1}{\rho}\begin{bmatrix} \frac{1}{\ell_{12}} & -\frac{1}{\ell_{12}} & & \\ \frac{n}{r_1+r_2} & \frac{n}{r_1+r_2} & & \\ & \frac{1}{\ell_{23}} & -\frac{1}{\ell_{23}} & \\ & \frac{n}{r_2+r_3} & \frac{n}{r_2+r_3} & \\ & & \frac{1}{\ell_{34}} & -\frac{1}{\ell_{34}} \\ & & \frac{n}{r_3+r_4} & \frac{n}{r_3+r_4} \\ -\frac{1}{\ell_{41}} & & & \frac{1}{\ell_{41}} \\ \frac{n}{r_4+r_1} & & & \frac{n}{r_4+r_1} \end{bmatrix} \qquad (27)$$

where $\ell_{ij} = \sqrt{(r_j - r_i)^2 + (z_j - z_i)^2}$.

The resulting $[S_v]$ matrix for the quadrilateral CAXIF4 element is:

$$[S_v] = \begin{bmatrix} S_c^q \\ \hline S_e^q \end{bmatrix} \qquad (28)$$

4.87.15.7 Stress Calculations for the AXIF Elements, Phase 2.

The element identification number, the indices of the connected points, and the $[S_v]$ matrices are given in the ESTB table. The pressures at the connected points, $\{P_i\}$, are given in the UGV matrix data block. Depending on the rigid format, the pressure values are either real or complex numbers and associated with each vector of pressures is a real eigenvalue, λ; a frequency, f, or a complex eigenvalue, P. The equation for velocity is

$$\{V\} = \frac{1}{\omega} [S_v] P_i \tag{29}$$

where $\{V\}$ is the vector of velocities in the element.

$\omega = \sqrt{|\lambda|}$ (real) in Rigid Format 3 ($\{P_i\}$ is real)

$\omega = 2\pi f$ (real) in Rigid Formats 8 and 11 ($\{P_i\}$ is complex)

$\omega = p$ (complex) in Rigid Formats 7 and 10 ($\{P_i\}$ is complex)

$\omega = 1.0$ in all other Rigid Formats ($\{P_i\}$ is real)

and $[S_v]$ is dimensioned 4x2, 9x3, or 11x4

for the CAXIF2, CAXIF3, and CAXIF4 elements respectively.

4.87.16 The SLØT3 and SLØT4 Fluid Elements

4.87.16.1 Input Data For the SLØT3 and SLØT4 Elements

1. The ECPT/EST entires for the SLØT3 are:

Symbol	Description
SIL_1, SIL_2, SIL_3	Scalar indices for the connected grid points
r_i, z_i, w_i, i = 1,2,3	Radius and axis location and slot width of connected grid points, i.
ρ	Density
B	Bulk Modulus
M	Number of Slots
N	Harmonic Number

2. ECPT/EST entries for the SLØT4 are the same as for the SLØT3 except four points are used.

4.87.16.2 General Calculations for the SLØT Elements

1. The overall factor for the number of slots is:

$$F = M, \quad 2N = 0, M, 2M, 3M, \ldots\ldots \tag{1}$$

$$F = \frac{M}{2}, \quad 2N \neq 0, M, 2M, 3M, \ldots\ldots \tag{2}$$

2. The SLØT4 element is composed of four overlapping triangles. If the SLØT4 element is used, its data is rearranged to the SLØT3 format and the following operations are carried out for all four subtriangles. A test is made on the direction of the vector normal to the surface of all four triangles if the number of negative normal vectors (NNEG) is one or three, a valid quadrilateral is impossible and a fatal error is set.

4.87.16.3 Stiffness Matrix Generation for the SLØT3 Elements

1. For each triangle the following terms are calculated:

$$2 \cdot A = A_2 = \left[r_1(z_2 - z_3) + r_2(z_3 - z_1) + r_3(z_1 - z_2)\right] \tag{3}$$

$$C_o = \frac{F}{6\rho|A_2|}\left[W_1 + W_2 + W_3\right] \tag{4}$$

$$\left.\begin{aligned} F_{ir} &= (r_k - r_j) \\ F_{iz} &= (z_j - z_k) \end{aligned}\right\} (i,j,k) = \begin{matrix}(1,2,3)\\(2,3,1)\\(3,1,2)\end{matrix} \tag{5}$$

2. The stiffness matrix terms are:

$$K_{ij} = C_o[F_{ij}\, F_{jr} + F_{iz}\, F_{jz}] \tag{6}$$

where

i = the "pivot point"

j = 1, 2, 3

4.87.16.4 Mass Matrix Generation for the SLØT3 Elements

1. The following coefficients are generated:

$$2 \cdot A = A_2 = (r_2 - r_1)(z_3 - z_1) - (r_3 - r_1)(z_2 - z_1) \tag{7}$$

$$\bar{w} = w_1 + w_2 + w_3 + w_i \ , \tag{8}$$

where i is the "pivot point"

$$C_o = \frac{F|A_2|}{120\ B}$$

2. The mass matrix terms are:

$$M_{ij} = C_o(\bar{w} + w_j) \qquad j = 1,2,3 \neq i$$

$$M_{ij} = 2C_o(\bar{w} + w_j) \qquad j = i$$

where i is the "pivot point".

4.87.16.5 Stress Matrix Calculations in the SLØT Elements (Phase 1)

The velocities in the SLØT elements are calculated in the same manner as stresses in a structural element. Phase 1 involves calculating pressure field - velocity matrices of the fluid passing through the element.

1. The data placed on the ESTB file are:

Id_e - element identification number

SIL_1, SIL_2,..., SIL_i - scalar indices

$[S_v]$ - matrix relation between pressure and velocity.

2. The $[S_v]$ matrix for the CSLØT3 element is a five by three matrix given as follows:

$$[S_v] = -\frac{1}{\rho}\begin{bmatrix} \frac{z_2-z_3}{A} & \frac{z_3-z_1}{A} & \frac{z_1-z_2}{A} \\ \frac{r_3-r_2}{A} & \frac{r_1-r_3}{A} & \frac{r_2-r_1}{A} \\ \hline -\frac{1}{\ell_{12}} & \frac{1}{\ell_{12}} & 0 \\ 0 & -\frac{1}{\ell_{23}} & \frac{1}{\ell_{23}} \\ \frac{1}{\ell_{23}} & 0 & -\frac{1}{\ell_{13}} \end{bmatrix} = \begin{bmatrix} S_v^t \\ \hline S_v^e \end{bmatrix} \tag{9}$$

where

$$\ell_{ij} = \sqrt{(r_j - r_i)^2 + (z_j - z_i)^2} \tag{10}$$

$$A = \frac{1}{2}\left[r_1(z_2 - z_3) + r_2(z_3 - z_1) + r_3(z_1 - z_2)\right]$$

The five rows of the matrix correspond to the velocities V_{rc} and V_{zc} at the centroid in the r and z direction and V_1, V_2, V_3 corresponding to velocities along the three edges.

3. The CSLØT4 element is composed of four overlapping triangles. The velocity at the intersection of the triangles is calculated to be the average of the velocities in each subtriangle. The subtriangles I, II, III and IV are each given three of the four points 1, 2, 3, 4 as in the following chart:

Triangle Number	Connected Points		
	a	b	c
I	1	2	3
II	1	2	4
III	1	3	4
IV	2	3	4

The $[S_v^t]$ matrix for each triangle is calculated and each of the three columns is inserted in one of the four corresponding columns in the $[S_v^q]$ matrix for the quadrilateral. For instance the first column of $[S_v^t]$ for triangle IV is inserted in column 2 of the $[S_v^q]$ matrix. Rows four through seven of the $[S_v^q]$ matrix are recalculated to correspond to the sides of the

quadrilateral. The resulting matrix for the CSLØT4 element is:

$$[S_v^q] = \begin{bmatrix} \text{First 2 rows} = \frac{1}{4}\sum [S_v^t] \\ \hline \frac{1}{\rho\ell_{12}} & -\frac{1}{\rho\ell_{12}} & & \\ & \frac{1}{\rho\ell_{23}} & -\frac{1}{\rho\ell_{23}} & \\ & & \frac{1}{\rho\ell_{34}} & -\frac{1}{\rho\ell_{34}} \\ -\frac{1}{\rho\ell_{41}} & & & \frac{1}{\rho\ell_{41}} \end{bmatrix} \qquad (11)$$

where

$$\ell_{ij} = \sqrt{(r_j - r_i)^2 + (z_j - z_i)^2}$$

4.87.16.6 CSLØTi Element, Phase 2

The data calculated above are extracted from the ESTB data file and the corresponding pressures, p_i, are extracted from the UGV data block. Associated with each vector is a real or complex number. The general equation for velocity in the element is:

$$\{V\} = \frac{1}{\omega}[S_v]\{p_i\} \qquad (12)$$

where $\{V\}$ is the vector of velocities in the element

$\omega = \sqrt{|\lambda|}$ (real) in Rigid Format 3 ($\{p_i\}$ is real)

$\omega = 2\pi f$ (real) in Rigid Formats 8 and 11 ($\{p_i\}$ is complex)

$\omega = p$ (complex) in Rigid Formats 7 and 10 ($\{p_i\}$ is complex)

$\omega = 1.0$ (real) in all other Rigid Formats ($\{p_i\}$ is real)

and $[S_v]$ has dimensions 7x3 or 8x4 for the CSLØT3 and CSLØT4 elements respectively

4.87.17 Solid Polyhedra Elements, TETRA, WEDGE, HEXA1, HEXA2

These elements define three-dimensional shapes with four points defining a tetrahedron (TETRA), six points defining a wedge (WEDGE), and eight points defining a hexahedron (HEXA1 or HEXA2). Constant strain and stress is assumed in each tetrahedron. The wedge and hexahedron elements are automatically fabricated from tetrahedron elements.

4.87.17.1 Input Data for the Solid Polyhedra Elements

1. The ECPT entries for the solid elements are:

Symbol	Description
I_d	Element identification number
M	Material identification number
SIL_i, i = 1, N	Scalar indices of connected grid points. N = 4, 6, or 8
CS_i, X_i, Y_i, Z_i } i = 1, N	Coordinate system identification number and location in basic coordinates of connected grid points
$\overline{T}$	Average element temperature

2. Coordinate System Data

The numbers CS_i, X_i, Y_i, and Z_i are used to calculate 3 x 3 global-to-basic transformation matrices $[T_i]$ for the connected points. Subroutine TRANSD or TRANSS is used.

3. Material Data

Subroutine MAT is used to generate the following material coefficients:

E	Modulus of elasticity
G	Shear modulus
ν	Poisson's ratio
ρ	Mass density
α	Thermal expansion coefficient
T_0	Reference temperature

4.87.17.2 Basic Equations for the TETRA Element

1. The matrix which transforms generalized displacements to grid point displacements is $[H_{qu}]$ where

$$[H_{uq}] = \begin{bmatrix} 1 & X_1 & Y_1 & Z_1 \\ 1 & X_2 & Y_2 & Z_2 \\ 1 & X_3 & Y_3 & Z_3 \\ 1 & X_4 & Y_4 & Z_4 \end{bmatrix} . \qquad (1)$$

This matrix is inverted to produce the matrix $[H_{qu}] = [H_{uq}]^{-1}$ and the determinant, D, of $[H_{uq}]$.

The value of the determinant is checked to see if it is consistent with the determinants of the other tetrahedra being used in a single element.

2. The material coefficients E, G, and ν are used to generate the 6 x 6 matrix [G] where the nonzero terms are:

$$G_{11} = G_{22} = G_{33} = \frac{E\,(1 - \nu)}{(1 + \nu)\,(1 - 2\nu)} , \qquad (2)$$

$$G_{12} = G_{21} = G_{13} =$$

$$G_{31} = G_{23} = G_{32} = \frac{E\,\nu}{(1 + \nu)\,(1 - 2\nu)} , \qquad (3)$$

$$G_{44} = G_{55} = G_{66} = G. \qquad (4)$$

3. The four 6 x 3 matrices $[C^i]$ which transform displacements at points to strains are generated using elements of the H_{qu} matrix: H_{11}, H_{12}, etc. The equation is:

$$[C^i] = \begin{bmatrix} H_{2i} & 0 & 0 \\ 0 & H_{3i} & 0 \\ 0 & 0 & H_{4i} \\ 0 & H_{4i} & H_{3i} \\ H_{3i} & 0 & H_{1i} \\ H_{2i} & H_{1i} & 0 \end{bmatrix} . \qquad (5)$$

4.87.17.3 Stiffness Matrix Generations for the TETRA Element (Subroutine KTETRA of Module SMA1)

The 3 x 3 partition of the element stiffness matrix (in global coordinates) connecting points i and j is:

$$[K_{ij}] = [T_i]^T [C^i]^T [G] [C^j] [T_j] ,$$

where $[T_i]$ and $[T_j]$ are the 3 x 3 global-to-basic transformation matrices. The matrices are produced for point j corresponding to the pivot point in the matrix assembly process.

4.87.17.4 Mass Matrix Generation for the TETRA Element (Subroutine MSØLID of Module SMA2)

The mass matrix for each point of the tetrahedron is formed as a 6 x 6 matrix and inserted on the diagonal of the overall mass matrix. Its equation is:

$$M_{ii} = \begin{bmatrix} m/4 & & & & & \\ & m/4 & & & -0- & \\ & & m/4 & & & \\ & & & 0 & & \\ & -0- & & & 0 & \\ & & & & & 0 \end{bmatrix} , \qquad (6)$$

where $m = 1/6\ \rho|D|$. (D is the determinant of the $[H_{uq}]$ matrix.)

4.87.17.5 Thermal Load Generation for the TETRA Element (Subroutine TETRA of Module SSG1)

The 3 x 1 thermal load vector $\{P_i\}$ for point i of the tetrahedron is:

$$\{P_i\} = [T_i]^T [C_i]^T [G] \{\varepsilon_t\} , \tag{7}$$

$$\text{where } \{\varepsilon_t\} = \begin{Bmatrix} \alpha \\ \alpha \\ \alpha \\ 0 \\ 0 \\ 0 \end{Bmatrix} (\bar{T} - T_0) , \tag{8}$$

and $\bar{T} = 1/4\ (T_1 + T_2 + T_3 + T_4)$ is the average temperature of the four connected points, given in data block GPTT.

4.87.17.6 Stress Calculations for the TETRA Elements (Subroutines SSØLID1 and SSØLID2 of Module SPR2)

The stress is calculated in two phases. Phase I is used to calculate the transformation matrices between displacements and temperatures to stresses. Phase II uses the actual displacements and temperatures to calculate stresses.

1. In Phase I, the following calculations are performed:

$$[S_i] = [G] [C_i] [T_i] \quad i = 1, 2, 3, 4, \tag{9}$$

$$\{S_t\} = [G] \{\alpha\} , \tag{10}$$

where

$$\{\alpha\} = \begin{Bmatrix} \alpha \\ \alpha \\ \alpha \\ 0 \\ 0 \\ 0 \end{Bmatrix} . \tag{11}$$

2. In Phase II, the 3 x 1 displacement vector, $\{u_i\}$, for each point, i, is extracted from the $\{u_q\}$ displacement vector and the average temperature, $\bar{T}$, is extracted from the GPTT data block. The stresses are calculated as follows:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{yz} \\ \tau_{xy} \\ \tau_{xy} \end{Bmatrix} = \sum_{i=1}^{4} [S_i] \{u_i\} - \{S_t\} (\bar{T} - T_0). \quad (12)$$

The hydrostatic pressure, P, and the octahedral shear stress, τ_0, are calculated by the equations:

$$P = - 1/3 (\sigma_x + \sigma_y + \sigma_z), \quad (13)$$

$$\tau_0 = 1/3 [2\sigma_x (\sigma_x - \sigma_y - \sigma_z) + 2\sigma_y (\sigma_y - \sigma_z) + 2\sigma_z^2 + 6 (\tau_{yz}^2 + \tau_{xz}^2 + \tau_{xy}^2)]^{1/2} \quad (14)$$

4.87.17.7 Basic Equations for the WEDGE, HEXA1, and HEXA2 Elements

The wedge element is connected to six grid points and is divided into four tetrahedron sub-elements. The connected points assigned to each tetrahedron are:

TETRA Number	Connected Points
I	1 2 3 6
II	1 2 6 5
III	1 4 5 6

The HEXA1 and HEXA2 elements are connected to eight grid points and are subdivided into five tetrahedra for the HEXA1 element and ten overlapping tetrahedra for the HEXA2 element. The connected points original to each tetrahedron are:

Subelement Number		Connected Points			
HEXA1	HEXA2				
I	I	1	2	3	6
II	II	1	3	4	8
III	III	1	3	8	6
IV	IV	1	5	6	8
V	V	3	6	7	8
	VI	2	3	4	7
	VII	1	2	4	5
	VIII	2	4	5	7
	IX	2	5	6	7
	X	4	5	7	8

The basic procedure used with these elements is to extract the data associated with each tetrahedron subelement and go to the tetrahedron calculations. In subroutine KSØLID of Module SMA1, the tetrahedron calculations and matrix insertion is done by calling subroutine KTETRA. In subroutine MSØLID of Module SMA2, the tetrahedron calculations and insertion are done in an internal subroutine. In subroutine SØLID of Module SSG1, the tetrahedron subroutine STETRA is used to calculate and invert the thermal loads. In subroutines SSØLID1 and SSØLID2 of Module SDR2, the tetrahedron calculations are done with an internal subroutine and the results are summed together to produce average stresses.

4.87.17.8 Stiffness Matrix Calculations and Geometry Checks for the WEDGE, HEXA1, and HEXA2 Elements (Subroutine KSØLID of Module SMA1)

With these elements, the order of the connections and the resulting geometry is critical for reasonable results. Three basic criteria must be met:

1. If the connections are correct, the calculated volumes for all tetrahedron subelements will be consistent. When the subroutine is called for the first time for each element, all of the tetrahedra are processed to produce the signs of the determinants of the $[H_{uq}]$ matrices. The signs must be either all positive or all negative, or an error is indicated.

2. The order of the connected points is checked by calculating the normal vectors to the top and bottom faces assuming a right-hand rule. The normal vectors must not have a negative scalar product.

3. The wedge has three quadrilateral faces and the hexagonal elements have six quadrilateral faces. Subroutine KPLTST is used to check these faces. The points must not deviate from being a plane by more than 10 percent.

Wedge

Face Number	Points on Face
1	1, 2, 5, 4
2	1, 4, 6, 3
3	2, 3, 6, 5

Hexahedron

Face Number	Points on Face
1	1, 2, 3, 4
2	1, 2, 6, 5
3	2, 3, 7, 6
4	3, 4, 8, 7
5	4, 1, 5, 8
6	5, 6, 7, 8

In the KSØLID subroutine, each element is tested for geometric consistency when the pivot point equals the first connected point. In any event, the ECPT data is converted to the TETRA format for as many times as necessary, and subroutine KTETRA is called each time. If a HEXA2 element is being processed, a flag is set, so the KTETRA subroutine will divide the stiffness of each tetrahedron by two.

4.87.17.9 Mass Matrix Generation for the WEDGE, HEXA1 and HEXA2 Elements (Subroutine MSØLID of Module SMA2)

The mass calculations involve the calculation of the total mass of each tetrahedron in the element and assigning one-fourth of the mass to each of the four points. If a HEXA2 element is used, the mass of each tetrahedron is divided by two.

4.87.17.10 Thermal Load Generation for the WEDGE, HEXA1 and HEXA2 Elements (Subroutine SØLID of Module SSG2)

This subroutine arranges the ECPT data into the TETRA format for each tetrahedron in the element. Subroutine TETRA is called each time to calculate the thermal loads and insert them in the load vector. If a HEXA2 element is used, a flag is set, so that the TETRA routine will divide the results by two.

4.87.17.11 Stress Data Recovery for the WEDGE, HEXA1 and HEXA2 Elements (Subroutines SSØLID1 and SSØLID2 of Module SDR2)

The first phase of stress recovery involves the calculation of displacement-stress matrices $[S_{ie}]$ and the temperature stress vector $\{S_{te}\}$. A 6 x 3 $[S_{ie}]$ matrix is generated for each connected point. Its equation is:

$$[S_{ie}] = \frac{1}{N} \sum_{\alpha = 1} [S_i]_\alpha , \tag{15}$$

where $[S_i]_\alpha$ is the matrix corresponding to tetrahedron number α associated with point i, and N is the total number of tetrahedra in the element. The $[S_i]_\alpha$ matrices are described in Section 4.87.17.6. As each tetrahedron is processed, the four $[S_i]$ matrices and the $\{S_t\}$ vector are added to the appropriate $[S_{ie}]$ matrices for the whole element. The TETRA element is also processed by this code with N = 1. The thermal stress vectors are added by the equation:

$$\{S_{te}\} = \frac{1}{N} \sum_{\alpha = 1}^{N} \{S_t\}_\alpha \tag{16}$$

In Phase II of stress recovery, the logic is given in Section 4.87.17.6. The code is identical for all elements, with the only difference being the number of connected grid points.

4.87.17.12 Thermal Analysis Calculations for the Solid Elements (Subroutine KTETRA of Module SMA1)

All of the solid elements (TETRA, WEDGE, HEXA1, and HEXA2) use the KTETRA subroutine to calculate and insert the final matrix terms. For thermal analysis, the following operations are performed:

1. The geometry is processed and the matrix $[H_{uq}]$ and the determinant, D, are produced for either structure or thermal analysis. See Section 4.87.17.3.

2. For thermal analysis, subroutine HMAT is used with INFLAG = 3 to produce the following data:

$$K_{xx}\ K_{xy}\ K_{xz}\ K_{yy}\ K_{yz}\ K_{zz}$$

3. The material matrix $[G_e]$ is calculated where:

$$[G_e] = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & K_{xx} & K_{xy} & K_{xz} \\ 0 & K_{xy} & K_{yy} & K_{yz} \\ 0 & K_{xz} & K_{yz} & K_{zz} \end{bmatrix}$$

4. The matrix terms associated with the pivot point (j) are:

$$\{\overline{K}_{j1}\ \overline{K}_{j2}\ \overline{K}_{j3}\ \overline{K}_{j4}\}^T$$

$$= \frac{D}{6} \{H^j_{uq}\}^T [G_e] [H_{uq}].$$

The vector $\{H^j_{uq}\}$ is the column of the $[H_{uq}]$ matrix associated with point j.

5. Each scalar term K_{ji} is expanded to a 6 x 6 matrix and inserted. The terms in each of the four matrix partitions are:

$$[K_{ij}] = \overline{K}_{ij} \left[\begin{array}{ccc|c} 1 & 0 & 0 & \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \\ \hline & 0 & & 0 \end{array}\right]$$

4.87.18 The HBDY Elements

4.87.18.1 Input Data for the HBDY Elements

The boundary condition element HBDY produces matrix terms only for the heat conduction option. The following data will be needed from the ECPT table.

Symbol	Description
IFLAG	Flag for element type (1 through 5)
H	Thermal convection coefficient
AF	Geometric property
SIL_i	Scalar indices and location in basic coordinates of the grid points
x_i	$i = 1, N$
y_i	
z_i	

The meaning of the data for various values of IFLAG are:

IFLAG	Element Type	N = Number of Grid Points	AF
1	point	1	area
2	line	2	thickness
3	revolution	2	- - -
4	triangle	3	- - -
5	quadrilateral	4	- - -

4.87.18.2 Stiffness Matrix Calculations (Subroutine HHBDY of Module SMA1)

For the revolution elements $x_i > 0$ and $y_i = 0$, otherwise there is illegal geometry. The matrix produced will be N x N, which must be expanded to put terms into the first three degrees of freedom at each connect grid point. The [C] matrix for each element type is given in the following table:

IFLAG	C
1	$H(AF)$
2	$\frac{H(AF)\ell}{6}\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}$
3	$\frac{H(2\pi)\ell}{12}\begin{bmatrix}(3x_1 + x_2) & (x_1 + x_2)\\ (x_1 + x_2) & (x_1 + 3x_2)\end{bmatrix}$
4	$\frac{Ha}{24}\begin{bmatrix}2 & 1 & 1\\ 1 & 2 & 1\\ 1 & 1 & 2\end{bmatrix}$
5	$\frac{H}{48}\begin{bmatrix}2(a_2 + a_3 + a_4) & (a_3 + a_4) & (a_2 + a_4) & (a_2 + a_3)\\ \text{SYM} & 2(a_1 + a_3 + a_4) & (a_1 + a_4) & (a_1 + a_3)\\ & & 2(a_1 + a_2 + a_4) & (a_1 + a_2)\\ & & & 2(a_1 + a_2 + a_3)\end{bmatrix}$ or $C_{ij} = \frac{H}{48}\left[(1 + \delta_{ij})(a_1 + a_2 + a_3 + a_4) - (a_i + a_j)\right]$ where $\delta_{ij} = \begin{cases}1 & i = j\\ 0 & i \neq j\end{cases}$

The length ℓ appears only when N = 2:

$$\ell = \left[(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2\right]^{1/2}$$

The factor a is twice the area of a triangle (N = 3).

Let

$$\vec{r}_i = \begin{Bmatrix}x_i\\ y_i\\ z_i\end{Bmatrix}$$

$$a = |(\vec{r}_2 - \vec{r}_1) \times (\vec{r}_3 - \vec{r}_2)|$$

The factors a_i are two times the area of the triangle which does not touch vertex i of a quadrilateral.

$$a_1 = |(\vec{r}_3 - \vec{r}_2) \times (\vec{r}_4 - \vec{r}_3)|$$

$$a_2 = |(\vec{r}_4 - \vec{r}_3) \times (\vec{r}_1 - \vec{r}_4)|$$

$$a_3 = |(\vec{r}_1 - \vec{r}_4) \times (\vec{r}_2 - \vec{r}_1)|$$

$$a_4 = |(\vec{r}_2 - \vec{r}_1) \times (\vec{r}_3 - \vec{r}_2)|$$

4.87.18.3 HBDY Element Thermal Loads (Subroutine HBDY of Module SSG1)

When the option HEAT is chosen, only the HBDY element will produce thermal loads. When the option is STRUCT, the HBDY element produces no loads. The heat conduction matrix [C] must be recomputed, exactly as in Section 4.87.18.2. The thermal loads are

$$\{P\} = [C] \{T\} ,$$

where the grid point temperature vector is

$$\{T\} = \begin{Bmatrix} T_1 \\ \vdots \\ T_N \end{Bmatrix} .$$

Each value, P_i, goes into the three translation degrees of freedom corresponding to gridpoint i.

4.88 DETERMINANT METHOD OF EIGENVALUE EXTRACTION

NASTRAN contains two double precision versions of the determinant method. One version is for the solution of real eigenvalue problems; and one version is for the solution of complex eigenvalue problems. The specifications for both versions are discussed in this document. Real arithmetic is used for the real problem, complex for the complex problem.

4.88.1 Fundamentals of the Determinant Method

The basic notion employed in the determinant method of eigenvalue extraction is very simple. If the elements in a matrix [A] are functions of the operator p, then the determinant of [A] can be expressed as:

$$D([A]) = (p-p_1)\,(p-p_2)\,\ldots\,(p-p_n), \tag{1}$$

where p_1, p_2, p_3 ...p_n are the eigenvalues of the matrix. The value of the determinant vanishes for $p = p_i$, $i = 1,2,\ldots,n$.

In the determinant method, the determinant is evaluated for trail values of p, selected according to some iterative procedure, and a criteria is established to determine when D([A]) is sufficiently small or when p is sufficiently close to an eigenvalue. The eigenvector is then found by solution of the equation:

$$[A]\,\{u\} = 0, \tag{2}$$

with one of the elements of {u} set to unity.

4.88.2 Evaluation of Determinant

The most convenient procedure for evaluating the determinant of a matrix employs the triangular decomposition of the matrix: [A] = [L] [U] where [L] is a lower unit triangle (unit values on the diagonal). The determinant of [A] is equal to the product of the diagonal terms of [U]. The matrix [A] may be expressed as

$$[A] = -p[M] + [K], \tag{3}$$

for real eigenvalue problems and as

$$[A] = p^2[M] + p[B] + [K], \tag{4}$$

for complex eigenvalue problems.

4.88.3 Iteration Algorithm

Consider a series of determinants $D_{k-2}^{(i)}$, $D_{k-1}^{(i)}$, $D_k^{(i)}$ evaluated for trial values of the eigenvalue $p = p_{k-2}$, p_{k-1}, p_k. Then a better approximation to the eigenvalue is obtained from the following calculations:

Let

$$h_k = p_k - p_{k-1}, \tag{5}$$

$$\lambda_k = h_k/h_{k-1}, \tag{6}$$

$$\delta_k = 1 + \lambda_k. \tag{7}$$

Then

$$h_{k+1} = \lambda_{k+1}\, h_k, \tag{8}$$

$$p_{k+1} = p_k + h_{k+1}, \tag{9}$$

where

$$\lambda_{k+1} = \frac{-2\, D_k^{(i)}\, \delta_k}{g_k \pm [g_k^2 - 4 D_k^{(i)}\, \delta_k\, \lambda_k\, (D_{k-2}^{(i)}\, \lambda_k - D_{k-1}^{(i)}\, \delta_k + D_k^{(i)})\,]^{1/2}}, \tag{10}$$

$$g_k = D_{k-2}^{(i)}\, \lambda_k^2 - D_{k-1}^{(i)}\, \delta_k^2 + D_k^{(i)}\, (\lambda_k + \delta_k). \tag{11}$$

The (+) or (-) sign in Equation 10 is selected to minimize the absolute value of λ_{k+1}. In the case where p_k, p_{k-1} and p_{k-2} are all aribitrarily selected initial values (starting points), the starting points should be arranged such that $|D_k| \leq |D_{k-1}| \leq |D_{k-2}|$ and the (+) or (-) sign in Equation 10 should be selected to minimize the distance from p_{k+1} to all 3 starting points.

In a real eigenvalue analysis it is possible to calculate a complex λ_{k+1}. In order to

preclude the use of complex arithmetic in a real eigenvalue analysis problem, only the real part of the λ_{k+1} should be used to estimate a p_{k+1}.

4.88.4 Scaling

In calculating the determinant of [A], the determinant is scaled by powers of 10 since the accumulated product will rapidly overflow or underflow the floating point size of a digital computer. All operations using the determinant are calculated in scaled arithmetic.

4.88.5 Sweeping of Previously Extracted Eigenvalues

Once an eigenvalue has been found to satisfactory accuracy, a return to that eigenvalue by the iteration algorithm can be prevented by dividing the determinant by the factor $(p-p_i')$ where p_i' is the accepted approximation to p in all subsequent calculations.

Thus:

$$D^{(1)}([A]) = \frac{D([A])}{p-p_1'} \tag{12}$$

should be used in place of D([A]) after the first eigenvalue has been found. In general, the reduced determinant used for finding the $i+1^{st}$ eigenvalue is:

$$D^{(i)}([A]) = \frac{D^{(i-1)}([A])}{(p-p_i')} = \frac{D([A])}{(p-p_1')(p-p_2')\cdots(p-p_i')} \quad . \tag{13}$$

This sweeping procedure is quite satisfactory provided that all p_i' have been calculated to an accuracy that is limited only by round-off error.

For problems in which zero is an eigenvalue, the number of such eigenvalues is specified by the user. In using the determinant method, zero eigenvalues should be eliminated from the determinant by a preliminary operation,

$$D^{(o)}([A]) = \frac{D([A])}{p^m} \quad , \tag{14}$$

where m is the multiplicity of the zero eigenvalue.

For problems with conjugate complex eigenvalues (complex eigenvalue analysis with real matrices) the conjugates of extracted eigenvalues should also be swept from the determinant. Thus

$$D^{(i)}([A]) = \frac{D^{(i-1)}([A])}{(p-p_i')(p-\bar{p}_i')} , \tag{15}$$

where $\bar{p}_i'$ is the conjugate of p_i'. It should be noted that the sweeping equations are indeterminant for $p = p_i'$. This situation will occur when a root coincides with a starting point or a new estimate with a root already extracted. When the first situation occurs, the starting point should be moved away from the root. When the second situation occurs, D_{k+1} should be set equal to D_k.

4.88.6 Convergence Criteria

Convergence criteria are based on successive values of the increment h_k in the estimated eigenvalue. No tests on the magnitude of the determinant or any of the diagonal terms of the triangular decomposition are necessary or desirable. Wilkinson[1] shows that for h_k sufficiently small, the magnitude of h_k is approximately squared for each successive iteration when using Muller's method. This is an extremely rapid rate of convergence. In a very few iterations the "zone of indeterminacy" is reached within which h_k remains small but exhibits random behavior due to round-off error. Wilkinson states that if it is desired to calculate the root to the greatest possible precision, the convergence criterion for accepting p_k as a root should be:

$$|h_{k+1}| > |h_k| . \tag{16}$$

The determinant method accepts this advice, tempered by practical considerations. The first of these is that Equation 16 may be falsely satisfied during the first few iterations while the root tracking algorithm is picking up the "scent". Thus it must, in addition, be required that $|h_k|$, $|h_{k-1}|$ and $|h_{k-2}|$ be reasonably small. The second practical consideration is that we may waste a few iterations within the zone of indeterminacy while waiting for Equation 16 to be satisfied. This is avoided by accepting p_k if $|h_k|$ is sufficiently small. Finally, if the number of iterations becomes excessively large without satisfying a convergence criterion, the Determinant Method assumes the existence of one iteration loop, gives up and proceeds to

a new set of starting points.

Figure 1 is a flow diagram of a set of tests which meet the requirements discussed above for real eigenvalue problems. The tests are based on calculated values of $\overline{H1}$, $\overline{H2}$, and $\overline{H3}$ which are defined as:

$$\overline{H}_1 = |h_{k-1}| / \sqrt{|p_k|}, \tag{17}$$

$$\overline{H}_2 = |h_k| / \sqrt{|p_k|}, \tag{18}$$

$$\overline{H}_3 = |h_{k+1}| / \sqrt{|p_k|}, \tag{19}$$

where p_k = k^{th} estimate of an eigenvalue and $h_k = p_k - p_{k-1}$.

A similar set of tests is described in Figure 2 for complex eigenvalue problems. In this case $\overline{H1}$, $\overline{H2}$ and $\overline{H3}$ are defined as:

$$\overline{H1} = |h_{k-1}|, \tag{20}$$

$$\overline{H2} = |h_k|, \tag{21}$$

$$\overline{H3} = |h_{k+1}|. \tag{22}$$

The magnitude of the convergence criterion ε should be selected as a compromise between running time and accuracy. Currently $\varepsilon = 10^{-11}$. If failure occurs because the number of iterations exceeds the iteration limit, NIT, for two successive sets of starting points, ε is increased by a factor of 10. If successive pairs of failures still occur, ε is again increased until the number of permissible changes in ε is exceeded. The user is informed of the reduced precision of the calculations.

Since eigenvalues are swept out after they are found, all sets of starting points will eventually lead to failure by the preliminary range checks or through successive iteration failure. When this occurs it is presumed that all eigenvalues within the range of interest have been found and the calculations are halted. If for some reason this does not occur the calculation must still be halted. The one remaining avenue for the computer to continue calculations indefinitely is if it continues to find roots. To block this avenue, the calcula-

tions are stopped if the number of roots found exceeds the maximum number of N_{EVM}. As a safeguard the order in which the roots are found is indicated to the user.

4.88.7 Extraction of Eigenvectors

Once an approximate eigenvalue p_j has been accepted, the eigenvector is determined by back substitution into the previously computed triangular decomposition of $[A(p_j)]$. Now since

$$[A(p_j)]\{u\} = [L(p_j)][U(p_j)]\{u\} = 0, \tag{23}$$

we work only with $[U(p_j)]$. Because partial pivoting (row interchanges) have been used, the last diagonal term in $[U(p_j)]$ will normally be the only term with a very small value. The normal appearance of $[U(p_j)]$ is as follows, for n = 7:

$$\begin{bmatrix} X & X & X & X & 0 & 0 & 0 \\ & X & X & X & X & 0 & 0 \\ & & X & X & X & X & 0 \\ & & & X & X & X & X \\ & 0 & & & X & X & X \\ & & & & & X & X \\ & & & & & & \delta \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \end{Bmatrix} = \{0\} . \tag{24}$$

The terms in the upper right corner are zero due to bandwidth. δ is a very small number. The eigenvector may be extracted by assigning an arbitrary value (such as 1.0) to u_7 and solving successively for u_6, u_5 etc., from the preceeding rows. Note that this is equivalent to placing a load vector {F} on the right-hand side that is null except for the last term which is set equal to δ.

Situations may occur in which U_{nn} is not the smallest diagonal term. Let U_{ii} be the smallest diagonal term with $i < n$. The most common reason for this occurrence is that the degrees of freedom $u_{i+1}, u_{i+2}, \ldots, u_n$ are, for some reason, uncoupled to the preceeding degrees of freedom. In this case all of the elements in the i^{th} row of $[U(p_j)]$ will be very small as shown for i = 4, n = 7:

$$\begin{bmatrix} X & X & X & X & 0 & 0 & 0 \\ & X & X & X & X & 0 & 0 \\ & & X & X & X & X & 0 \\ & & & \delta_{44} & \delta_{45} & \delta_{46} & \delta_{47} \\ & 0 & & & X & X & X \\ & & & & & X & X \\ & & & & & & X \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \end{Bmatrix} = \{0\}. \qquad (25)$$

In the event of multiple or pathologically close eigenvalues two or more rows of $[U(p_j)]$ will consist of very small values, exhibited below for the very exceptional case where the n^{th} row is <u>not</u> very small:

$$\begin{bmatrix} X & X & X & X & 0 & 0 & 0 \\ & X & X & X & X & 0 & 0 \\ & & X & X & X & X & 0 \\ & & & \delta_{44} & \delta_{45} & \delta_{46} & \delta_{47} \\ & 0 & & & X & X & X \\ & & & & & \delta_{66} & \delta_{67} \\ & & & & & & X \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \end{Bmatrix} = \{0\} . \qquad (26)$$

In order to accommodate the exceptional cases described above with the more general case of $\delta = U_{nn}$, a full load vector $\{F\}$ is used for the eigenvector calculations. The load vector will also contain elements of the same order of magnitude as the smallest diagonal element of the triangularized matrix $[U(p_j)]$ in order to prevent digital overflow when the eigenvector is calculated. In addition, a distinct load vector is formed for each eigenvalue to ensure that independent eigenvectors are calculated for multiple or pathologically close eigenvalue problems. The following equations are used for $\{F\}$. For real eigenvalues, we have

$$F_i = \frac{\delta(-1)^{ij}}{1 + (1 - \frac{i}{n})\, j} \; ; \qquad (27)$$

For complex eigenvalues,

$$Re(F_i) = \frac{|\delta| (-1)^{ij}}{1.0 + (1.0 - \frac{i}{n}) j}, \quad (28)$$

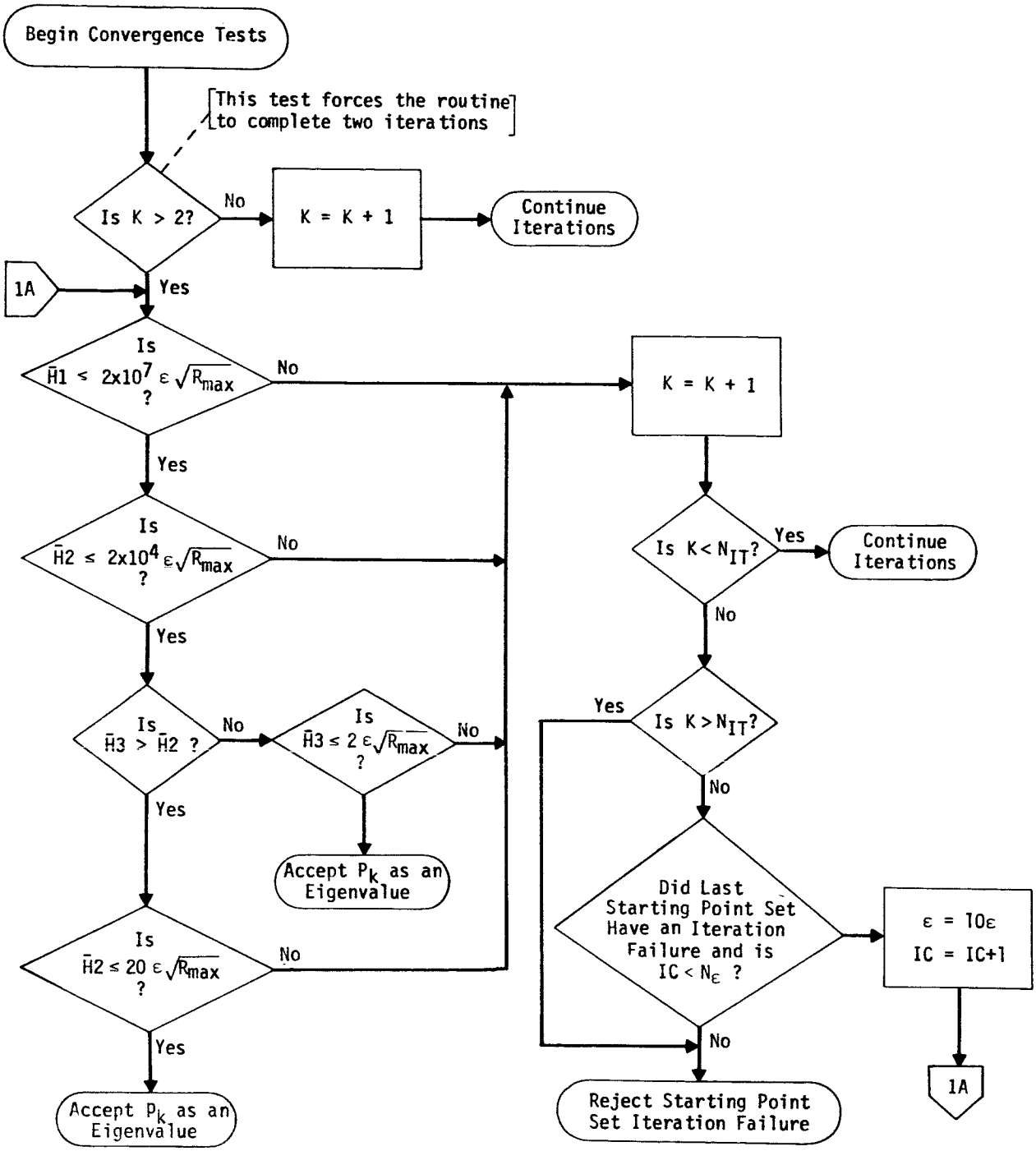
$$Im(F_i) = 0.0, \quad (29)$$

where δ = smallest U_{ii}, j = eigenvalue count, i = i^{th} element of {F} and n = number of rows.

There is a possibility that the smallest diagonal element of [U] may be exactly zero for some eigenvalue. This will be the case when the accepted eigenvalue (p_j) is exactly equal to an eigenvalue of the problem. When this occurs, $\delta = 1.0 \times 10^{-8}$. The calculated eigenvectors are normalized to a unit maximum real element value.

REFERENCE

1. Wilkinson, J.H., "The Algebraic Eigenvalue Problem", Clarendon Press, Oxford, 1965.



ε- Convergence Criterion

K - Iteration Counter

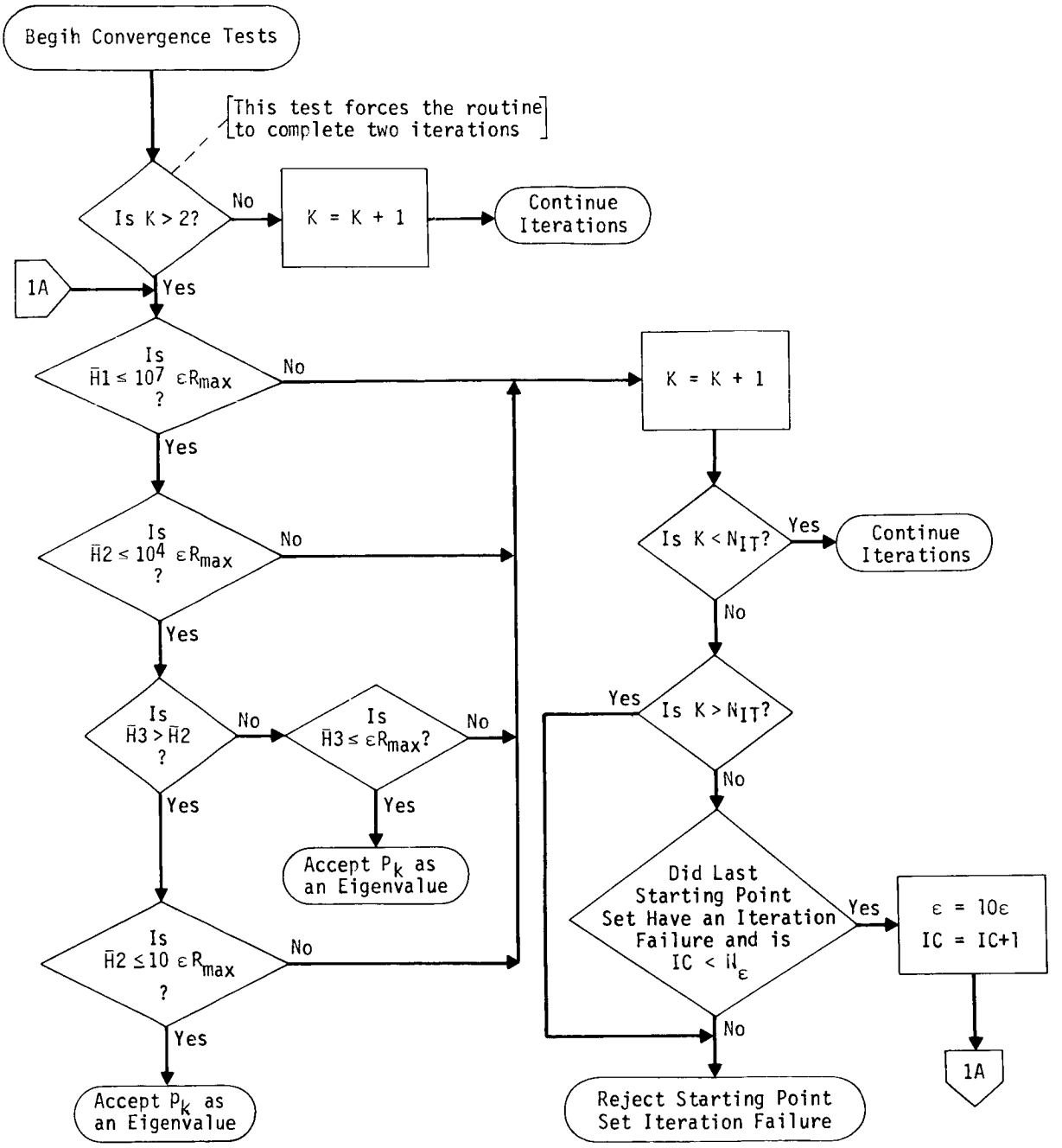
IC - Criterion Change Counter

$\bar{H}1 = |h_{k-1}| \; / \sqrt{|P_k|}$

$\bar{H}2 = |h_k| \; / \sqrt{|P_k|}$

$\bar{H}3 = |h_{k+1}| \; \sqrt{|P_k|}$

Figure 1. Real eigenvalue problems convergence tests



ε- Convergence Criterion $\quad \bar{H}1 = |h_{k-1}|$

K - Iteration Counter $\quad \bar{H}2 = |h_k|$

IC - Criterion Change Counter $\quad \bar{H}3 = |h_{k+1}|$

Figure 2. Complex eigenvalue problems convergence tests

4.89 EXECUTIVE PREFACE MØDULE IFP4 (INPUT FILE PROCESSOR - PHASE 4)

4.89.1 Entry Point: IFP4

4.89.2 Purpose

1. To convert the data card images related to fluid and hydroelastic analysis into conventional data card images as output from the IFP module.

2. To calculate data related to the boundaries and the harmonic degrees of freedom of the axisymmetric fluid and append this data to the MATPØØL data block.

4.89.3 Calling Sequence

CALL IFP4. IFP4, an Executive Preface Module, is called only by the Preface driver SEMINT.

4.89.4 Input Data Blocks

AXIC - Bulk Data Deck cards related to the hydroelastic problem as output from IFP.

GEØM1 - Grid Point and Coordinate System Data.

GEØM2 - Scalar Point and Element Connection Data.

GEØM4 - Constraint Data.

MATPØØL - Direct Input Matrix Data.

4.89.5 Output Data Blocks

Same as the Input Data Blocks.

4.89.6 Parameters

Not applicable to IFP4.

4.89.7 Method

IFP4 allocates the available core as it proceeds. Each type of data card image on the AXIC data block is read and used to form tables or new data card images. The new data and any existing data on the Input data blocks are merged and written on one of two scratch files. After the scratch file data are complete the data are then copied back on the Input/Output data files. (This is not normally allowed. The preface modules, however, have the privilege of writing on an input file.)

Data cards as referenced below refer to card images as found on the AXIC input data block. The actual data cards are read and first processed by the IFP. The fluid data card types found on the AXIC data block, and used by IFP4, are listed below along with a list of the output card images produced as a result of their presence, and the data blocks effected.

IFP4 Input Card Image	IFP4 Output Card Image	Data Block Effected
AXIF	none	all below
BDYLIST	data	MATPØØL
CFLUID2	CFLUID2	GEØM2
CFLUID3	CFLUID3	GEØM2
CFLUID4	CFLUID4	GEØM2
DMIAX	DMIG	MATPØØL
FLSYM	data (header)	MATPØØL
FREEPT	SPØINT MPC	GEØM2 GEØM4
FSLIST	CMFREE SPC	GEØM2 GEØM4
GRIDB	GRID	GEØM1
PRESPT	SPØINT MPC	GEØM2 GEØM4
RINGFL	GRID SEQGP	GEØM1 GEØM1

It should be noted that the output card images may be a function of several types of input card images as detailed in the following.

4.89.7.1 Data values found on the AXIF card are first stored in core for subsequent use. They are:

1. CS_f, the coordinate system number for the fluid system
2. g, the value of gravity
3. ρ_d, the default value of fluid density
4. B_d, the default value of the compression coefficient
5. NØSYM, an integer 0 or 1 indicating whether the unsymmetric (*series) terms are used in the computations.

6. A list of harmonic numbers n_j, j = 1,2,...,J, indicating the harmonics to be formulated. If none are supplied by the user, it is implied that the fluid is not to be solved, however the processing of the boundary points (GRIDB) may be necessary as discussed later.

The list of harmonic numbers (n_j) are converted to an in core list of index numbers (I_j) as follows.

If NØSYM=0, implying only the symmetric series:

$$I_j = 2n_j + 2 \quad , \quad n_j \geq 0 \quad , \tag{1}$$

for j = 1 to J.

If NØSYM=1, implying the symmetric and unsymmetric (*) series:

$$I_j = 2n_j + 2 \quad , \quad n_j \geq 0 \quad , \tag{2}$$

for j = 1 to J, plus the additional indices:

$$I_j^* = 2n_j + 1 \quad , \quad n_j > 0 \quad , \tag{3}$$

for j = 1 to J.

The list of indices as formed above is sorted and held in core for subsequent use. The complete list of indices may thus be up to 2J in length. Henceforth the number of indices in the list is referred to as N.

4.89.7.2 GEØM1 Data Block Processing

1. The GEØM1 file is read and the coordinate system as specified by CS_f is located among the CØRD1C, CØRD2C, CØRD1S, or CØRD2S card images. Its type (cylindrical or spherical) is saved as a flag for use in later processing. If the coordinate system is not located among the above card types a fatal error is indicated to the user and a cylindrical type is assumed to permit further checking of data.

2. GRIDB card images are read and stored in core, 5 words per image. A GRIDB card image defines a normal grid point except that it's location is fixed to a fluid (RINGFL) point.

3. If any GRIDB card images are present IFP4 at this time forms a boundary list table in core.

4. For each fluid point, IDF_j, contained in a BDYLIST card image, a seven word entry is placed in the boundary list table. The contents of this entry are, using data from the BDYLIST card image:

1.	IDF_j	
2.	1	Integer 1's (temporary flags)
3.	1	
4.	1	
5.	IDF_{j-1}	
6.	IDF_{j+1}	
7.	ρ_b	

where j indicates the respective IDF in the BDYLIST list of IDFs.

If IDF_{j-1} or IDF_{j+1} does not exist a zero (0) is entered.

If IDF_{j-1} or IDF_{j+1} is designated to be AXIS then a minus one (-1) is entered.

Should ρ_b as specified in the BDYLIST card image be missing, the default ρ_d, as specified on the AXIF card image, is used for position 7 of the entry. If both are missing, a user fatal error results. Missing is denoted by an integer -1.

After all BDYLIST card images have been processed and the entries added to the boundary list table, a sort is performed such that the entries are in sort by the primary IDF (found in the first position of each entry).

5. An initial "pass" of RINGFL card images is now made. The meridinal angles (x_2 for a cylindrical coordinate system or x_3 for a spherical system) must be zero and are checked. A binary search is performed to find one or more entries whose primary IDF matches the IDF of each RINGFL card image. When found the values X1, X2, and X3 of the respective images replace the three integer ones in position 2, 3, and 4 of that entry. If an entry is not found, a user fatal error is indicated.

If after all RINGFL card images have been passed, any of the entries in the boundary list table (residing in core) still contain the three integer ones in positions 2, 3, and 4, a user fatal error message is indicated for those particular BDYLIST identification numbers (IDF_js).

6. At this time a normal GRID card image is created from each GRIDB image and merged along with existing GRID card images on GEØM1. Additional GRID card images will be added to GEØM1 in subsequent manipulations.

   For each GRIDB card image now residing in core (note 4.89.7.2-2) a normal GRID card is created and consists of the following eight values.

Field	Symbol	Description
1	ID_g	ID given on GRIDB image.
2	CS_ℓ	CS_f from the AXIF image.
3-5	x_1, x_2, x_3	These values are formulated by finding X1, X2, X3 in the boundary list table entry whose primary identification number matches the reference identification number (IDF) given on the GRIDB card image, and then: x_1 = X1 x_2 = ϕ if CS_f is cylindrical, or X2 if CS_f is spherical. x_3 = X3 if CS_f is cylindrical, or ϕ if CS_f is spherical. Where ϕ is supplied by the GRIDB card image.
6	CS_d	CD from the GRIDB image.
7	PS	PS from the GRIDB image.
8	0	Not used.

   The resulting GRID data card images are merged with the existing GRID cards on data blocks GEØM1. If no harmonics exist for the fluid, the module processing is complete.

7. To generate the nonsymmetric connection tables for the boundary, the boundary list table is further altered at this time to result in a table listing the geometry and related grid points for each boundary fluid point.

   a. For each fluid point entry now in the boundary list table the values X1, X2, and X3 are converted to r and z values which are stored respectively in place of X1 and X2. If CS_f is cylindrical then:

$$\left.\begin{aligned} r &= X1 \\ z &= X3 \\ &X2 \text{ must be zero.} \end{aligned}\right\} \qquad (4)$$

If CS_f is spherical then:

$$\left.\begin{aligned} r &= X1 \sin\left(\frac{\pi}{180} X2\right) \\ z &= X1 \cos\left(\frac{\pi}{180} X2\right) \\ &X3 \text{ must be zero.} \end{aligned}\right\} \qquad (5)$$

b. For each set of three fluid point identification numbers (position 1, 5, and 6 of each entry), the three pairs of coordinates are extracted. The primary values r_j and z_j are given with each entry. The secondary values r_{j-1}, z_{j-1}, r_{j+1}, z_{j+1} must be found by finding the entries which have the same primary identification number as the secondary identification numbers (IDF_{j-1} or IDF_{j+1}) in question. If "axis" (-1) is a secondary identification number, then:

$$\left.\begin{aligned} r_{axis} &= 0 \\ z_{axis} &= z_j \end{aligned}\right\} \qquad (6)$$

If "not available" (0) is a secondary identification number, then:

$$\left.\begin{aligned} r &= r_j \\ z &= z_j \end{aligned}\right\} \qquad (7)$$

The values ℓ, c, and s are calculated and replace the 4th, 5th and 6th word of each entry in the boundary point list at this time such that each entry will now contain:

Field	Symbol	Description
1	IDF_j	Fluid point identification
2	r_j	Radial location
3	z_j	Vertical location
4	ℓ	Length and associated angle components of a conical section
5	c	
6	s	
7	ρ_b	Fluid density

where:

$$\ell = \sqrt{\Delta r^2 + \Delta z^2} \tag{8}$$

$$c = \frac{\Delta z}{\ell} \tag{9}$$

$$s = \frac{\Delta r}{\ell} \tag{10}$$

and:

$$\Delta r = \frac{1}{2}\left\{r_{j+1} - r_{j-1} + \frac{1}{4r_j}\left[(r_{j+1} - r_j)^2 - (r_{j-1} - r_j)^2\right]\right\} \tag{11}$$

$$\Delta z = \frac{1}{2}\left\{z_{j-1} - z_{j+1} + \frac{1}{4r_j}\left[(r_{j+1} - r_j)(z_j - z_{j+1}) - (r_j - r_{j-1})(z_{j-1} - z_j)\right]\right\} \tag{12}$$

This list, now referred to as the "boundary point geometry table", remains in core. The values ℓ, s, and c correspond to the cross section length, and the sine and cosine of the angle ψ as given in Equation 14, Section 16.1.5 of the Theoretical Manual.

c. As any number of GRIDB points may be connected to a fluid point, the GRIDB card images are now sorted on the referenced fluid point identification (the fifth word of each GRIDB entry). For each set of GRIDB points with the same referenced fluid point the sort is further made on the angle (ϕ).

d. The boundary point geometry table, generated above, is used at this time to form the boundary matrix part of the MATPØØL data block. For each entry in the table, all GRIDB points which reference it are appended to form a new entry of the following form.

Field	Symbol	Description
1	Id_f	Fluid point identification
2-7	r,z,ℓ,c,s,ρ_b	Fluid point properties
8	$Id_g(1)$	GRIDB identification
9	ϕ_1	Angular position of GRIDB point
.	.	.
.	.	.
.	.	.
6+2M	$Id_g(M)$	GRIDB identification
7+2M	ϕ_M	Angular position of GRIDB point
8+2M	-1	End of entry flags
9+2M	-1	

where M equals the number of GRIDB points that reference Id_f. Each new boundary fluid point entry is then placed in the MATPØØL data block. The list of harmonic indices n_j, the gravity G, the NØSYM flag, the fluid coordinate system CS_f, and the symmetric boundary information (from the FLSYM card image) are placed in the first record of the boundary list data in the MATPØØL data block. If DMIG data card images resulting from DMIAX data cards are present on the MATPØØL data block, they are merged to the existing DMIG card image data. Matrix names are checked for uniqueness.

8. The RINGFL data cards define a ring (fluid point) with its axis coincidental with the axis of the fluid coordinate system. Its degrees of freedom are the harmonics of the pressure around the circle. Special GRID point card images corresponding to the RINGFL data cards are generated at this time and added to the GRID card images now on GEØM1. Each RINGFL card image is read and N GRID card images are created containing the following data.

Field	Value	Description
1	$Id_f + 5 \cdot 10^5 \cdot (I_i)$	Point identification
2	CS_f	Fluid coordinate system number
3-5	X1,X2,X3	Location coordinates
6	-1	Fluid point flag
7	0	Permanent single point constraints
8	0	Not used

where i goes from 1 to N for each RINGFL card image read.

SEQGP card images are created for each RINGFL card image and merged with SEQGP cards on GEØM1. The contents of the entry are:

Field	Value	Description
1	$Id_f + 5 \cdot 10^5 \cdot (I_i)$	Grid identification
2	$Id_f \cdot 10^3 + (I_i - 1)$	Sequence number

where i goes from 1 to N for each RINGFL data card image.

4.89.7.2 GEØM2 Data Block Processing

1. The fluid element connections as specified by the CFLUID2, CFLUID3, and CFLUID4 card images are now operated upon. Each input card image is used together with the harmonic indices to define N "structural elements". The data given by the input card image is:

Field	Value	Description
1	Id_e	Element identification number
2 thru j+1	Id_j	Where j = 2, 3, or 4 fluid point connections
j+2	ρ	Fluid density
j+3	B	Fluid bulk modulus

For each input card image, connection card images are created for all harmonics in the problem. Their format is:

Field	Value	Description
1	$Id_e \cdot 10^3 + I_i$	Converted element identification
2 thru j+1	$Id_j + 5 \cdot 10^5 (I_i)$	Where j = 2, 3, or 4 connected fluid points
j+2	ρ	Fluid density
j+3	B	Fluid bulk modulus
j+4	n	Harmonic number

where i = 1, 2, ..., N and n is an integer such that,

$$\frac{I_i - 3}{2} < n \leq \frac{I_i - 1}{2} \qquad (13)$$

The harmonic element connection card images are merged into the GEØM2 data block as they are generated.

2. FSLIST card images each define a sequential list of fluid (RINGFL) points on a free surface. The FREEPT card images input to IFP4 each define a point on the free surface where a displacement may be output. The following operations are a result of FSLIST and FREEPT card images data.

   For each fluid point (IDF_j) defined in a FSLIST card image, a three word entry is placed in core containing IDF_j, IDF_{j+1}, and ρ. The subscript j indicates the respective IDF in the FSLIST card image list of IDFs. if IDF_j or IDF_{j+1} is represented by "AXIS" in the FSLIST card image, a minus one (-1) is used. If IDF_j is the last point in the list, IDF_{j+1} is set to -2. If the fluid density (ρ) is not present (an integer -1) in the FSLIST card image, the default fluid density (ρ_d) from the AXIF image is used. If both ρ and ρ_d are missing a user fatal error results.

   A set of structural mass elements are generated for each of the entries just added to core. Each set represents all harmonics in the problem. Connection card images called CMFREE elements are created such that each element consists of the following:

Field	Symbol	Description
1	Id	Element Id = $10^6 k + I_i$
2	Idg_1	$IDF_{k,1} + 5 \cdot 10^5 I_i$
3	Idg_2	$IDF_{k,2} + 5 \cdot 10^5 I_i$
4	γ_j	(ρ times G) the weight density, where G = gravity from AXIF image
5	n	Integer harmonic number such that; $\frac{I_i - 3}{2} < n \leq \frac{I_i - 1}{2}$

where I_i represents the i^{th} entry in the harmoric index list, and k is the index of the entry in the FSLIST table of entries. If $IDF_{k,1} = -1$, $IDF_{k,1}$ is set to $IDF_{k,2}$. If $IDF_{k,2} = -1$, then $IDF_{k,2}$ is set to $IDF_{k,1}$. Both can not be -1 initially. Thus for each entry, k = 1 thru K (the total number of entries), CMFREE images are created for all harmonic indices (I_i), i = 1 thru N. These CMFREE element entries are merged into the GEØM2 data block as were the CFLUID2, CFLUID3, and CFLUID4 card images.

4.89.7.4 GEØM4 Data Block Processing

1. If FREEPT (free surface displacement point) card images are present, and gravity as specified in the AXIF card image is nonzero, a multipoint constraint (MPC) is generated at this time along with a scalar point (SPØINT) having the same identification number (Id_p) as specified by each FREEPT card image. As each FREEPT card is read an SPØINT card image is placed in core and the following MPC card image is merged into the MPC data of GEØM4:

	Field	Symbol	Value	Description
	1	SID	102	Set identification number
	2	GID	Id_p	FREEPT identification number
	3	Comp	0	Component
	4	A_1	$-\|\rho G\|$	Density times gravity
Repeats for i=1 to N	2+3i	GID_i	$Id_f+5\cdot10^5(I_i)$	Fluid point harmonic identification
	3+3i	Comp	0	Component
	4+3i	A_{i+1}	C_i	Harmonic coefficient
	.	.	.	.
	.	.	.	.
	.	.	.	.
	5+3N	Flag	-1	End of mage flag
	6+3N	Flag	-1	
	7+3N	Flag	-1	

I_i is a harmonic index, and n equals an integer such that;

$$\frac{I_i - 3}{2} < n \leq \frac{I_i - 1}{2} \quad , \tag{14}$$

then:

$$\left.\begin{aligned} C_i &= \text{cosine } \frac{n\pi\phi}{180} \quad \text{if } I_i \text{ is even,} \\ C_i &= \text{sine } \frac{n\pi\phi}{180} \quad \text{if } I_i \text{ is odd,} \end{aligned}\right\} \tag{15}$$

where: ϕ is the angle given in the FREEPT card image.

2. Additional MPC card images are created if PRESPT card images are present. For each PRESPT card image read, an SPØINT is added to the in-core list of SPØINTs, and the following MPC card image is merged onto GEØM4.

	Field	Symbol	Value	Description
	1	SID	102	Set identification
	2	GID	Id_p	PRESPT identification
	3	Comp	0	Component
	4	A_1	-1.0	Coefficient
Repeat for i=1 to N	2+3i	GID_i	$Id_f+5\cdot10^5(I_i)$	Connected fluid harmonic identification
	3+3i	Comp	0	Component
	4+3i	A_{i+1}	C_i	Harmonic coefficient
	.	.	.	.
	.	.	.	.
	.	.	.	.
	5+3N	Flag	-1	
	6+3N	Flag	-1	End of image flag
	7+3N	Flag	-1	

I_i is a harmonic index, and n equals an integer such that,

$$\frac{I_i - 3}{2} < n \leq \frac{I_i - 1}{2} \tag{16}$$

$$\left.\begin{aligned} C_i &= \text{cosine } \frac{n\pi\phi}{180} \qquad \text{if } I_i \text{ is even.} \\ C_i &= \text{sine } \frac{n\pi\phi}{180} \qquad \text{if } I_i \text{ is odd.} \end{aligned}\right\} \tag{17}$$

ϕ is the angle given in the PRESPT card image.

3. If any SPØINTs were placed in core as a result of the presence of FREEPT or PRESPT card data, they are merged with the existing scalar point data on a scratch file.

4. At this time, if any harmonics are specified, an MPCADD card image is generated for each unique set identification present in the MPC and MPCADD card images on GEØM4. This MPCADD card image will then contain the internal set identification and include the user set identification. Thus as the MPC and MPCADD card images are read from GEØM4, a list of the set identifications present is created in core. An MPCADD card is then generated for

each unique set identification (Id) present. Its format is:

Field	Value	Description
1	$2 \cdot 10^8$ + Id	Internal set identification
2	Id	User set identification
3*	102	Generated MPC set identification
3 or 4*	-1	End of image flag

If any MPCADD card images are present on GEØM4, as a result of the user's specifications, their set identification (Id) in field one is modified to an internal set identification ($2 \cdot 10^8$ + Id), and if any MPC card images have been internally generated for set 102, the 102 set identification is added to the list of included set identifications therein.

If any MPC card images have been created for set 102, the following MPCADD card is generated in any event so as to assure that the 102 set be included in the solution. The set identification used here ($2 \cdot 10^8$), will be referenced in later computations if the user has not referenced any MPC constraint set.

Field	Value	Description
1	$2 \cdot 10^8$	Set identification
2	102	Generated MPC set to be included
3	-1	End of image flag

5. Should the user specify gravity G to be zero (0) on the AXIF card, it is assumed that the effects of gravity on the free surface are to be removed. To accomplish this, a single point constraint (SPC set 102) set is created at this time by IFP4.

   For each fluid point Id_f not equal to minus one (-1) or minus two (-2) in the free surface list, an SPC1 card image is merged onto GEØM4 containing the constraint information for all harmonics of this point. Its format is the following:

*Set identification 102 is inserted only if any MPC card images have been generated for set 102. If Id = 102 a user fatal error is indicated.

Field	Value	Description
1	102	Set identification
2	0	Component to be constrained
2+1	$Id_f + 5 \cdot 10^5 I_i$	Point to be constrained
.	.	.
.	.	.
.	.	.
2+i	$Id_f + 5 \cdot 10^5 I_i$	Point to be constrained
.	.	.
.	.	.
.	.	.
2+N	$Id_f + 5 \cdot 10^5 I_N$	Point to be constrained
3+N	-1	End of image flag

I_i is the i^{th} entry in the list of harmonic indices.

6. Analogous operations to those described in paragraph (4) of this section are performed at this time for existing SPC, SPC1 and SPCADD card images. The data is merged onto a scratch file and when complete, the scratch file is merged onto the GEØM4 data block.

4.89.8 Subroutines

4.89.8.1 Subroutine Name: IFP4A

1. Entry Point: IFP4A
2. Purpose: To write the first line of the user fatal error messages.
3. Calling Sequence: CALL IFP4A(NUM)

   NUM - Message number minus 4030.

4.89.8.2 Subroutine Name: IFP4B

1. Entry Point: IFP4B
2. Purpose : To copy data from IFP data files up to and including a given record onto a scratch file. On option the data on the scratch file may be copied onto the original data block.

3. Calling Sequence:

CALL IFP4B(FILE,SCRT,ANY,SPACE,LSPACE,RECID,EØF)

where:

FILE - File Number

SCRT - Scratch File Number

ANY - Flag = .TRUE. if RECID is found on FILE,
= .FALSE. if record is missing

SPACE - Area of core for working space

LSPACE - Length of working space

RECID - Record Number of FILE where the copy process stops. If -1 is used the copy process proceeds to the end of FILE and the data on SCRT is copied back onto FILE.

EØF - Flag = .TRUE. if end of record is encountered on return.

4.89.8.3 Subroutine Name: IFP4C

1. Entry Point: IFP4C

2. Purpose: To open an IFP generated file and a scratch file and to copy the header record from the IFP file onto the scratch file.

3. Calling Sequence:

CALL IFP4C(FILE,SCRT,BUF1,BUF2,EØF)

where:

FILE - File number

SCRT - Scratch file number

BUF1 - Buffer area in core for reading FILE

BUF2 - Buffer area in core for writing SCRT

EØF - Flag = .TRUE. if FILE is null

4.89.8.4 Subroutine Name: IFP4E

1. Entry Point: IFP4E

2. Purpose: To check identification numbers of fluid points for possible difficulties with large numbers.

3. Calling Sequence: CALL IFP4E(ID)

   where:

   ID - Identification number

4.89.8.5 Subroutine Name: IFP4F

1. Entry Point: IFP4F

2. Purpose: To test if a bit in a trailer record word is on or off.

3. Calling Sequence: CALL IFP4F(IBIT,FILE,BIT)

   where:

   IBIT - Position of bit in trailer

   FILE - File number

   BIT - Flag = .TRUE. if bit is on

   = .FALSE. if bit is off

4.89.8.6 Subroutine Name: IFP4G

1. Entry Point: IFP4G

2. Purpose: To turn on a bit in a trailer record.

3. Calling Sequence: CALL IFP4F(IBIT,FILE)

   where:

   IBIT - Position of bit in trailer

   FILE - File number

4.90 FUNCTIONAL MODULE BMG (BOUNDARY MATRIX GENERATOR FOR HYDROELASTIC PROBLEMS)

4.90.1 Entry Point: BMG

4.90.2 Purpose

The MATPØØL data block may contain data related to fluid boundaries which is generated by the IFP4 preface module. The purpose of this module is to combine these data with the geometry data (EQEXIN, BGPDT, and CSTM data blocks) to produce matrix terms which describe fluid-structure connection forces. These matrix terms are produced in the form of internal DMIG data card images. The module MTRXIN must always be used in conjunction with module BMG to produce NASTRAN matrices.

4.90.3 DMAP Calling Sequence

```
BMG     MATPØØL,BGPDT,EQEXIN,CSTM / BDPØØL / V,N,NØKBFL / V,N,NØABFL / V,N,MFACT $
```

4.90.4 Input Data Blocks

MATPØØL - Direct Input Matrices and Hydroelastic Boundary data.

BGPDT - Basic Grid Point Definition Table.

EQEXIN - Equivalence between External and Internal Grid Point numbers.

CSTM - Coordinate System Transformation Matrices.

4.90.5 Output Data Blocks

BDPØØL - Boundary Matrices ABFL and KBFL in DMIG Format.

4.90.6 Parameters

NØKBFL - Existence of KBFL Matrix Data = 0,
No KBFL Data = -1, output parameter.

NØABFL - Existence of ABFL Matrix Data = 0,
No ABFL Data = -1, output parameter.

MFACT - Complex Factor for Symmetric Structures, output parameter.

4.90.7 Method

The fluid boundary data, contained in the MATPØØL data block, is grouped by the fluid points on the boundary. For each fluid point the geometric parameters of the surface and the positions of the associated grid points are listed. The input data read for each fluid point are operated

on to produce matrix terms. The output matrix data are written on two files. The ABFL matrix terms are written on the BDPØØL file. The KBFL data are written on a scratch file. After the processing of the input file is complete, the KBFL data is appended to the BDPØØL file.

During the processing the core is allocated for the geometry data blocks. For each fluid point, tables are also created which must fit in the remaining core. The following description lists the form of the input data and the various steps used in the process.

4.90.7.1 Form of the Boundary Data Record on the MATPØØL Data Block

Three levels of data are contained within this record. The first level is a list of the overall definition parameters of the fluid and the boundary. The second level consists of fluid points and their associated data. Attached to each fluid point is a third level consisting of a list of the connected structural grid points and their angular position on the fluid circle. The actual data in the record are:

1. Header data:

Symbol	Description
CS_f	Fluid coordinate system identification
M	Number of symmetric sections
S1 S2	Symmetry definitions of first and second boundary
g	Value of gravity
NØSYM	Flag for n* series
k	Number of harmonic indices below
$n_1, n_2, \ldots, n_j, \ldots, n_k$	List of harmonic indices

2. Fluid point data

Symbol	Description
Id_{f1}	First fluid point (RINGFL) identification
r,z,ℓ,C,S,ρ	Fluid point properties
N_g	Number of connected grid points below
Id_1	Grid point identification
ϕ_1	Angular position of First grid point
Id_2	⋮
ϕ_2	⋮
⋮	⋮
Id_i	⋮
ϕ_i	(grid point data)
⋮	⋮
Id_g	⋮
ϕ_g	⋮
Id_{f2}	Second fluid point
⋮	⋮
etc.	etc.

4.90.7.2 Selection of Harmonics to Match Boundary Conditions

The Header Record for the boundary data is read and a list of harmonics (n_j and n_j^*) to be included in the matrices are precalculated. If NØSYM = YES, the indices for the sine series will be included. A test is made on each value of n and n^* using the values of S1 and S2 in the header data.

1. If M = 0 or 1 accept all values of n and n*.

2. If S1 = S2, Calculate:

$$K = \frac{2n}{M} \qquad (1)$$

   a. If K is not an integer reject n or n^*

   b. If K is an integer:

      accept n if S1 = S

      accept n^* if S1 = A

3. If S1 ≠ S2, calculate:

$$K = \frac{1}{2}\left[\frac{4n}{M} - 1\right] \qquad (2)$$

a. If K is not an integer reject n or n^*

b. If K is an integer:

accept n if S1 = S

accept n^* if S1 = A

A list of allowable values of n and n^* is built in core. If the final list is null, only the KBFL matrix is generated. The parameter MFACT is the complex number (M,0) if M is nonzero. The value (1,0) is used if M is zero.

4.90.7.3 Formation of Geometry Table for Internal Use

The core is allocated for the BGPDT data block and an extra word for each of its entries. The data is read in groups of four words and stored in five word entries, reserving the first word for the external identification number. The EQEXIN data contains a paired list of external and internal numbers. The EQEXIN is read and the external numbers are placed in the corresponding BGPDT entries in core. The resulting BGPDT data are sorted on the external identification numbers. The referenced coordinate system number and the basic location vector for any grid point are now available by using a single binary search.

4.90.7.4 CSTM Processing

The CSTM data block is now read and stored in core. The fluid coordinate system identification number, CS_f. is found and the 3 by 3 transformation matrix, $[T_{of}]$, is extracted directly from the data.

4.90.7.5 File Initialization

The processing of the matrix data may now begin. The files for the ABFL and KBFL output data are opened and the matrix header data is written. The boundary data on the MATPØØL data block are read and one fluid point at a time is processed.

4.90.7.6 Calculations of Areas Associated with Boundary Grid Points

The first set of the parameters Id, r, z, ℓ_k, c_k, S_k, and ρ_k are read for the fluid point where k = 1 if the fluid point has only one entry or k = 1, 2, 3... if the fluid point is connected with multiple boundaries. The connected grid point numbers (Id_i) and angles (ϕ_i) are read and placed in core. Twenty-six words are allocated for each grid point.

For each connected grid point the calculated data are:

(1)	Id_i	Identification number
(2)	ϕ_i	Azimuthal angle (radians)
(3)	ϕ_{0i}	Angle midway to previous point
(4)	ϕ_{1i}	Angle midway to next point
(5-22)	$[V_i]$	3x3 double precision transformation
(23-26)	$\{W_i\}$	3x1 vector

The midway angles are defined in general as:

$$\phi_{0i} = \frac{\phi_i + \phi_{i-1}}{2} \quad , \qquad \phi_{1i} = \frac{\phi_i + \phi_{i+1}}{2} \quad . \tag{3}$$

The angles for the first point are:

$$\phi_{01} = \phi_1 \quad , \quad M \geq 2 \quad , \qquad \phi_{01} = \frac{\phi_1 + \phi_N - 2\pi}{2} \quad , \quad M = 0. \tag{4}$$

The angles for the last point are:

$$\phi_{1N} = \phi_N \quad , \quad M \geq 2 \quad , \qquad \phi_{1N} = \frac{\phi_N + \phi_1 + 2\pi}{2} \quad , \quad M = 0 \quad . \tag{5}$$

All of the grid point data are sorted on the grid point numbers before the transformations $[V_i]$ and $\{W_i\}$ are calculated.

The equations for the transformation matrices are:

$$[V_i] = [T_i]^T [T_{of}] \quad ,$$
$$\{W_i\} = [T_i]^T [T_{of}] \begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} \quad , \tag{6}$$

Where $[T_i]$ is the 3 by 3 global-to-basic transformation matrix for grid point i.

4.90.7.7 Calculation of Matrix Terms

The matrix terms corresponding to one fluid point are generated for the ABFL and KBFL data tables at this stage. The ABFL matrix terms are generated as follows:

1. For each allowable value of n or n^* a matrix column is generated in the ABFL table. The internal numbers, G_j, for the fluid point identification number, Id_f, are:

$$G_j = Id_f + (n + 1)10^6 \quad \text{cosine series}$$
$$G_j = Id_f + \frac{2n^* + 1}{2} 10^6 \quad \text{sine series}$$

   These numbers label the column of the matrix.

2. Each row position in the matrix is labeled by a grid point, Id_i, and its three components: C = 1, 2, 3. The values corresponding to these positions are the values of the vector $\{A_{in}\}$ where:

$$\{A_{in}\} = \sum_k A^n_{ik} [V_i] \begin{Bmatrix} C_k \cos \phi_i \\ C_k \sin \phi_i \\ S \end{Bmatrix} \quad . \tag{7}$$

   The vector $\{A^*_{in}\}$ is similar. The coefficients are:

$$\left.\begin{aligned} A^o_{ik} &= r\ell_k (\phi_{1i} - \phi_{0i}) \quad , \quad n = 0 \\ A^n_{ik} &= \frac{r\ell_k}{n} [\sin(n\phi_{1i}) - \sin(n\phi_{0i})] \quad , \quad n > 0 \\ A^{n*}_{ik} &= \frac{r\ell_k}{n} [\cos(n^*\phi_{1i}) - \cos(n^*\phi_{0i})] \quad , \quad n^* > 0 \end{aligned}\right\} \tag{8}$$

where k = 1, 2, 3, ... is an index if the fluid point occurs more than once in the boundary list tables.

3. If gravity, g, is nonzero the KBFL matrix terms are calculated. Each grid point, Id_i, connected to the fluid point is used to produce three columns of the matrix corresponding to the three components, C_j = 1, 2, 3. The three rows for each column are the same three components, C_i = 1, 2, 3, of the grid point. The equation for the three terms in each column is:

$$\{K_i\}_j = \sum_k B_{ii}^k W_{ij} [V_i] \begin{Bmatrix} C_k \cos \phi_i \\ C_k \sin \phi_i \\ S_k \end{Bmatrix} \tag{9}$$

where:

$$W_{ij} \text{ is the } j^{th} \text{ component of } \{W_i\} \text{ and:}$$
$$B_{ii}^k = r\ell_k \rho_k (\phi_{il} - \phi_{i0})g \, . \tag{10}$$

k is the index used if the points are included in more than one boundary list entry.

4.90.7.8 Wrapup Operation

The final operations involve rewinding the scratch file containing the KBFL data and appending that data to the BDPØØL data block output file.

4.90.8 Additional Subroutines

BMGTNS - This routine is a slightly modified version of utility subroutine PRETRD so as to have only one entry point.

4.90.9 Design Requirements

The major core requirements are that the BGPDT data must fit and that twenty-six words for each boundary grid point converted to one fluid point must fit in core.

4.90.10 Diagnostic Messages

The following system fatal messages may be issued by BMG:

***SYSTEM FATAL MESSAGE 2148, CØØRDINATE SYSTEM = XXXXX CAN NØT BE FOUND IN CSTM DATA.

***SYSTEM FATAL MESSAGE 2149, CØNNECTED FLUID PØINT ID = XXXXX IS MISSING BGPDT DATA.

4.91 EXECUTIVE PREFACE MODULE IFP5 (INPUT FILE PROCESSOR - PHASE 5)

4.91.1 Entry Point: IFP5

4.91.2 Purpose

1. To convert the data card images related to acoustic analysis into conventional grid points and elements.
2. To calculate slot-cavity interface matrix terms and generate corresponding scalar elements.
3. To generate plot elements describing the sides of the acoustic elements.

4.91.3 Calling Sequence

CALL IFP5. IFP5, an Executive Preface Module, is called only by the Preface driver SEMINT.

4.91.4 Input Data Blocks

AXIC - Contains Bulk Data Cards related to the acoustic parameter, points, and boundaries.

GEØM1- Grid point and coordinate system data

GEØM2- Element Data, including acoustic elements.

4.91.5 Output Data Blocks

GEØM1 - Same format as input, acoustic points are merged in as GRID points.

GEØM2 - Same format as input, scalar elements and plot elements are added.

4.91.6 Parameters

Not applicable to IFP5

4.91.7 Method

IFP5 converts the data on the AXIC data block into conventional grid points and elements. The GEØM1 and GEØM2 data are read and merged with the new data on scratch files. The complete data sets are copied back onto the GEØM1 and GEØM2 files. (This is not normally allowed in a NASTRAN Module. The preface modules, however, have the privilege of writing on an input file.)

The data cards listed below are processed by IFP5. The corresponding output card image and its data block are given for each card.

IFP5 Input Card Image	Data Block In	IFP5 Output Card Image	Data Block Out
AXSLØT	AXIC	(all below)	(all below)
CAXIF2, CAXIF3, CAXIF4, CSLØT3, CSLØT4	GEØM2	CAXIF2, CAXIF3, CAXIF4, CSLØT3, CSLØT4, PLØTEL	GEØM2
GRIDF, GRIDS	AXIC	GRID	GEØM1
BDYLIST	AXIC	CELAS2	GEØM2

It should be noted that the formats of the CAXIFi data cards are exactly the same as the CFLUIDi data cards as generated by IFP4, Section 4.89. The following steps are followed to process the data:

1. The AXSLØT card is read from the AXIC file, its data are:

   ρ_d - default density

   B_d - default bulk modulus

   N - harmonic number

   w_d - default slot width

   M - Number of slots

2. The GRIDS data card images are read and stored in core. The contents of each card are:

   Id_s - identification number

   r - radius

   z - axial coordinate

   w - slot width

   Id_f - identification of assoicated GRIDF

3. The GRIDF data card images are read and stored in core. The contents of each card are

   Id_f - identification number

   r - radius

   z - axial coordinate

4. If the value in field 5 of GRIDS card is nonzero an IDF card is generated with the values Id_f, r, z as given on the GRIDS card. These cards are added to the GRIDF images and the complete list of GRIDF cards is sorted.

5. Data blcok GEØM1 is copied onto the first scratch file up to the first GRID card. The GRIDF and GRIDS cards are merged with the GRID cards in the GRID card format as follows:

GRID Field	Value GRIDF	Value GRIDS
1	Id_f	Id_s
2	0	0
3	r	r
4	z	z
5	0	w
6	-1	-1
7	0	0

6. The remainder of GEØM1 is copied onto the scratch file. The scratch file is then copied back onto GEØM1, starting from the beginning.

7. The SLBDY data card images are read from the AXIC data block. For each entry, Id_i on a logical card, five words are alocated in core and the following is stored.

$$Id_i,\ Id_{i-1},\ Id_{i+1},\ RHØ,\ M$$

where Id_i is a point number in the list

Id_{i-1} is the previous point number in the list

Id_{i+1} is the next point number in the list

RHØ, M are given on the logical card

If Id_i is the first entry on a logical card, $Id_{i-1} = -1$. If Id_i is the last entry on a logical card, $Id_{i+1} = -1$.

8. After all SLBDY cards are processed the above list is sorted on the first entry in each group of 5.

9. Plot elements (PLØTEL) are generated and placed on the first scratch file. The GEØM2 data block is read and for each (AXIFi) data card a series of PLØTEL cards are generated and written on the first scratch file (SCRT1).

CAXIF2 Data	PLØTEL Data
Id	Id + 10^6
G1	G1
G2	G2
ρ	
B	
N	

CAXIF3 Data	PLØTEL Data
Id	Id + $2 \cdot 10^6$
G1	G1
G2	G2
G3	
ρ	Id + $3 \cdot 10^6$
B	G2
N	G3
	Id + $4 \cdot 10^6$
	G3
	G1

CAXIF4 Data	PLØTEL Data	
Id	Id + $5 \cdot 10^6$	Id + $6 \cdot 10^6$
G1	G1	G2
G2	G2	G3
G3		
G4	Id + $7 \cdot 10^6$	Id + $8 \cdot 10^6$
ρ	G3	G4
B	G4	G1
N		

10. A second scratch file (SCRT2) is opened and the GEØM2 data is copied onto SCRT2 to the CELAS2 data card position. The boundary list data is processed and CELAS2 data cards are generated and appended to SCRT2. For each five word entry in the Boundary Table search the GRIDS data card images for the following data

r_i, z_i, w_i, IDF from GRIDS card "IDS_i"

r_{i-1}, z_{i-1}, w_{i-1} from GRIDS card "IDS_{i-1}"

r_{i+1}, z_{i+1}, w_{i+1} from GRIDS card "IDS_{i+1}"

where $r = r_i$, $z = z_i$ if the corresponding identification number IDS is -1. If a GRIDS card can not be found a fatal error exists. The following data is calculated for each entry:

$$\ell_1 = \sqrt{(z_{i+1} - z_i)^2 + (r_{i+1} - r_i)^2} \ ,$$

$$\ell_2 = \sqrt{(z_{i-1} - z_i)^2 + (r_{i-1} - r_i)^2} \ ,$$

$$\bar{\ell} = \frac{1}{2}\sqrt{(z_{i+1} - z_{i-1})^2 + (r_{i+1} - r_{i-1})^2} \ ,$$

$$\bar{w} = \frac{1}{4(\ell_1+\ell_2)}\left[\ell_1 w_{i+1} + \ell_2 w_{i-1}\right] + \frac{3}{4} w_i \ ,$$

$$\bar{r} = \frac{1}{4(\ell_1+\ell_2)}\left[\ell_1 r_{i+1} + \ell_2 r_{i-1}\right] + \frac{3}{4} r_i \ .$$

The coefficients for slot interaction are:

$$\beta = \frac{2\pi\bar{r}}{M\bar{w}}$$

(If $\beta \geq 1$ a fatal error exists)

$$\ell_c = \frac{\bar{W}}{2\pi}\left[(\beta + \frac{1}{\beta})\log_e\left(\frac{\beta+1}{\beta-1}\right) + 2\log_e\frac{(\beta+1)(\beta-1)}{\beta r}\right]$$

and

$$\ell_e = \text{Max}\ (\ell_c, .01\bar{W})$$

$$K_f = \frac{\bar{W}\bar{\ell}}{\rho\ell_e} F_i$$

where $F_i = M$ if $N = 0$ or $N = \frac{M}{2}$, $G_i = \frac{M}{2}$ otherwise.

11. For each entry in the Boundary Table, corresponding GRIDF data card with ID = IDF is found in core. For the corresponding GRIDF point IDF_j calculate the following:

$$\alpha = \frac{\sin\frac{N\bar{w}}{2\bar{r}}}{\frac{N\bar{w}}{2\bar{r}}}$$

12. CELAS2 elements are now generated for the slot point IDS_i and the corresponding axisymmetric fluid point IDF_j. The format of this data is:

Id	K	G1	C1	G2	C2
$Id_e + 1$	$(1-\alpha)K_f$	IDS_i	"1"	blank	blank
$Id_e + 2$	αK_f	IDS_i	"1"	IDF_i	"1"
$Id_e + 3$	$\alpha(1-\alpha)K_f$	IDF_i	"1"	blank	blank

The element identification numbers Id_e are sequential starting with 10,000,001. With each new point on the boundary list, IDF_i, the value Id_e is incremented by 3.

13. When all points on the boundary list are processed, the remainder of GEØM2 is copied onto SCRT2. If CSLØT3 and/or CSLØT4 elements are encountered, they will produce PLØTEL data card images which are written on SCRT1 in the following format:

CSLØT3 Data	PLØTEL Data
Id	$Id + 9 \cdot 10^6$
G1	G1
G2	G2
G3	
ρ	$Id + 10 \cdot 10^6$
B	G2
M	G3
N	
	$Id + 11 \cdot 10^6$
	G3
	G1

CSLØT4 Data	PLOTEL Data
Id	$Id + 12 \cdot 10^6$
G1	G1
G2	G2
G3	
G4	$Id + 13 \cdot 10^6$
ρ	G2
B	G3
M	
N	$Id + 14 \cdot 10^6$
	G3
	G4
	$Id + 15 \cdot 10^6$
	G4
	G1

14. When GEØM2 has been completely copied onto SCRT2, the files are rewound and the data from SCRT2 (containing the new CELAS2 elements) and the PLØTEL data from SCRT1 are merged and copied back onto GEØM2.

4.91.8 Subroutines

4.91.8.1 IFP5A

1. Entry Point: IFP5A
2. Purpose: Prints formal part of messages for IFP5.
3. Calling Sequence: CALL IFP5A (NUM)

   NUM = IFP5 message number.

4.91.9 Design Requirements

Discussed under Method.

4.91.10 Diagnostic Messages

Many user messages relevant to the acoustic cavity modeling data may be issued.

4.92 FUNCTIONAL MODULE PLTTRAN

4.92.1 Entry Point: PLTTRA

4.92.2 Purpose

To modify the SIL and BGPDT tables for the purpose of plotting special scalar grid points. Each grid point with one degree of freedom is given six degrees of freedom in the modified SIL data block. These points are identified in the BGPDP data block by the value (-2) in the first entry for each point.

4.92.3 DMAP Calling Sequence

```
PLTTRAN  BGPDT,SIL / BGPDP,SIP / V,N,LUSET / V,N,LUSEP $
```

4.92.4 Input Data Blocks

Data Block BGPDT - Four entries per grid or scalar point as follows:

1. Local coordinate system number or -1 if point is a scalar point.

2-4. X, Y, Z location in basic coordinate system.

Data Block SIL - One entry per grid or scalar point. The value of the entry is the location of the first degree of freedom of the point in the vector containing all degrees of freedom.

4.92.5 Output Data Blocks

Data Block BGPDP - Same format as BGPDT. If a point is determined to have one degree of freedom and is not a scalar point, the value (-2) is placed in the first entry for that point.

Data Block SIP - Same format as SIL. All points except time scalar points are given six (6) degrees of freedom. A true scalar point has the value (-1) in the first slot of its BGPDT entry.

4.92.6 Parameters

LUSET - Total number of degrees of freedom

LUSEP - New value for LUSET taking into account the change in the number of degrees of freedom when the special scalar points are expanded to six degrees of freedom.

4.92.7 Method

The SIL is read 1 word at a time; the BGPDT is read 4 words at a time. If the difference between the new SIL number and the previous SIL value is 1 and the first entry in the BGPDT is zero a fluid scalar grid point exists. In this event the new SIP increment is 6 and the value -2 is placed in the first word of the BGPDP entry.

4.92.8 Subroutines

None.

4.92.9 Design Requirements

Open core is defined at /PLTRN1/ and must be sufficient to hold four (4) GINØ buffers.

4.92.10 Diagnostic Messages

Messages 3001, 3002, 3003, 3008, 5011 and 5012 may be issued.

4.93 MATRIX MODULE UPARTN (PARTITIONS A MATRIX BASED ON USET)

4.93.1 Entry Point: DUPART

4.93.2 Purpose:

To compute a partitioning vector based on the displacement sets as defined by USET and create the symmetric partitions of the input matrix.

For example this module will perform

$$[K_{nn}] \Longrightarrow \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right]$$

4.93.3 DMAP Calling Sequence

```
UPARTN     USET,KNN / KFF,KSF,KFS,KSS / C,Y,MAJØR=N / C,Y,SUBO=F / C,Y,SUB1=S $
```

4.93.4 Input Data Blocks

USET - Displacement set definitions table (This may also be USETD if extra points are present).

KNN - Any square displacement matrix. The associated set of KNN (N) must be given in the first parameter.

Note: 1. USET may not be purged.

2. If KNN is purged, UPARTN will return.

4.93.5 Output Data Blocks

KFF - Matrix. It will have SUBO rows and columns.

KSF - Matrix. It will have SUB1 rows and SUBO columns.

KFS - Matrix. It will have SUBO rows and SUB1 columns.

KSS - Matrix. It will have SUB1 rows and columns.

Note: Any purged or omitted output data blocks will not be written.

4.93.6 Parameters

MAJØR - Input - BCD - No default value. This is the set of KNN.

SUBO - Input - BCD - No default value. This is the first subset of MAJØR.

SUB1 - Input - BCD - No default value. This is the second subset of MAJØR.

Note: 1. MAJOR, SUBO, and SUB1 must be selected from the following list: M,Ø,R,SG,SB,L, A,F,S,N,G,E,P,NE,FE, and D.

2. The set equation MAJØR = SUBO + SUB1 should be satisfied.

4.93.7 Method

The module driver, DUPART, checks the compatibility of the parameter data and directly calls UPART and MPART (an entry point in UPART). All work is then accomplished in the UPART routine.

4.93.8 Subroutines

UPART - See subroutine description, section 3.5.9.

4.93.9 Design Requirements

One scratch file.

4.93.10 Diagnostic Messages

UPARTN may issue one of the following diagnostic messages:

3007 or 3059

4.94 MATRIX MODULE UMERGE (MERGES TWO MATRICES BASED ON USET).

4.94.1 Entry Point: DUMERG

4.94.2 Purpose:

To merge two matrices into a third based on the displacement sets. For example, this module will perform:

$$\begin{Bmatrix} \Phi_a \\ \Phi_o \end{Bmatrix} \Longrightarrow \{\Phi_f\}$$

4.94.3 DMAP Calling Sequence

```
UMERGE    USET,PHIA,PHIØ / PHIF / C,Y,MAJØR=F / C,Y,SUBO=A / C,Y,SUB1=Ø $
```

4.94.4 Input Data Blocks

USET - Displacement set definitions table (this may also be USETD if extra points are present.)

PHIA, PHIØ - Any two matrices except that their rows must be associated with degrees-of-freedom specified by USET and the parameter list. PHIA's degrees-of-freedom are specified by SUBO and PHIØ's by SUB1.

Note: Either matrix may not be present and its respective degrees-of-freedom will be filled with zeros.

4.94.5 Output Data Blocks

PHIF - Matrix. Its terms will be associated with degrees-of-freedom in the set specified by MAJØR.

Note: PHIF must be present.

4.94.6 Parameters

MAJØR - Input - BCD - No default value. This is the set of PHIF.

SUBO - Input - BCD - No default value. This is the set of PHIA.

SUB1 - Input - BCD - No default value. This is the set of PHIØ.

Note: 1. MAJOR, SUBO, and SUB1 must be selected from the following list: M,Ø,R,SG,SB,L,A, F,S,N,G,E,P,NE,FE and D.

2. The set equation MAJØR = SUBO + SUB1 should be satisfied.

4.94.7 Method

The module driver, DUMERG, checks the compatibility of the parameter data and directly calls SDR1B. All work is then accomplished in the SDR1B routine.

4.94.8 Subroutines

SDR1B - See its subroutine description, section 3.5.

4.94.9 Design Requirements

One scratch file.

4.94.10 Diagnostic Messages

UMERGE may issue one of the following diagnostic messages:

3007 or 3059

4.95 MATRIX MODULE VEC (CREATES PARTITIONING VECTOR BASED ON USET)

4.95.1 Entry Point: VEC

4.95.2 Purpose:

VEC creates a partitioning vector based on USET that may be used in PARTN and MERGE.

4.95.3 DMAP Calling Sequence

```
VEC     USET / V / C,N,SET / C,N,SET0 / C,N,SET1 $
```

4.95.4 Input Data Blocks

USET - Displacement set definition table (this may be USETD if extra points are present).

Note: USET must be present.

4.95.5 Output Data Blocks

V - Partitioning vector.

Note: V may not be purged.

4.95.6 Parameters

SET - Input-BCD-no default. SET indicates the set to which the partitioning vector applies.

SET0 - Input-BCD-no default. SET0 indicates the upper partition of SET.

SET1 - Input-BCD-no default. SET1 indicates the lower partition of SET.

4.95.7 Method

The BCD parameters SET, SET0, and SET1 are converted to bit positions in USET. They must be one of the following 17 symbols: M,Ø,R,SG,SB,L,A,F,S,N,G,E,P,NE,FE,D,H or else a fatal error will result.

USET is read into core and the file closed. The output file is then opened and each entry is compared with the three converted parameters as follows:

1. USET is searched for members of SET. If the entry is not a member of SET, it is checked that it is not a member of SET0 or SET1 before going to the next entry.

2. The entry that belongs to SET is then checked if it is also a member of SET1. If it is, the entry is also checked if it is a member of SET0, which is fatal, before replacing the entry with 1.0.

3. If the entry is a member of SET and not a member of SET1, the entry is checked to verify that it is a member of SET0 before replacing it with a 0.0.

4. After all entries have been successfully processed, a check is made to insure that a vector exists and that the entries are not all zeros or ones (fatal error).

5. The rewritten entries are then written onto the output data block as a matrix consisting of one (1) column.

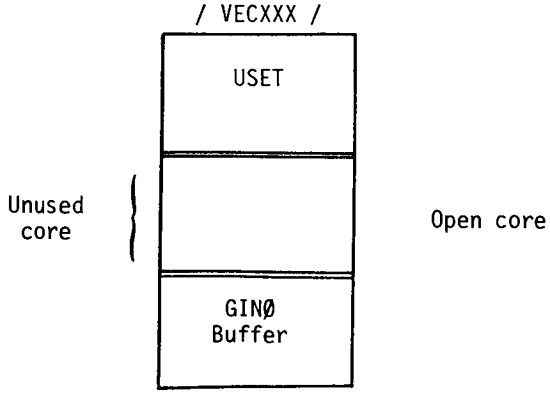
4.95.8 Subroutines

VEC has no auxiliary subroutines.

4.95.9 Design Requirements

1. Open core is defined at / VECXXX /

2. Layout of open core is as follows:



4.96 MATRIX MODULE ADD5 (ADD MATRICES)

4.96.1 Entry Point: DADD5

4.96.2 Purpose

To compute $[X] = \alpha[A] + \beta[B] + \gamma[C] + \delta[D] + \varepsilon[E]$.

4.96.3 DMAP Calling Sequence

```
ADD   A,B,C,D,E/X/C,Y,ALPHA=(1.0,2.0)/C,Y,BETA=(3.0,4.0)/C,Y,GAMMA=(5.0,6.0)/
          C,Y,DELTA=(7.0,8.0)/C,Y,EPSLN=(9.0,0.0) $
```

4.96.4 Input Data Blocks

A, B, C, D, and E must be distinct matrices.

Note: Any of the input matrices may be purged.

4.96.5 Output Data Blocks

X - Matrix.

The type of X is maximum of the types of A, B, C, D, E, α, β, γ, δ, ε. The shape of X is the shape of A if A is present. Otherwise it is that of the first non-purged input.

Note: X cannot be purged.

4.96.6 Parameters

ALPHA - Input-complex-no default value. This is the scalar multiplier for A.

BETA - Input-complex-no default value. This is the scalar multiplier for B.

GAMMA - Input-complex-no default value. This is the scalar multiplier for C.

DELTA - Input-complex-no default value. This is the scalar multiplier for D.

EPSLN - Input-complex-no default value. This is the scalar multiplier for E.

Note: If $Im(\alpha)$, $Im(\beta)$, $Im(\gamma)$, $Im(\delta)$ or $Im(\varepsilon) = 0.0$, the parameter will be considered real.

4.96.7 Method

If [A] is not purged, the number of columns, rows, and form of [X] = number of columns, rows, and form of [A]. Otherwise the descriptors of the first non-purged input are used. The type of

[X] is the maximum compatible type of [A], [B], [C], [D], [E], ALPHA, BETA, GAMMA, DELTA and EPSLN. ALPHA, BETA, GAMMA, DELTA and EPSLN are assumed to be real if their imaginary parts are zero.

4.96.8 Subroutines

SADD - See subroutine description, Section 3.5.26.

4.96.9 Design Requirements

Open core is defined at /DADDA/.

4.96.10 Diagnostic Messages

None.

4.97 FUNCTIONAL MODULE INPUT (INPUT GENERATOR)

4.97.1 Entry Point

INPUT

4.97.2 Purpose

Generates the bulk data input for a large number of academic test problems.

4.97.3 DMAP Calling Sequence

INPUT I1,I2,I3,I4,I5 / Ø1,Ø2,Ø3,Ø4,Ø5 / C,N,α / C,N,β / C,N,δ $

4.97.4 Input Data Blocks

Ii - As required by the execution of the module*.

4.97.5 Output Data Blocks

Øi - As required by the execution of the module*.

4.97.6 Parameters

α - Problem Type Selector* (Input, integer, default value = -1 (an illegal value for execution))

β - Problem type option selector* (Input, integer, default value = 0)

δ - Problem type option selector* (Input, integer, default value = 0)

4.97.7 Method

Based on the values of the parameters, INPUT reads, via FØRTRAN, one or more data cards from the input stream. Since the data deck has already been processed through the ENDDATA card at this point, these data cards always follow the ENDDATA card. Since FØRTRAN I/Ø is used, integer data on these cards must be right-justified. Once the data cards are read and checked, INPUT generates the table data blocks that would have been generated if the equivalent actual cards had appeared in the bulk data deck. These generated records are merged in with any coming from the corresponding input data block (generated by IFP) and are written onto the appropriate output data block.

4.97.8 Subroutines

IUNIØN - Integer function which computes the union of constraint codes.

INPABD - Initializes the common block /INPUTA/

4.97.9 Design Requirements

Open core is defined at /INPUTX/ and must be sufficient to hold two GINØ buffers.

4.97.10 Diagnostic Messages

Many user messages are generated by INPUT. These are mostly related to improper or inconsistent data presented by the user and are usually self-explanatory. The messages generated internally within INPUT are 1738 through 1745. In addition, INPUT writes an echo of all data read from the input stream and certain informational output related to the processing that occurs while generating the user's problem data.

*The workings of INPUT are described from the user's point of view in Section 2.6 of the NASTRAN User's Manual, NASA SP-222.

4.98 FUNCTIONAL MODULE INPUTT1

4.98.1 Entry Point

INPTT1

4.98.2 Purpose

Recovers GINØ-written data blocks (tables or matrices) from User Tapes designated for that purpose (NASTRAN permanent GINØ files INPT, INP1, INP2, ---, and/or INP9). Normally, these tapes would be written by the companion module ØUTPUT1 (see Section 4.100) in a previous run.

4.98.3 DMAP Calling Sequence

INPUTT1 / Ø1,Ø2,Ø3,Ø4,Ø5 / V,N,P1 / V,N,P2 / V,N,P3 $

4.98.4 Input Data Blocks

None.

4.98.5 Output Data Blocks

Øi - Any data block which is to be recovered from the User Tape. Purged outputs (either implicit or explicit) are ignored.

4.98.6 Parameters

P1 - Tape positioning option (Input, integer, default value = 0)

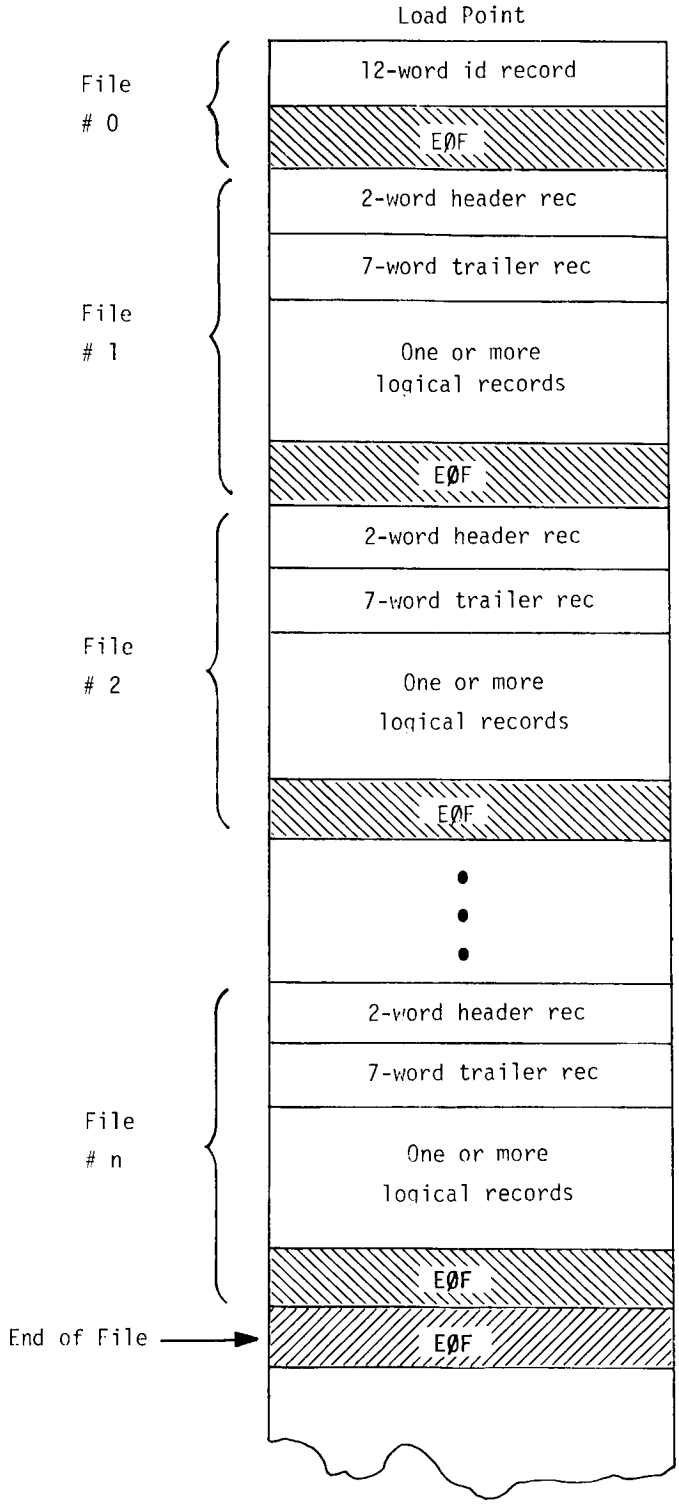
P2 - User Tape code (Input, integer, default value = 0)

P3 - User Tape Label (Input, alphanumeric, default value = 'XXXXXXXX')

4.98.7 Method

INPTT1 examines the first parameter and positions the User Tape designated by the second parameter (checking the User Tape Label defined by the third parameter if appropriate). INPTT1 then copies the next data blocks from the User Tape and writes them on the non-purged output data blocks in the DMAP instruction. The User Tape is left positioned wherever it is when the DMAP instruction requirements are satisfied. In this way, multiple calls can be made.

The configuration of files and records on the User Tape is shown in the sketch below.



4.98.8 Subroutines

None.

4.98.9 Design Requirements

Open core is defined at /INP1XX/ and must be sufficient to hold two GINØ buffers plus one word of working core. Since blast I/Ø techniques are used, efficiency is enhanced by any additional core up to the longest logical record to be read in any one data block.

The User Tapes must be physical tapes.

4.98.10 Diagnostic Messages

Messages 3008, 4105, 4106, 4107, 4108, 4109, 4110, 4111, 4112, 4113, 4127, 4132, 4133, 4134, 4135, 4136, 4137, 4138, 4139, 4140, 4141, and 4142 may be issued.

In addition, when a file table of contents is requested, printout is generated giving the file number and the value of the first two words of the header record for each 'file' on the tape.

4.99 FUNCTIONAL MODULE INPUTT2

4.99.1 Entry Point:

INPTT2

4.99.2 Purpose

Recovers FØRTRAN-written data blocks (tables or matrices) from User Tapes. Any legitimate FØRTRAN unit number not already utilized by NASTRAN may be used for this purpose. On the CDC machines, these unit numbers must also be compiled into the system in deck NASTRAN. Normally, these files would be written by the companion module ØUTPUT2 (see Section 4.101) in a previous run. It is intended that files also be easily generated by external FØRTRAN programs, however.

4.99.3 DMAP Calling Sequence

INPUTT2 / Ø1,Ø2,Ø3,Ø4,Ø5 / V,N,P1 / V,N,P2 / V,N,P3 $

4.99.4 Input Data Blocks

None.

4.99.5 Output Data Blocks

Øi - Any data block which is to be recovered from the User Tape. Purged outputs (either implicit or explicit) are ignored.

4.99.6 Parameters

P1 - File Positioning Option (Input, integer, default value = 0)

P2 - User Tape Code (Input, integer, default value = 0). This is the FØRTRAN unit number for the file.

P3 - User Tape Label (Input, Alphanumeric, default value = 'XXXXXXXX'.)

4.99.7 Method

INPUTT2 examines the first parameter and positions the User Tape designed by the second parameter (checking the User Tape Label defined by the third parameter if appropriate). INPTT2 then copies the next data blocks from the User Tape and writes them (via GINØ) on the non-purged output data blocks in the DMAP instruction.

The User Tape is left positioned wherever it is when the DMAP instruction requirements are satisfied. In this way, multiple calls may be made.

A description of the file configuration is given below for those FØRTRAN programmers who may wish to generate User Tapes with their own external programs for input to NASTRAN.

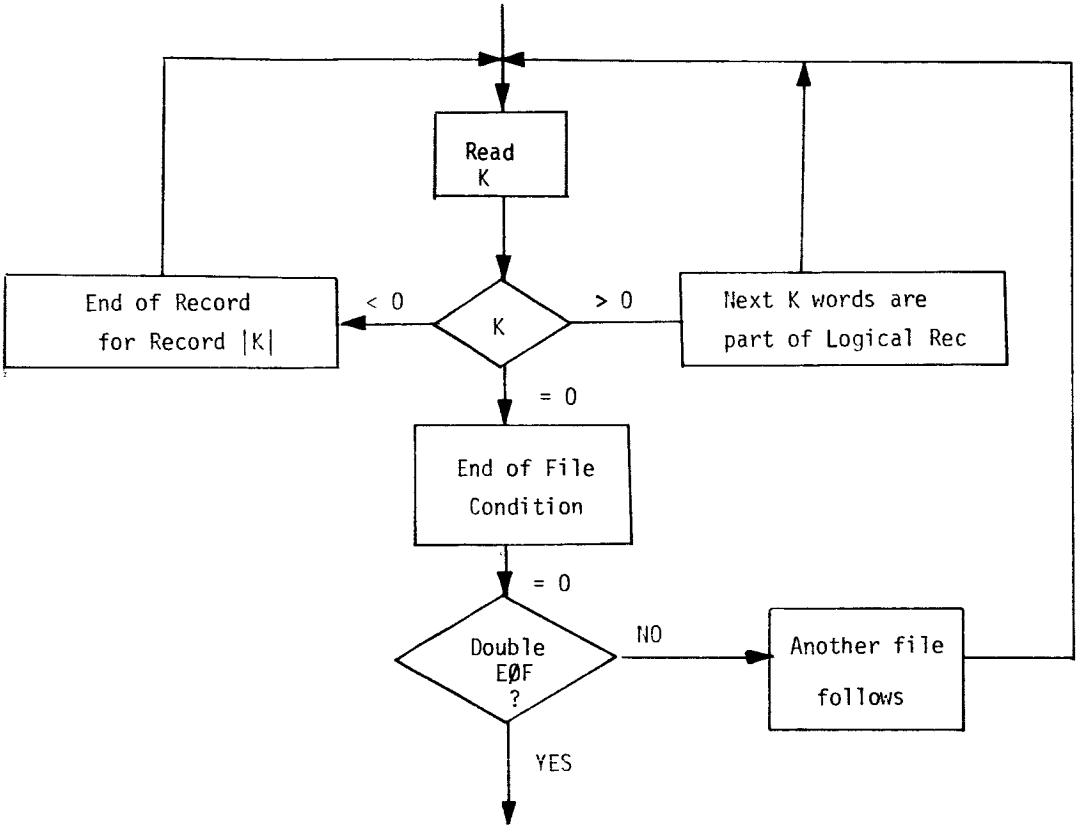
Format of INPUTT2/ØUTPUT2 File

NASTRAN File	Rec			FØRTRAN Rec	Length
1	1	KEY > 0		1	1
		{Data} ↕ KEY		2	KEY
		KEY > 0		3	1
		{Data} ↕ KEY		4	KEY
		KEY < 0	EØR	5	1
	2	KEY > 0		6	1
		{Data} ↕ KEY		7	KEY
		KEY < 0	EØR	8	1
		KEY = 0	EØF	9	1
2	1	KEY > 0		10	1
		{Data} ↕ KEY		11	KEY
		KEY < 0	EØR	12	1
		KEY = 0	EØF	13	1
3		KEY = 0	EØF = EØD	14	1

Restrictions:

1. Enough core must be available to hold the longest record segment.
2. A FØRTRAN unit must be available. On the CDC, this means that the PRØGRAM Deck (NASTRAN) must be re-compiled and Link 0 re-done.

The logic by which the NASTRAN logical 'records' are interrogated is given in the sketch below:



4.99.8 Subroutines

None.

4.99.9 Design Requirements

Open core is defined at /INP2XX/ and must be sufficient to hold two GINØ buffers plus the longest FØRTRAN logical record on the User Tape. The 'User Tape' files may be on any FØRTRAN readable device.

4.99.10 Diagnostic Messages

Messages 2187, 2190, 3008, 4105, 4106, 4107, 4108, 4109, 4110, 4111, 4112, 4113, 4132, 4133, 4134, 4135, 4136, 4137, 4138, 4139, 4140, 4141, and 4142 may be issued.

4.100 FUNCTIONAL MODULE ØUTPUT1

4.100.1 Entry Point:

ØUTPT1

4.100.2 Purpose

Creates GINØ-written User Tapes containing data blocks (tables or matrices) as requested by the user via the DMAP instruction. These tapes are written on NASTRAN permanent GINØ files INPT, INP1, INP2, ---, and/or INP9. It is anticipated that these tapes will be read by the companion module INPUTT1 in a subsequent run.

4.100.3 DMAP Calling Sequence

```
ØUTPUT1   I1,I2,I3,I4,I5 / V,N,P1 / V,N,P2 / V,N,P3 $
```

4.100.4 Input Data Blocks

Ii - Any data block which the user desires to be written on a User Tape. Purged inputs (either implicit or explicit) are ignored.

4.100.5 Output Data Blocks

None.

4.100.6 Parameters

P1 - Tape positioning option (Input, integer, default value = 0)

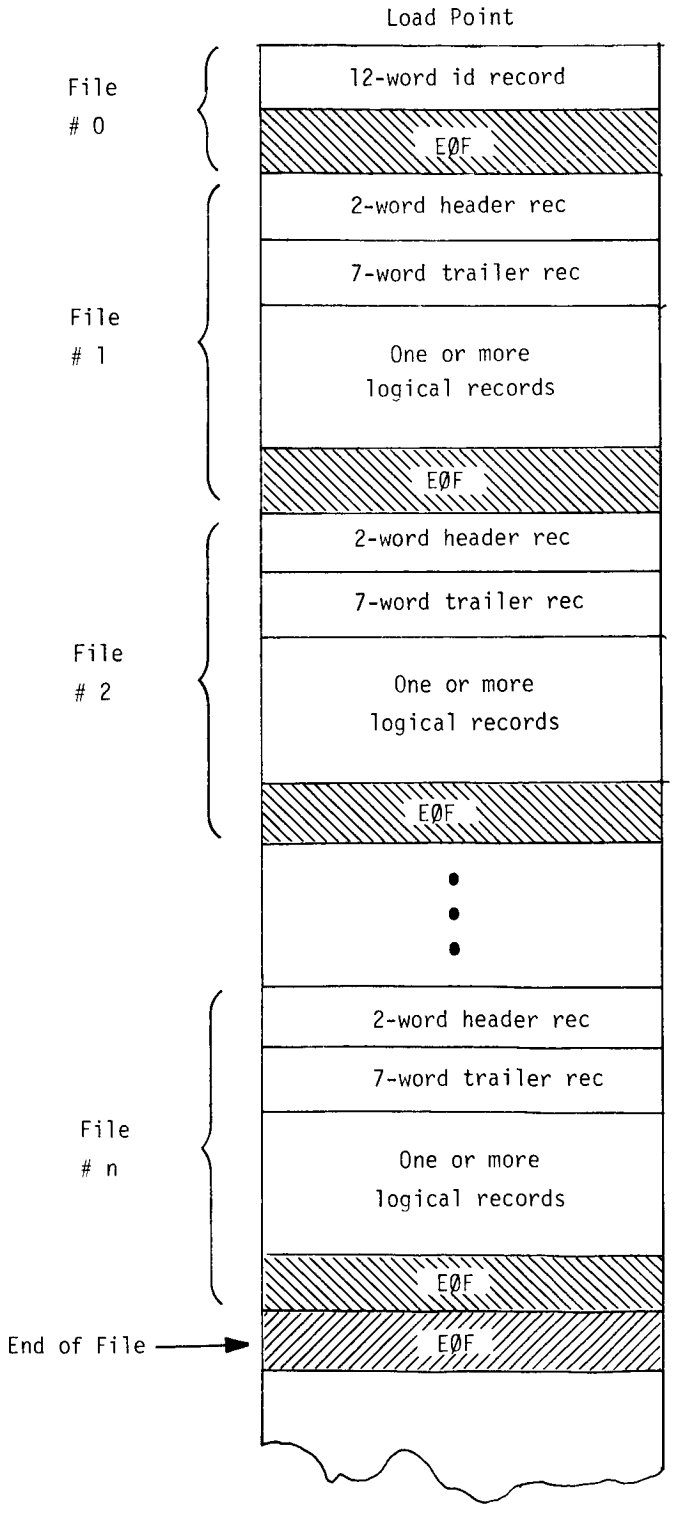
P2 - User Tape Code (Input, integer, default value = 0)

P3 - User Tape Label (Input, Alphanumeric, default value = 'XXXXXXXX')

4.100.7 Method

ØUTPT1 examines the first parameter and positions the User Tape designated by the second parameter (checking or writing the User Tape Label defined by the third parameter if appropriate). ØUTPT1 then writes onto the User Tape all non-purged input data blocks in the DMAP instruction. The User Tape is left positioned wherever it is when the DMAP instruction requirements are satisfied. In this way, multiple calls may be made to write as much material as desired on each User Tape.

The configuration of files and records on the User Tape is shown in the sketch below.



4.100.8 Subroutines

None.

4.100.9 Design Requirements

Open core is defined at /ØUT1XX/ and must be sufficient to hold two GINØ buffers plus one word of working core. Since blast I/Ø techniques are used, efficiency is enhanced by any additional core up to the longest logical record to be read in any one data block.

The User Tapes must be physical tapes.

4.100.10 Diagnostic Messages

Messages 3008, 4114, 4115, 4116, 4117, 4118, 4119, 4120, 4127, 4128, 4129, 4130, and 4131 may be issued.

In addition, when a file table of contents is requested, printout is generated giving the file number and the value of the first two words of the header record for each 'file' on the tape.

4.101 FUNCTIONAL MODULE ØUTPUT2

4.101.1 Entry Point:

ØUTPT2

4.101.2 Purpose

Creates FØRTRAN-written User Tapes containing data blocks (tables or matrices) as requested by the user via the DMAP instruction. Any legitimate FØRTRAN unit number not already utilized by NASTRAN may be used for this purpose. On the CDC machine, these unit numbers must also be compiled into the system in deck NASTRAN. Normally, it is anticipated that these files will be read by the companion module INPUTT2 in a subsequent run. It is expected, however, that users will want to generate their own User Tapes with external programs completely unrelated to NASTRAN. Towards this end, a scheme has been implemented by which NASTRAN-like logical files and records can be simulated by unformatted FØRTRAN I/Ø calls.

4.101.3 DMAP Calling Sequence

```
ØUTPUT2   I1,I2,I3,I4,I5 / V,N,P1 / V,N,P2 / V,N,P3 $
```

4.101.4 Input Data Blocks

Ii - Any data block which the user desires to be written on a User Tape file. Purged inputs (either implicit or explicit) are ignored.

4.101.5 Output Data Blocks

None.

4.101.6 Parameters

P1 - File positioning option (Input, integer, default value = 0)

P2 - User Tape Code (Input, integer, default value = 0)

P3 - User Tape Label (Input, Alphanumeric, default value = 'XXXXXXXX')

4.101.7 Method

ØUTPT2 examines the first parameter and positions the User Tape designated by the second parameter (checking or writing the User Tape Label defined by the third parameter if appropriate). ØUTPT2 then writes onto the User Tape file all non-purged input data blocks in the DMAP instructions. The User Tape file is left positioned wherever it is when the DMAP instruction requirements are satisfied. In this way, multiple calls may be made to write as much material as desired on each User Tape file.

A description of the file configuration is given below for those FØRTRAN programmers who may wish to generate User Tape files with their own internal programs for input to NASTRAN.

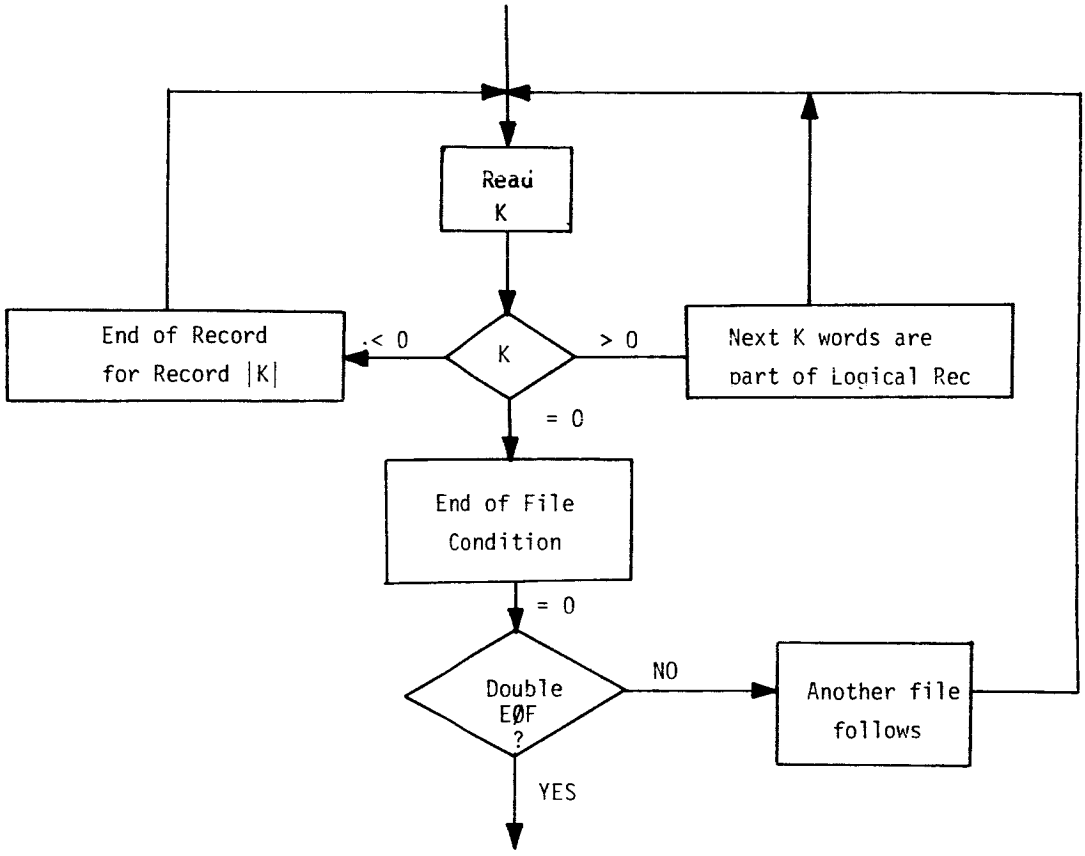
Format of INPUTT1/ØUTPUT2 File

NASTRAN File	Rec			FØRTRAN Rec	Length
1	1	KEY > 0		1	1
		{Data} ↕	KEY	2	KEY
		KEY > 0		3	1
		{Data} ↕	KEY	4	KEY
		KEY < 0	EØR	5	1
	2	KEY > 0		6	1
		{Data} ↕	KEY	7	KEY
		KEY < 0	EØR	8	1
		KEY = 0	EØF	9	1
2	1	KEY > 0		10	1
		{Data} ↕	KEY	11	KEY
		KEY < 0	EØR	12	1
		KEY = 0	EØF	13	1
		KEY = 0	EØF = EØD	14	1

Restrictions:

1. Enough core must be available to hold the longest record segment.
2. A FØRTRAN unit must be available. On the CDC, this means that the PRØGRAM deck (NASTRAN) must be re-compiled and Link 0 re-done.

The logic by which the NASTRAN logical 'records' are interrogated is given in the sketch below:



4.101.8 Subroutines

None.

4.101.9 Design Requirements

Open core is defined at /ØUT2XX/ and must be sufficient to hold two GINØ buffers plus the longest FØRTRAN logical record on the User Tape. The 'User Tape' files may be on any device accessible to the FØRTRAN I/Ø routines.

4.101.10 Diagnostic Messages

Messages 2187, 2190, 3008, 4114, 4115, 4116, 4118, 4119, 4120, 4128, 4129, 4130, and 4131 may be issued.

4.102 OUTPUT MODULE ØUTPUT3

4.102.1 Entry Point:

ØUTPT3

4.102.2 Purpose

Punches onto DMI cards the contents of matrix data blocks. Single-precision values are output on double-field cards. If full square matrices are considered, a maximum order of 196 is imposed since a maximum of 10000 cards (including the header card) are allowed.

4.102.3 DMAP Calling Sequence

```
ØUTPUT3   I1,I2,I3,I4,I5 // V,N,PRINTØPT / V,N,N1 / V,N,N2 / V,N,N3 / V,N,N4 / V,N,N5 $
```

4.102.4 Input Data Blocks

Ii - Any real matrix data block. Only sufficiently small non-purged data blocks will be punched onto DMI cards.

4.102.5 Output Data Blocks

None.

4.102.6 Parameters

PRINTØPT - Print echo option (Input, integer, default value = 0)
If this parameter is negative, an echo of the DMI card images generated will be printed on the FØRTRAN unit given by -PRINTØPT.

Ni - Continuation string - (Input, alphanumeric, default values: N1,NO default; N2-N5, default value = 'XXX'). Used to form a unique continuation string for the DMI cards.

4.102.7 Method

ØUTPT3 reads each matrix, non-zero term by non-zero term (by column), and passes these items to the DMI card-punching subroutine PHDMIA.

4.102.8 Subroutines

4.102.8.1 Subroutine Name: PHDMIA

1. Entry Points: PHDMIA, PHDMIB, PHDMIC, PHDMID

2. Purpose: To collect and punch DMI card images.

3. Calling Sequence:

   CALL PHDMIA - Initializes matrix.

   CALL PHDMIB - Initializes non-null column.

   CALL PHDMIC - Collect each non-zero term of column.

   CALL PHDMID - Wraps up column.

   CØMMØN / PHDMIX / N(2),C,IFØ,TIN,TØUT,IR,IC,NØ,KPP,NLP,ERNØ,ICØL,IRØ,XX

   Communication area for PHDMIA.

4. Method: A single call is made to PHDMIA for each matrix data block to be punched. A call is made to PHDMIB for each non-null column, followed by a call to PHDMIC for each non-zero term in the column, followed by a wrap-up call to PHDMID.

4.102.9 Design Requirements

Open core is defined at /ØUT3XX/ and must be sufficient to hold a single GINØ buffer.

4.102.10 Diagnostic Messages

Messages 3008, 4100, 4101, 4102, 4103, and 4104 may be issued.

4.103 OUTPUT MODULE TABPRT (FORMATTED TABLE PRINTER)

4.103.1 Entry Point:

TABFMT

4.103.2 Purpose

To print selected table data blocks with format for ease of reading.

4.103.3 DMAP Calling Sequence

```
TABPRT   TDB // V,N,KEY / V,N,ØPT1 / V,N,ØPT2 $
```

4.103.4 Input Data Blocks

TDB - Table Data Block having a format which is processable by the routine.

4.103.5 Output Data Blocks

None.

4.103.6 Parameters

KEY - Keyword (Input, alphanumeric, no default value)
The value of KEYWØRD identifies the format to be used in printing the table.

ØPT1 - Option (Input, integer, default value = 0)

ØPT2 - Option (Input, integer, default value = 0)

4.103.7 Method

TABFMT examines the parameters and selects a format for printing the contents of the input data block. The input data block is then read record by record and the contents printed according to the selected format. A line of printout may contain part of a logical record, a complete logical record, or more than one logical record. Coding or decoding of the data items encountered may be done as the programmer wishes. The trailer data are also printed.

4.103.8 Subroutines

TABFBD - Block Data routine to set tables for TABFMT in common block /TABFTX/ .

4.103.9 Design Requirements

Open core is defined at /TABFTZ/ and must be sufficient to hold one GINØ buffer plus a small number of words of data, the number of which depends on KEY.

4.103.10 Diagnostic Messages

Fatal message 3008 may be issued.

Warning messages 2094, 2095, 2096, 2097, 2098, and 2099 may be issued and will cause termination of the module but not of the program.

5.1 INTRODUCTION

NASTRAN operates on: 1) the IBM 7094/7040(44) Direct Couple System under the IBSYS operating system; 2) the IBM System/360 under Operating System (ØS); 3) the Univac 1108 under the Exec 8 operating system; and 4) the CDC 6600 under the SCØPE 3 operating system. This section discusses the interfaces between NASTRAN and these operating systems with respect to: 1) input/output; 2) link switching; 3) overlay considerations and implementation of the open core concept; 4) the setup of the operating system control cards preceding (and, in the case of the Univac 1108, following) the NASTRAN data decks; 5) generation of an executable NASTRAN system; and 6) machine dependent routines.

The vocabulary used in each subsection is the one used by systems programmers familiar with the particular operating system being discussed. It is to these system programmers that each subsection is addressed.

5.2 NASTRAN ON THE IBM 7094/7040(44) DCS (IBSYS)

This section has been deleted since the IBM 7094 is no longer an active NASTRAN machine.

5.3 NASTRAN ON THE IBM SYSTEM 360-370* OPERATING SYSTEM (ØS)

5.3.1 Introduction

NASTRAN operates as a single job step on the IBM System 360-370 class of computers under ØS (Operating System). The NASTRAN executable is created as a Partitioned Data Set (PDS) with each NASTRAN functional link comprising a member of the PDS. In addition to the fourteen (14) functional links, the executable PDS has one member unique to the IBM 360 configuration that controls the execution of the other links. This additional member is referred to as the Super-link. The PDS member name for the super-link is NASTRAN, and the member names for the fourteen functional links are LINKNSØ1 thru LINKNS14.

NASTRAN execution on the IBM 360-370 involves two links in core at a time, the Super-link (NASTRAN) and a currently operating functional link (LINKNSxx). The super-link is always core resident and contains the NASTRAN driver routine (NASTRAN), NASTRAN I/Ø package (PACKUNPK, GINØ, NASTIØ, IØMSG), and the FØRTRAN I/Ø packages. The functional links are located and loaded as required during execution. Within each functional link, a 360 dependent control routine with the same name as the link (LINKNSxx) provides the intermediate entry point for that link, as well as the communication vector between links. The Super-link is always loaded and entered first; it in turn always calls LINKNSØ1 (the preface link). From that point on the link execution sequence is determined by SEARCH calls from the currently operating functional link which returns control to the Super-link when another functional link is needed. This sequence continues until a CALL EXIT within a functional link returns control to ØS. The downward calls from the super-link to the functional links are accomplished via the ØS link macro and all intra-link calls are accomplished via standard FØRTRAN call statements.

5.3.2 Input/Output

Within the NASTRAN program all data transfer operations between primary and secondary storage with the exception of card, print, plot and special input/output are performed through the General Input/Output Routine (GINØ).

*The terms SYSTEM 360-370, IBM 360, SYSTEM 360, etc. will be used synonymously in this discussion as NASTRAN execution is identical on both the IBM 360 and the IBM 370 computers.

All non-GINØ I/Ø is performed through normal FØRTRAN I/Ø statements. Printed output is generated by formatted output statements to FØRTRAN logical units 4 and 6 (DDNAME=FT04F001 and DDNAME=FT06F001). This output may be routed as desired although it normally appears as a system output (SYSØUT) class. The usual output for the NASTRAN execution appears on FT06F001 while the Run Log appears on FT04F001. Data card input is read by formatted input statements, a card (record) at a time, from FØRTRAN logical unit 5 (DDNAME=FT05F001). Again, the input source may be designated as desired although it normally appears as the system input (SYSIN) unit. Punched cards are written on FT07F001 which normally appears as a system output (SYSØUT) class.

The transliteration routine writes its output on FT01F001 in a form as indicated in the PRØC given in Section 5.3.5. Other FØRTRAN data sets may be needed by users who use utility modules INPUTT2 or ØUTPUT2 (see Section 5 of the User's Manual).

The SGINØ (Special GINØ) plotter output routines within the S/360 NASTRAN system function independently of other I/Ø. Unique DD cards within the Execution Deck Setup (see Section 5.3.5) describe the required output tape file formats. Two separate plotter files may be generated, one on FØRTRAN unit 13 and the other on unit 14.

GINØ, which is written in assembly language, uses the Basis Sequential Access Method (BSAM) to read and write blocks of a fixed size that may be adjusted to fit hardware and problem requirements by using the NASTRAN control card. GINØ input/output operations result in calls to GINØIØ which calls entry point IØ36O in NASTIØ to do the physical reads or writes.

In addition to the use of the Standard BSAM READ and WRITE macros, NASTRAN uses the NØTE and PØINT macros. The use of the NØTE and PØINT macros, along with fixed block sizes permits the use of the disk secondary storage in a direct access form, and through use of properly kept locators permits NASTRAN to accomplish backspacing across disk boundaries. It should also be noted that use of BSAM I/Ø processing permits I/Ø operations to be accomplished directly in the GINØ buffer areas. As a result, no data transfers take place (as opposed to FØRTRAN I/Ø which does transfer the data) and a considerable savings of both core storage and CPU time is effected.

The way in which temporary storage (scratch files) are allocated in NASTRAN is a by-product of the I/Ø method used. NASTRAN uses three classes of temporary files: primary files, secondary files, and tertiary files.

The following example depicts the way in which this space is managed. Assume NASTRAN data blocks A, B, C, D and E are of the following sizes:

A	10 blocks (records)
B	100 blocks
C	210 blocks
D	625 blocks
E	72 blocks

Further assume that each primary unit has preallocated space of 100 blocks and that each secondary unit has preallocated space of 400 blocks (e.g., 4 blocks/track and 25 tracks allocated to primaries and 100 tracks allocated to secondaries).

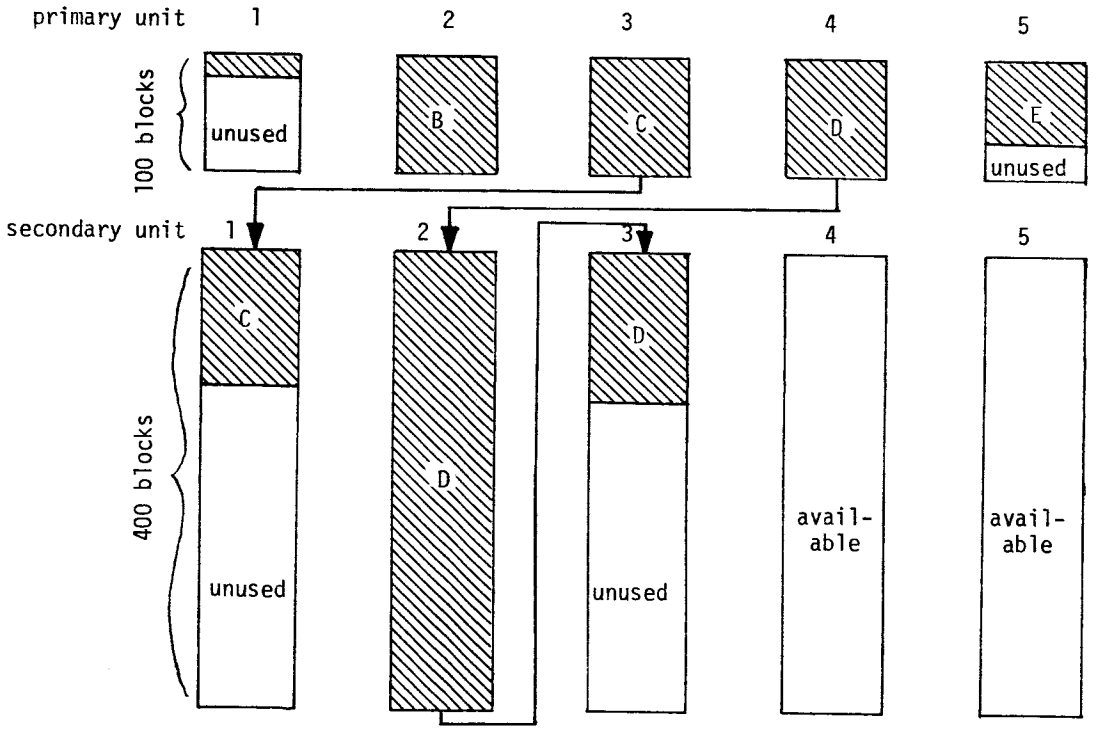


Figure 1. Space Allocation Diagram on the IBM 360

In the previous example, data blocks A, B, and E are contained in their initial primary allocations. Data block C is continued from primary unit 3 to secondary unit 1. Data block D is

continued from primary unit 4 to secondary unit 2 to secondary unit 3. Note that since data block B exactly fills primary unit 2, any additional write operation will cause an extent. In this case, secondary unit 4 will be attached to primary unit 2. "Backspacing across Disks", for example from block number 101 in data block C to block number 100, is accomplished by recognizing that block number 100 is in primary unit 3 and issuing a PØINT to that block.

In this example no tertiary files are used. Tertiary files are for the most part reserved for extremely large data blocks and all secondary space is exhausted before tertiary files are attached. Unlike the secondary files which may be attached to a data block and then detached when the data block is purged, the tertiary files remain attached once they are attached for the duration of the job. Only after the tertiaries are exhausted is ØS permitted to obtain extents on the data set it recognizes. Through efficient use of this primary, secondary, and tertiary file concept of allowing NASTRAN to allocate and attach files as needed, the amount of scratch storage space can be greatly reduced, and the system abend B37 can be controlled.

5.3.3 Link Switching

NASTRAN link switching on the 360 is performed by the Super-link and directed by the SEARCH entry within the control routine, LINKNSii, ii = 01, 02, ..., 13. When the XSEMii subroutine within an operating functional link determines that the next module to be operated resides in a link other than its own, the required link is requested through a call to SEARCH. The SEARCH call carries an argument naming the link requested. SEARCH branches back to the Super-link with the new link name. The Super-link executes the LINK macro to load the proper member and transfer control into this new NASTRAN link. Only one functional link at a time will occupy the 360 memory below the Super-link. Since the functional links are individual members of the NASTRAN Partitioned Data Set, the number of links is essentially open ended.

5.3.4 Overlay Considerations and Implementation of Open Core

Each NASTRAN functional link is created by the ØS Linkage Editor during the generation (SUBSYS) procedure (see Section 5.3.6). Each link contains a zero level or root segment and the series of overlay segments necessary to NASTRAN operating logic. The specially named common blocks which define the beginning of various open core areas are placed at their required location by linkage editor INSERT directives. An ØS overlay tree functions by automatically loading all

segments in the branch between the calling segment and the called segment. Local FØRTRAN variables and common blocks residing within segments are not cleared at load time.

Several NASTRAN links contain a special type origin for the overlay tree. This origin is created by declaring a particular segment boundary to be at a region boundary. This region boundary automatically begins at the end of the longest branch in the previous region. Since many links contain a series of small functional module drivers of different lengths followed by a structure of matrix routines used by these drivers, a region boundary is usually utilized following the drivers. The following sketch illustrates a link structure with regions.

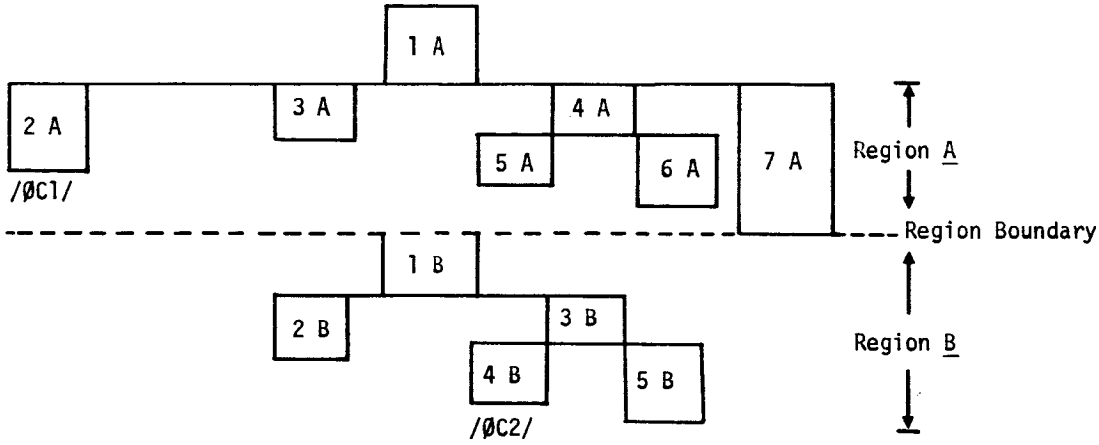


Figure 2. A tree diagram for a NASTRAN link on the IBM 360

Note that since segment 1B was requested to be begun at a region boundary, the ØS Linkage Editor placed its origin following the longest segment (7A) of the previous region.

Special caution must be exercised when operating within open core under a region structure. Operations within each region are independent of other regions. Thus, if a branch of segments within region B, say 1B and 3B, is in core because of previous calls, a call from region A to region B, say 5B, will not reload segments 1B and 3B. Therefore, if an open core area starting at ØC1/ were utilized, some of the programs within region B could be destroyed without the ØS loader's knowledge. Because of this possibility, all NASTRAN open core origins lie within a lower level region. Therefore open core starting areas such as /ØC1/ are not used in S/360 NASTRAN overlay structures.

Because NASTRAN must operate on most models of System 360 with a variety of memory sizes and ØS operating modes, a flexible method of utilizing all memory available to the job is incorporated.

In both primary and multi-programmed environments, the ØS loader requests storage from the core memory available to the job through the ØS GETMAIN macro. ØS storage-management routines make sufficient core available, and the link is placed in memory. Core memory outside of that requested for the link is storage protected by the ØS system. An attempt to store into these protected areas causes an interrupt and job termination. The NASTRAN open core concept requires use of those areas that are available but protected (i.e., the area between the link and the region boundary). To remove this protected status, the NASTRAN initialization program within each functional link issues a conditional GETMAIN for all remaining memory within the job region. The return from this GETMAIN specifies the origin and the size of the block of core memory acquired. A small portion of this block is returned (via the FREEMAIN macro) to ØS for use as FØRTRAN I/Ø buffers and for other ØS functions. The remainder of this memory is made available to NASTRAN by adjusting the upper core address used by the NASTRAN CØRSZ function. All NASTRAN modules may thus utilize the maximum core memory provided to the job.

5.3.5 Execution Deck Setup

Running or executing the NASTRAN system on a System 360 computer once the generation procedure (see Section 5.3.6) is complete requires some basic knowledge of the type of structural problem being solved and the type of output requested. In addition, the hardware configuration and capacities should be known in order to most adequately match the problem being solved to the computer.

The following procedure should provide the basic Job Control Language (JCL) necessary for all NASTRAN runs.

Table 1. Basic Job Control Language (JCL) for NASTRAN Runs

```
1.  //NASTRAN PROC PUNITS=TRK,P1=025,P2=025,
    //              SUNITS=TRK,S1=075,S2=025,
    //              TUNITS=CYL,T1=006,T2=005,
    //              PACK=DOC313,NAME=NSTRLMOD,
    //              DENPLT=1
    //*
    //*-------------------------------------------------------------------
    //*---                                                             ---
    //*---       ********************************                      ---
    //*---       *  PROCEDURE  N A S T R A N    *                      ---
    //*---       ********************************                      ---
    //*---                                                             ---
    //*-------------------------------------------------------------------
    //*
2.  //NS       EXEC PGM=NASTRAN,REGION=300K,TIME=20
3.  //STEPLIB  DD   UNIT=2314,VOL=SER=&PACK,DISP=SHR,DSN=&NAME
4.  //FT01F001 DD   UNIT=SYSDA,SPACE=(CYL,(5,1)),
    //               DCB=(RECFM=FB,LRECL=80,BLKSIZE=7280,BUFNO=1)
5.  //FT04F001 DD   SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=141),
    //               SPACE=(CYL,(2,1))
6.  //FT05F001 DD   DDNAME=SYSIN
7.  //FT06F001 DD   SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=3429),
    //               SPACE=(CYL,(10,1))
8.  //FT07F001 DD   SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=800),
    //               SPACE=(CYL,(2,1))
9.  //FT13F001 DD   DDNAME=PLT1
10. //FT14F001 DD   DDNAME=PLT2
11. //INPT     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
12. //INP1     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
13. //INP2     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
14. //INP3     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
15. //INP4     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
16. //INP5     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
17. //INP6     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
18. //INP7     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
19. //INP8     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
20. //INP9     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
21. //NPTP     DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2)),DISP=(NEW,PASS)
22. //NUMF     DD   DSN=NULLFILE,LABEL=(,NL),DISP=(NEW,PASS)
23. //OPTP     DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
24. //PLT1     DD   DSN=NULLFILE,LABEL=(,NL),
    //               DCB=(RECFM=U,BLKSIZE=2400,BUFNO=1,TRTCH=E,DEN=&DENPLT)
25. //PLT2     DD   DSN=NULLFILE,LABEL=(,NL),
    //               DCB=(RECFM=U,BLKSIZE=2400,BUFNO=1,DEN=&DENPLT)
26. //POOL     DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
27. //UMF      DD   DSN=NULLFILE,LABEL=(,NL),DISP=OLD
28. //PRIO1    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
29. //PRIO2    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
30. //PRIO3    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
31. //PRIO4    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
32. //PRIO5    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
33. //PRIO6    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
34. //PRIO7    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
35. //PRIO8    DD   UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
```

Table 1. Basic Job Control Language (JCL) for NASTRAN Runs (Continued)

```
36. //PRI09    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
37. //PRI10    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
38. //PRI11    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
39. //PRI12    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
40. //PRI13    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
41. //PRI14    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
42. //PRI15    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
43. //PRI16    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
44. //PRI17    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
45. //PRI18    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
46. //PRI19    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
47. //PRI20    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
48. //PRI21    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
49. //PRI22    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
50. //PRI23    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
51. //PRI24    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
52. //PRI25    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
53. //PRI26    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
54. //PRI27    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
55. //PRI28    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
56. //PRI29    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
57. //PRI30    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
58. //PRI31    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
59. //PRI32    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
60. //PRI33    DD  UNIT=SYSDA,SPACE=(&PUNITS,(&P1,&P2))
61. //SEC01    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
62. //SEC02    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
63. //SEC03    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
64. //SEC04    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
65. //SEC05    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
66. //SEC06    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
67. //SEC07    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
68. //SEC08    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
69. //SEC09    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
70. //SEC10    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
71. //SEC11    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
72. //SEC12    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
73. //SEC13    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
74. //SEC14    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
75. //SEC15    DD  UNIT=SYSDA,SPACE=(&SUNITS,(&S1,&S2))
76. //TER01    DD  UNIT=SYSDA,SPACE=(&TUNITS,(&T1,&T2))
77. //TER02    DD  UNIT=SYSDA,SPACE=(&TUNITS,(&T1,&T2))
78. //TER03    DD  UNIT=SYSDA,SPACE=(&TUNITS,(&T1,&T2))
79. //TER04    DD  UNIT=SYSDA,SPACE=(&TUNITS,(&T1,&T2))
80. //SNAPSHOT DD  SYSOUT=A,DCB=(RECFM=VBA,LRECL=125,BLKSIZE=1632)
    //*-------------------------------------------------------------------
    //*---                    END OF PROCEDURE                           ---
    //*-------------------------------------------------------------------
81. // PEND
```

Each card or group of cards within the NASTRAN procedure is discussed by item below. The item numbers match those along the left margin of the preceding deck listing.

Item — Description

1. The PRØC card defines the name of the instream procedure and sets default values for the symbolic parameters.

SYMBOLIC PARAMETER	DEFAULT VALUE	DESCRIPTION
PUNITS	TRK	Defines the space allocation units for the primary files.
P1	15	Defines the initial space allocation for the primary files.
P2	20	Defines the increment space allocation for the primary files.
SUNITS	TRK	Defines the space allocation units for the secondary files.
S1	70	Defines the initial space allocation for the secondary files.
S2	20	Defines the increment space allocation for the secondary files.
TUNITS	CYL	Defines the space allocation uniss for the tertiary files.
T1	06	Defines the initial space allocation for tertiary files.
T2	5	Defines the increment space allocation for tertiary files.
PACK	DOO313	Defines the Volume Serial number of the pack that the executable is on.
NAME	NSTNLMØD	Defines the data set name of the executable.
DENPLØT	1	Defines the density of the plot tape.

2. The EXEC card defines the name of the program to be executed, NASTRAN, the region size in which NASTRAN is to be executed, and the step time.

3. The STEPLIB card defines the data set name and the location of the executable.

4. The FTO1FOO1 DD card defines the data set to be used as intermediate storage for NASTRAN input. BCD or EBCDIC card images are read and converted to BCD card images and written on unit 1, then NASTRAN reads its input from unit 1.

5. The FT04F001 DD card defines the data set that will contain the run log. The NASTRAN run log contains internal timing for NASTRAN and a trace of the modules that are executed in an execution. It is usually assigned to a printer (SYSØUT=A); however, it may be assigned to any device or set to dummy and thereby deleted as desired.

6. The FT05F001 DD card is deferred by the use of the DDNAME=SYSIN parameter and will be discussed in the example for follows.

7. The FT06F001 DD card defines the printed output from the NASTRAN run. This printed output is written in BCD. As with FT04F001, it can be modified at execution time by the user as desired.

8. The FT07F001 DD card defines the punched output from NASTRAN executions. It can be modified as desired.

9. The FT13F001 DD card is deferred by the use of DDNAME=PLT1 (see Item 24).

10. The FT14F001 DD card is deferred by the use of DDNAME=PLT2 (see Item 25).

11 thru 20. These DD cards define data sets to be used as user tapes through the use of INPUT2 and ØUTPUT2 routines. All have the parameter DSN=NULLFILE which restricts ØS from allocating them unless they are supplied as override JCL.

21. The NPTP DD card is used to describe the new problem tape (checkpoint tape) to be used by NASTRAN. It is set up as a temporary file and should be overridden if it is to be saved for later use.

22. The NUMF DD card describes the new user master file that is to be created in the current NASTRAN execution. It is set to DSN=NULLFILE, and must be overridden if needed.

23. The ØPTP card defines the old problem tape (previous checkpoint tape) for the NASTRAN run. It must exist prior to the NASTRAN run in which it is used, and in this procedure DSN=NULLFILE must be overridden before the ØPTP could be used to retrieve data.

24. The PLT1 DD card defines the output data set containing EAI or Benson Lehner plotting data.

25. The PLT2 DD card defines the output data set containing the SC4020, Calcomp or DD80 plotting data.

26. The PØØL DD cards define the data set to be used as the Data Pool file. It is always present and refers to temporary scratch disk.

27. The UMF DD card defines the data set that contains the user master file data to be input to NASTRAN. It must be specified if it is needed.

28 thru 60. These DD cards define the primary units to be used by NASTRAN as temporary working files.

61 thru 75. These DD cards define the secondary units to be used by NASTRAN as temporary working files.

76 thru 79. These DD cards define the tertiary units to be used by NASTRAN as temporary working files.

80. The SNAPSHØT DD card defines the data set that contains the diagnostic dump if NASTRAN takes a user abort. It is assigned to the printer.

81. The PEND card signifies the end of an instream procedure. It should be removed before the JCL is placed on the PRØCLib.

A sample NASTRAN execution with the instream procedure could be:

```
// NASTRAN JØB ------------
{Instream  }
{Procedure }
{Deck      }
// EXEC NASTRAN
// NS. SYSIN DD *
{NASTRAN Input}
{Deck         }
/*
```

The following restrictions for Level 15 should be noted: 1) Only one type direct access device (2314) is allowed for primary, secondary and tertiary storage files. 2) Plot tapes must be 7-track tapes; any remaining tapes (problem tapes, UMF, etc.) may be 7 or 9 track as the user desires.

The NASTRAN execution deck setup is presented as an instream procedure such that it may be verified before addition to the installation procedure library (PRØCLIB) to permit easy recall and reuse.

The procedure provided is intended for use on an IBM 360 computer operating under straight ØS. It should be reviewed for each installation prior to actual use. Among the items that may necessitate modification of the procedure are the following:

1. Any modification to the standard IBM ØS operating system could make modification of the PRØC necessary. For example, all SYSØUT=A and SYSØUT=B data sets are provided with DCB information and space allocation. If a particular installation is using HASP (Houston Automatic Spooling System), it becomes necessary to remove the DCB parameters and the space allocation is no longer needed. Similar modifications will be necessary when running under ASP (Auxiliary Support Processor) or related systems.

2. This procedure should be reviewed and changed for any installations that have other than 2314 disk units defined for SYSDA data sets. The primary, secondary and tertiary files are supported only for the 2314 disk facility. The results of using other types of DASD units are unpredictable but usually disastrous.

3. The procedure as provided has temporary scratch file space sufficient for small to medium size problems. Medium to large problems will require the initial space allocation for primary and secondary files to be doubled (P1=030, S1=140), while very large problems often tax the resources of the computer and must be dealt with on an individual basis.

4. If the number of DD statements in the procedure is too great, it may be reduced (at some cost in performance) as follows with the most expendable data sets listed first:

a. INPT,INP1,INP2,---,INP9,NUMF,ØPTP,UMF,PLT1(and FT13F001), PLT2(and FT14F001). These data sets are not used by NASTRAN unless requested by the user through his data.

b. TER01,TER02,---. Tertiary files may be eliminated if careful thought is given to the selection of the space allocation parameters P1 and S1.

c. The secondary files (SEC01,SEC02,---SEC15) may be cut back to a single one (SEC01) as long as enough space is pre-allocated for the primary files (PRI01,PRI02,---) to run the problem. It is recommended that at least four or five secondary files be retained, however.

d. The number of primary files (PRI01,PRI02,---) can be cut back to a minimum number which will be problem-dependent. For static analysis this number is around 25. This is not recommended because the program will be forced to copy data blocks to and from the PØØL file in order to function with a restricted number of primary files.

5.3.6 Physical Items and Generation of NASTRAN Executable System

5.3.6.1 Description of NASTRAN Physical Items

The following eleven tapes represent the official NASTRAN Level 15 delivery to NSMØ. They are all 800 BPI, unlabeled, 9-track tapes prepared by standard IBM utilities (IEHMØVE, IEBGENER, or IEHDASDR). All tapes other than the IEHDASDR tapes are single file tapes with a DCB of: DCB=(RECFM=FB, LRECL=80, BLKSIZE=800,DEN=2). The IEHDASDR tapes contain two files spanning two volumes with a DCB of: DCB=(RECFM=U, BLKSIZE=7294,DEN=2).

Tape No.	Created by	Data Set	Description
1	IEHMØVE	DEMØDATA	Data set contains 50 members which are the input for the 50 official demonstration problems. The restored PDS that results from this tape has the following DCB: DCB = (DSØRG=PØ, RECFM=FB, LRECL=80, BLKSIZE=7280). It requires 44 tracks of 2314 disk storage and 3 directory blocks.
2	IEHMØVE	NSTNLMØD	Data set contains 15 members. This constitutes the NASTRAN executable. The restored PDS that results from this tape has the following DCB: DCB = (DSØRG=PØ, RECFM=U, BLKSIZE=7294). It requires 1028 tracks of 2314 disk storage and 3 directory blocks.

Tape No.	Created by	Data Set	Description
3	IEHMØVE	ØBJ	Data set contains 843 members which are load modules of each individual subroutine with unresolved external references in the form of a call library to be input to the Linkage Editor. The restored PDS has the following DCB: DCB = (DSØRG=PØ, RECFM=U, BLKSIZE= 7294). It requires 567 tracks of 2314 disk storage and 121 directory blocks.
4	IEHMØVE	SØU1	Data set contains 808 members. It is the NASTRAN machine-independent FØRTRAN source code. The restored PDS has the following CDB: DCB = (DSØRG=PØ, RECFM=FB, LRECL=80, BLKSIZE=7280). It requires 2015 tracks of 2314 disk storage and 29 directory blocks.
5	IEHMØVE	SØU2	Data set contains 11 members. It is the IBM 360 machine-dependent FØRTRAN source code. The restored PDS has the following DCB: DCB = (DSØRG=PØ, RECFM=FB, LRECL=80, BLKSIZE= 7280). It requires 7 tracks of 2314 disk storage and 1 directory block.
6	IEHMØVE	SØU3	Data set contains 25 members, which are the Assembly Language routines used by NASTRAN. The restored PDS has the following DCB: DCB = (DSØRG=PØ, RECFM=FB, LRECL=80, BLKSIZE=7280). It requires 110 tracks of 2314 disk storage and 2 directory blocks.
7	IEHMØVE	SUBSYS	Data set contains 15 members which are the linkage editor control cards corresponding to the 15 members of NSTNLMØD. The restored PDS has the following DCB: DCB = (DSØRG=PØ, RECFM=FB, LRECL=80, BLKSIZE=3200). It requires 26 tracks of 2314 disk storage and 1 directory block.
8	IEBGENER	UMFINDTA	Data set is a sequential data set to be input to NASTRAN to build a new UMF tape. The data set may be input directly from tape or stored on the NASTRAN pack. It has a DCB of DCB = (RECFM=FB, LRECL=80, BLKSIZE=800, DEN=2) as do the IEHMØVE tapes; however, it may be blocked up to 7280 when placed on the 2314 disk pack. It will then occupy 141 tracks of 2314 disk storage.
9	IEHMØVE	UTILMØDS	Data set consists of 4 members. These are programs used auxiliary to NASTRAN for check-out and maintenance. The restored data set has the following DCB: DCB = (DSØRG=PØ, RECFM=U, BLKSIZE=7294). It will occupy 16 tracks of 2314 disk space and 3 directory blocks.
10 & 11	IEHDASDR	D00313	These two tapes constitute an 800 BPI IEHDASDR pack dump and contain the previous 9 data sets. Where usable, this form will save 80% of the computer time required for restore the nine data sets from the IEHMØVE and IEBGENER tapes.

5.3.6.2 Installation of NASTRAN Physical Items

Partitioned data sets to be restored by IEHMØVE should be pre-allocated on the pack. To do this, use the following JCL (NSTNLMØD is used here as an example):

```
//ALØCAT        EXEC        PGM=IEFBR14
//XXX            DD         UNIT=2314,VØL=SER=xxxxxx,DISP=(NEW,KEEP),DSN=NSTNLMØD,
//                          SPACE=(TRK,(1028,,3)),DCB=(DSØRG=PØ,RECFM=U,BLKSIZE=7294)
/*
```

The following JCL may be used to recreate the partitioned data sets unloaded by IEHMØVE. This JCL can be used for data sets DEMØDATA, NSTNLMØD, ØBJ, SØU1, SØU2, SØU3, SUBSYS, and UTILMØDS. When using this JCL for SØU1 and ØBJ it will be necessary to increase the initial space allocation to 80 tracks on the UN1 DD card and add a PARM='PØWER=2' option to the IEHMØVE EXEC card.

JCL FOR IFHMØVE

```
//ALL             EXEC        PGM=IEFBR14
//UN1              DD         UNIT=2314,DISP=(NEW,DELETE),SPACE=(TRK,(40)),,CØNTIG)
//MØV             EXEC        PGM=IEHMØVE
//SYSPRINT         DD         SYSØUT=A
//SYSUT1           DD         UNIT-2314,VØL=REF=*.ALL.UN1,DISP=ØLD
//DD1              DD         UNIT=2314,VØL=SER=xxxxxx,DSN=NSTNLMØD,DISP=(ØLD,PASS)
//TAPE1            DD         UNIT=2400,VØL=SER=zzzzzz,DISP=ØLD,LABEL=(,BLP),
//                            DCB=(RECFM=FB,LRECL=80,BLKSIZE=800,DEN=2),
//                            DSN=NSTNLMØD
//SYSIN            DD         *
   CØPY          PDS=NSTNLMØD,FRØM=2400=zzzzzz,TØ=2314=xxxxxx,FRØMDD=TAPE1
/*
```

The following JCL may be used to restore the Level 15 archive pack which includes all of the nine data sets previously described from the IEHDASDR pack dump tapes.

JCL FOR IEHDASDR

```
//RE313           EXEC        PGM=IEHDASDR
//SYSPRINT         DD         SYSØUT=A
//TAPE             DD         UNIT=2400,VØL=SER=(bbbbbb,cccccc),DISP=ØLD,
//                            DSN=DO0313,LABEL=(,BLP),DCB=DEN=2
//DISK             DD         UNIT-2314,VØL=SER=aaaaaa,DISP=ØLD
//SYSIN            DD         *
   RESTØRE FRØMDD=TAPE,TØDD=DISK,CPYVØLID=NØ
/*
```

After preparation of the archive pack, either by processing the nine data sets individually or by processing them through IEHDASDR as a pack dump, the NASTRAN program may be executed by the instream procedure provided. Care should be taken to insure that the instream procedure provided does not conflict with any requirements placed on the user by his particular installation.

5.3.6.3 Generation of the NASTRAN Executable System (SUBSYSING)

The following Instream Procedure was used to produce the individual links of the NASTRAN executable (NASTNLMØD) on the IBM 360:

Table 2. Basic Job Control Language (JCL) for NASTRAN SUBSYSING

```
1.  //JPRPLINK PRØC N=1,LMØD=NSTNLMØD,PACK1=DOO313,PAKLMØD=DOO313,
    //              PACKS=DOO313
    //*
    //*---LINKEDIT THE ØVERLAY STRUCTURE FØR THE LINK SPECIFIED---
    //*
2.  //LLLL  EXEC PGM=IEWL,PARM='MAP,LET,ØVLY,LIST,SIZE=(230K,062K)'
    //           REGIØN=300K,TIME=5
3.  //SYSPRINT DD SYSØUT=A,DCB=(RECFM=FBM,LRECL=121,BLKSIZE=1210),
    //            SPACE=(CYL,(10,1))
4.  //SYSUT1   DD UNIT=SYSDA,SPACE=(7294,(80,20)),DCB=BLKSIZE=7294
5.  //SYSLIB   DD DSN=SYS1.FØRTLIB,DISP=SHR
6.  //LIB      DD UNIT=2314,VØL=SER=&PACK1,DISP=SHR,DSN=ØBJ
7.  //SYSLIN   DD UNIT=2314,VØL=SER=&PACKS,DISP=SHR,DSN=SUBSYS(&N)
8.  //SYSLMØD  DD UNIT=2314,VØL=SER=&PAKLMØD,DISP=ØLD,DSN=&LMØD
    //*
    //         PEND
```

Each card within the NASTRAN procedure is discussed by item below. The item numbers match those along the left margin of the preceding deck listing.

Item — Description

1. The PRØC card defines the name of the instream procedure and sets the default values for the symbolic parameters.

SYMBOLIC PARAMETER	DEFAULT VALUE	DESCRIPTION
N	1	Defines the link to be created by this execution of the linkage editor. The default value is set to 1 and will produce a JCL error unless it is supplied.
LMØD	NSTNLMØD	Defines the name of the preallocated data set to contain the linkage editor output load module.
PACK1	DOO313	Defines the pack that contains the individual subroutine load module library (ØBJ).
PACKLMØD	DOO313	Defines the pack that contains the preallocated data set that is to contain the output of the linkage editor.
PACKS	DOO313	Defines the pack that contains the linkage editor control cards for each link as members of a PDS such that each member corresponds to a member of the LMØD data set (NSTNLMØD).

Item | Description

2. The EXEC card defines the program to be executed, the linkage editor (IEWL) and the options selected (PARAM), as well as the region (300K) and the step time (5 Min.).

3. The SYSPRINT DD card defines the printer output data set.

4. The SYSUT1 DD card defines the temporary work data set for IEWL.

5. The SYSLIB DD card defines the system library containing the FØRTRAN support modules available to the FØRTRAN programs.

6. The LIB DD card defines the load module library where each subroutine has previously been compiled and linked independently.

7. The SYSLIN DD card defines the linkage editor control data set (SUBSYS).

8. The SYSLMØD DD card defines the output load module for the linkage editor.

This procedure assumes that all necessary NASTRAN subroutines have been previously compiled and linked individually as members of the partitioned data set ØBJ. Also, the output partitioned data set (NASTNLMØD) for the completed executable system must be available. The linkage editor control data set is assumed to be on the partitioned data set SUBSYS with one member corresponding to each member of the executable NSTNLMØD PDS. These conditions will result if the NASTRAN system is restored according to Section 5.4.6.2.

5.3.7 Machine Dependent Routines

The routines discussed in this section consist of those programs unique to the IBM 360 or those routines which are implemented differently on the IBM 360. The language for each deck is indicated by the letter F for the FØRTRAN decks or the letter A for the assembly language decks following the deck name. GINØ and GINØ related routines are discussed in Section 5.3.8.

1. EJDUM2 (A)

   EJDUM2 initializes and establishes open core (see Section 5.3.4). It is used for each functional link except Link 1.

2. MAPFNS (A)

In addition to the standard functions described in Section 3, the following were added:

a. TDATE(LØC)

Subroutine TDATE returns the date in a three word integer array LØC where:

LØC(1)=Month
LØC(2)=Day
LØC(3)=Year

b. WHEN(WCLØCK)

Subroutine WHEN executes the ØS TIME macro, which returns time in seconds after midnight. The initial call saves the time which is then used to calculate the elapsed time. WHEN returns the time in integer seconds after the initial call.

c. NØW(TTIME)

The NØW routine initializes and user the interval timer on S/360 configurations with the timer option. NØW sets and interrogates the interval timer through the STIMER and TTIMER ØS macros. The STIMER macro is executed with the TASK option which specifies that the timer is to operate only when the task is active. This has the effect of measuring the CPU operation time for a particular task. NØW returns the time in integer seconds from the initial call.

d. PDUMPX(SWITCH)

Subroutine PDUMPX through execution of the SNAP macro produces a problem program memory dump or a trace table depending on the value of SWITCH.

SWITCH=1 - Produces a complete problem program dump.

SWITCH=0 - Produces only a trace table

The resulting dump or trace table is output on the SNAPSHOT data set.

e. TYPWRT(MESSAGE)

This subroutine will print up to eighty-character messages on the operator console defined in the variable MESSAGE.

f. DUMPME

Subroutine DUMPME produces a dump of the problem area of core and terminates the run.

3. TYPØUT (A)

The TYPØUT routine is used to print an eighty-character message on the typwriter.

4. WALTIM (A)

Subroutine WALTIM executes the ØS macro TIME and returns the time of day in integer seconds after midnight in the calling argument variable.

5. CDMPBD (F)

CDMPBD is a block data routine to initiate the common block /CDCMPX/.

6. CØNMSG (F)

This routine has several entry points other than the primary entry point CØNMSG.

The description of the entry points follow.

a. CØNMSG(BUF,N,K)

The primary entry point for this routine, CØNMSG, is used to write messages on the operator's console and on unit four run log. The message is defined by the input variable BUF, the length of the message is defined by the variable N, and K is used as a switch to determine whether the message is to be written to the operator's console where:

K=0 Do not write message on console

K≠0 Write message on operator's console

b. DUMP

The DUMP routine calls the DUMPME routine described under MAPFNS above to terminate the run.

c. PDUMP

The PDUMP routine calls the PDUMPX routine described above under MAPFNS and produces a dump or traceback depending on whether DIAG 1 is set or not. If DIAG 1 is set a full dump is produced, otherwise only a traceback is produced.

d. CLØCK, ØPRMES, REWNLD

These three routines are dummy routines only. They are included here to avoid having unresolved external references from the linkage editor, and are not used in NASTRAN on the IBM 360.

e. KLØCK(ITIME)

The KLØCK routine uses the NØW routine described under MAPFNS above to return the CPU time in integer seconds in the variable ITIME.

f. SECØND(TIME)

The SECØND routine uses the NØW routine described under MAPFNS above to return the CPU time in the floating point variable TIME.

7. CØRSZ (F)

The integer function CØRSZ calls the function XCØRSZ in MAPFNS and returns the length of open core. The value of the function is printed on unit four if DIAG 13 is supplied.

8. DCMPBD (F)

DCMPBD is a block data routine to initialize the /DCØMPX/ common block.

9. IØMSG (F)

The IØMSG routine is used by the NASTIØ routine, described in Section 5.3.8, to write the messages needed by that routine.

10. ØPMESG (F)

    The ØPMESG routine calls the TYPØUT routine described above to write messages on the operator console.

11. PXIT36

    The PXIT36 routine is executed at the end of each NASTRAN run in order to insure the print buffers are flushed properly.

12. SEMTRN (F)

    The SEMTRN routine is used to convert NASTRAN data cards that may be in either BCD or EBCDIC to the BCD card images acceptable to NASTRAN and output them onto unit 1 where NASTRAN processing can read them.

13. TAPSWI (F)

    The TAPSWI routine provides for multi-volume processing in NASTRAN. When processing a tape and an EØV indicator is sensed, this routine writes a message to the operator, unloads the first tape and pauses to permit the operator to mount the next tape.

5.3.8 GINØ (Generalized Input/Output Processor for NASTRAN)

The GINØ package for the IBM 360 consists of the following two decks with entry points as indicated.

DECK	ENTRY POINT
GINØ	ØPEN
	CLØSE
	READ
	WRITE
	BCKREC
	FWDREC
	EØF
	SKPFIL
NASTIØ	I0360

Documentation for GINØ and the calling sequence for its entry points are essentially machine independent and are discussed in Section 3 of the Programmer's Manual. The documentation for NASTIØ is unique to the IBM 360 and is provided as follows:

Purpose

To perform I/Ø operations for NASTRAN files using the Basic Sequential Access Method (BSAM).

Calling Sequence

CALL IO360(ØPCØDE,BLØCK), where

ØPCØDE = the operation code for the operation to be performed according to the following list:

1. - Rewind
2. - Write
3. - Read
4. - Backrec
5. - Forward rec
6. - Open
7. - Close
8. - Reread
10. - Unload

BLØCK = The GINØ Reference Number of the file being processed.

Additional communication is accomplished through the use of the IØTABLE. The IØTABLE is a table defined in NASTIØ (like a common block) which is initialized by GNFIAT and use by NASTIØ. The contents are as follows:

```
IØTABLE    DS     H       BLKSIZE IN BYTES
           DS     H       1ST UNIT REF NØ. -- PERMANENT UNITS
           DS     H                           PRIMARY UNITS
           DS     H                           SECØNDARY UNITS
           DS     H                           TERTIARY UNITS
           DS     H       NUMBER ØF UNITS -- PERMANENT
           DS     H                          PRIMARY
           DS     H                          SECØNDARY
           DS     H                          TERTIARY
           DS     H       NUMBER ØF BLØCKS -- 1ST ALLØC -- PRIMARY
           DS     H                                        SECØNDARY
           DS     H                           2ND ALLØC -- PRIMARY
           DS     H                                        SECØNDARY
           DS     A       NUMBER ØF DECB'S
           DS     A       ADDR ØF FILE CØNTRØL BLØCKS (FCB)
           DS     A       ADDR ØF DATA CØNTRØL BLØCKS (DCB)
           DS     A       ADDR ØF DATA EVENT CØNTRØL BLØCKS (DECB)
           DS     A       NUMBER ØF BLØCKS PER TRACK
           DS     H       DCB LENGTH IN BYTES
           DS     H       DECB LENGTH IN BYTES
```

This table is only referenced by NASTIØ and GNFIAT.

Method

The NASTIØ routine performs transfers of record blocks between main storage and secondary storage and performs positioning of secondary storage devices. All I/Ø operations

are performed using the macros of the Basic Sequential Access Method (BSAM) such as Open, Close, Read, WRITE, CHECK, NØTE, and PØINT. Fields of the appropriate FCB are updated for each operation. Some examples of call chains for NASTIØ are:

Level	0	1	2	3	4
	User	ZBLPKI	QWRITE	IØ360	(BSAM)
	User	ZNTPKI	QREAD	IØ360	(BSAM)
	User	INTPK	READ	IØ360	(BSAM)
		user	WRITE	IØ360	(BSAM)

Note: Most calls are serviced at levels 1 and 2.

Calls to level 3 occur when a block is to be transferred between main and secondary storage. All calls to level 3 result in at least one call to level 4.

It should be noted that when a write operation is scheduled which would exceed the space allocated to the unit, the pool of secondary units is examined to find an available unit. If a unit is available, it is attached to the primary, and the write operation is made on the secondary. Correspondingly, if a secondary unit fills, another secondary unit is attached. Only when all secondary units are filled does NASTRAN attach a tertiary unit, if available, and only when all tertiary units are used does ØS request an extent. It should also be noted that each time a file is opened to write with rewind, all secondary units previously assigned to the file are released and made available for future assignment to other files (data blocks).

5.3.9 Special Error Codes from NASTRAN on the System 360

One of the following two types of error codes will accompany any abnormal end (ABEND) output from NASTRAN operating under ØS on the IBM System 360:

1. SYSTEM = XXX

   Where XXX is an ØS code described in the IBM System Reference Library (SRL), Form 628-6631, titled IBM System/360 Operating System Messages and Codes.

2. USER = YYY

   Where YYY is a NASTRAN code described as follows:

USER CODE	SUBROUTINE	CAUSE
001	NASTRAN	A link name has been requested that is beyond the range of those available.
002	GNFIAT	Insufficient core for NASTIØ. Core requirement for NASTIØ equals 26 times the number of non-dummy DD statements.
003	GNFIAT	Insufficient core to release the core to ØS that is necessary for FØRTRAN.
004	GNFIAT	Core is discontinuous.
005	EJDUM2	Insufficient core.
009	GNFIAT	The SPACE parameter in a DD statement for a primary or secondary file was not coded CYL or TRK.
012	MAPFNS	DUMP was called.
401	NASTIØ	Space for Data Event Control Blocks has been exceeded. Increase MAXØPN parameter on NASTRAN card.
601	GINØ	Block number check failed.
602	GINØ	Block number check failed.
603	GINØ	Incorrect return from MESAGE.
608	GINØ	Premature end of record segment.
610	GINØ	Premature end of record segment.
690	PACKUNPK	Bad order of row descriptors.
777	MAPFNS	SNAP macro failed.
900	NASTIØ	Block number check failed.
901	NASTIØ	Block number check failed.
902	NASTIØ	No unit associated with block number.
904	NASTIØ	Block number check failed.
905	NASTIØ	No unit associated with block number.
906	NASTIØ	I/Ø output in progress at the wrong time.
907	NASTIØ	No unit associated with block number.
984	GINØ	User executed a CALL WRITE with a negative word count.

5.3.10 System 360 FØRTRAN Compilers used for NASTRAN

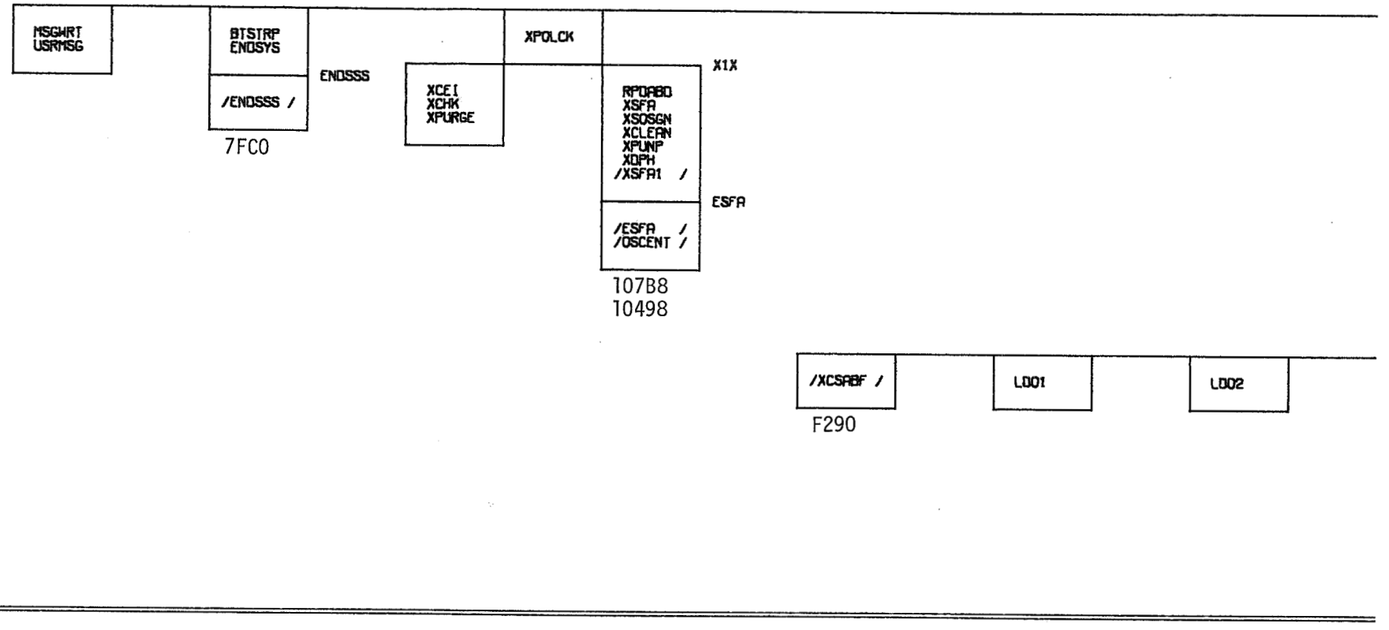
All NASTRAN Level 15 FØRTRAN subroutines, with the following exceptions, were compiled using the standard, IBM release 20, H level FØRTRAN compiler using option 1.

SUBROUTINE	COMPILER
CXLØØP	H(ØPT=2)
DLØØP	H(ØPT=2)
LDO1	G
LDO2	G
LDO3	G
LDO4	G
LDO5	G
LDO6	G
LDO7	G
LDO8	G
LDO9	G
LD10	G
LD11	G
LD12	G
LD13	G
LØØP	H(ØPT=2)
PLØTBD	G

The reason for selecting other compilers in the above were, in the case of the inner loop routine, H(ØPT=2) was selected to optimize the code as much as possible, while in the other routines the G compiler was used to overcome deficiencies in the H level compiler.

5.3.11 IBM 360-370 Overlay Charts

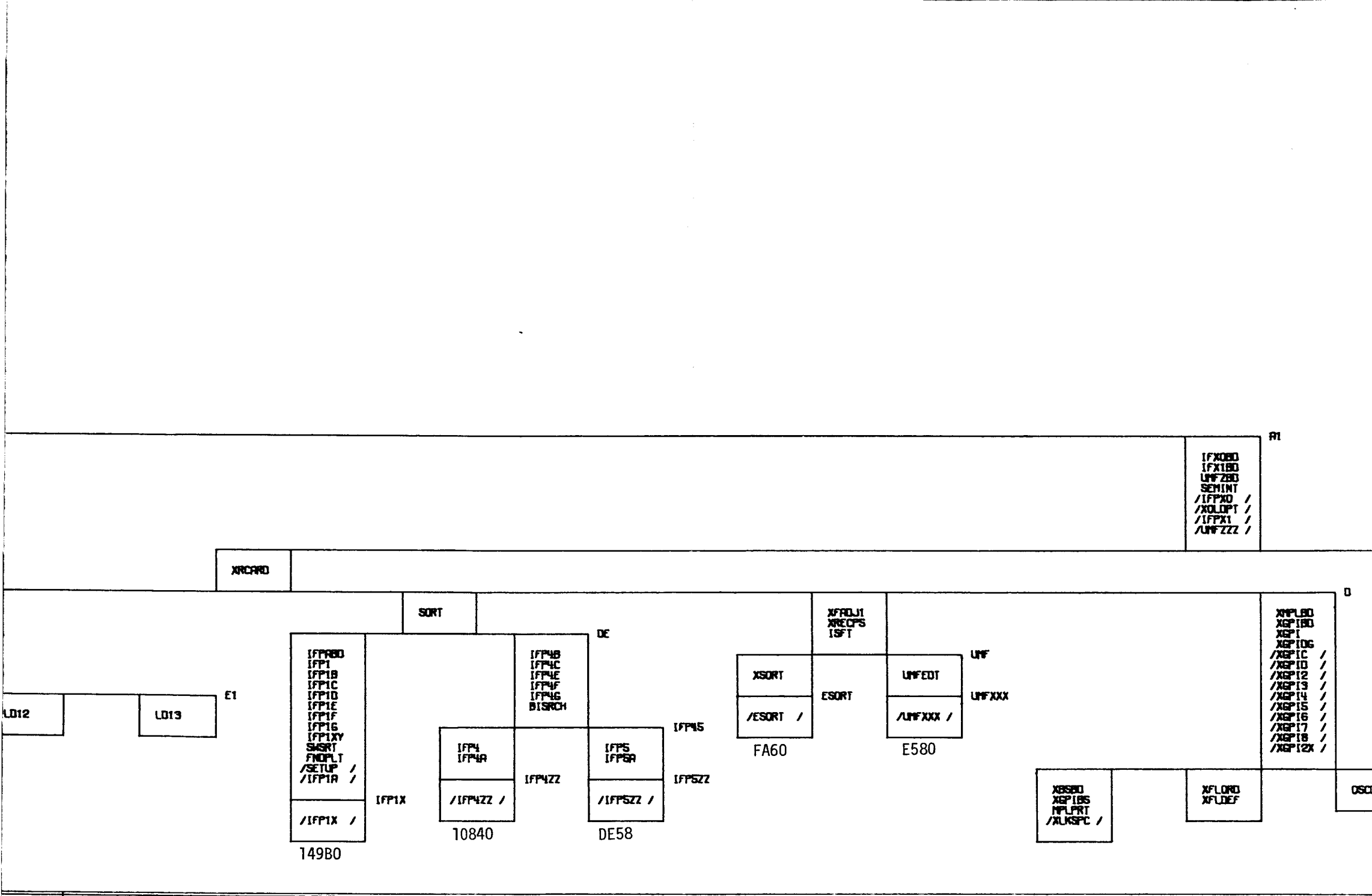
Figure 3. Overlay Structure for Link NASTRAN on the IBM 360-370.


MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
ENDSSS
7FC0
XPOLCK
XCEI
XCHK
XPURGE
X1X
RPQABO
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
/XSFA1 /
ESFA
/ESFA /
/OSCENT /
107B8
10498
/XCSABF /
F290
L001
L002
REGION

PEXIT
PXIT36
LINKNSO
XSEM1
XSORBO
CORSZ
SEMOBO
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FNAME
PRELOC
WRITRL
TAPBIT
PAGE
/XSRTBO /

GNFIAT
TTLPGE
XCSA
XSBSET
SEMTRN
XRGOFM
WALTIM

LD03 | LD04 | LD05 | LD06 | LD07 | LD08 | LD09 | LD10 | LD11


A1
IFX0BD
IFX1BD
UMF2BD
SEMINT
/IFPX0 /
/XOLOPT /
/IFPX1 /
/UMFZZZ /
XRCARD
D
SORT
DE
IFP1BD
IFP1
IFP1B
IFP1C
IFP1D
IFP1E
IFP1F
IFP1G
IFP1XY
SWSRT
FNOFLT
/SETUP /
/IFP1A /
/IFP1X /
IFP1X
149B0
IFP4B
IFP4C
IFP4E
IFP4F
IFP4G
BISRCH
IFP4
IFP4A
/IFP4ZZ /
IFP4ZZ
10840
IFP45
IFP5
IFP5A
/IFP5ZZ /
IFP5ZZ
DE58
XFADJ1
XRECPS
ISFT
XSORT
/ESORT /
ESORT
FA60
UMF
UMFEDT
/UMFXXX /
UMFXXX
E580
XMPL8D
XGPI8D
XGPI
XGPIDG
/XGPIC /
/XGPID /
/XGPI2 /
/XGPI3 /
/XGPI4 /
/XGPI5 /
/XGPI6 /
/XGPI7 /
/XGPI8 /
/XGPI2X /
XBSBD
XGPIBS
MPLPRT
/XLKSPC /
XFLORD
XFLDEF
OSCI
E1
LD12
LD13
EJDUM2 /

LINK 01

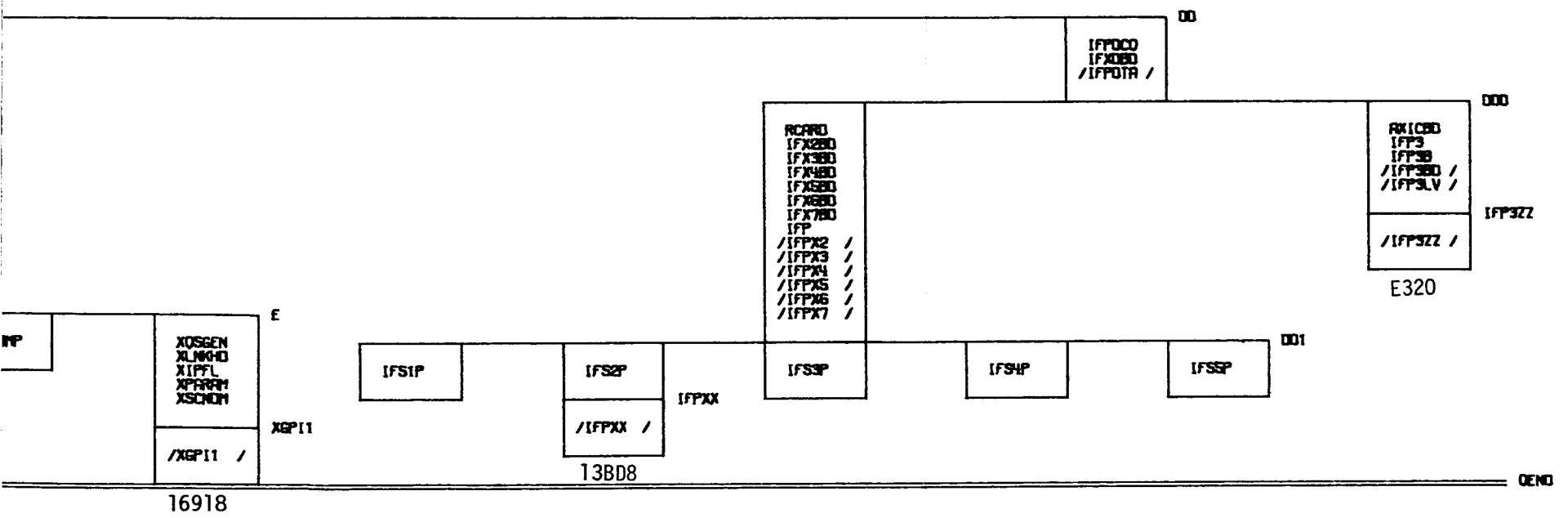
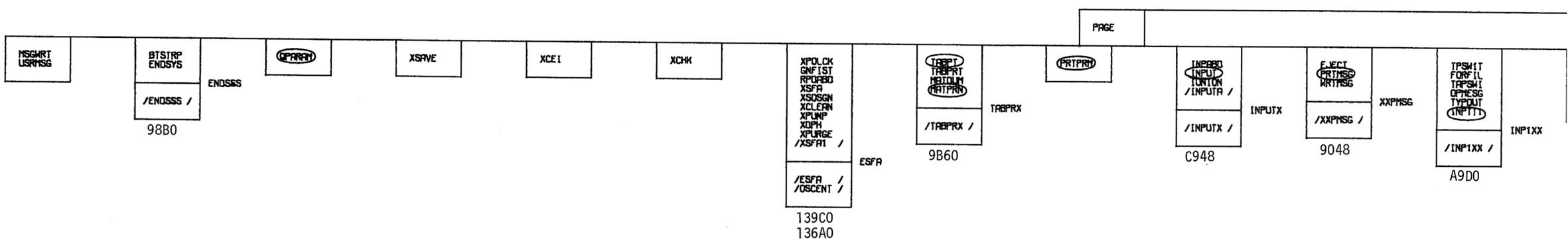


Figure 4. Overlay Structure for Link 01 on the IBM 360-370.


MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
98B0
ENDSBS
QPARAM
XSAVE
XCEI
XCHK
XPOLCK
GNFIST
RPDABO
XSFA
XSOSGN
XCLEAN
XPUNP
XOPH
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
139C0
136A0
ESFA
TABPT
TABPRT
MAIDUM
MATPRM
/TABPRX /
9B60
TABPRX
PAGE
PRTPRM
INPABO
INPUT
TORTON
/INPUTA /
/INPUTX /
C948
INPUTX
EJECT
PRTMSG
WRTMSG
/XXPMSG /
9048
XXPMSG
TPSWIT
FORFIL
TAPSWI
OPMESG
TYPOUT
INPTTY
/INP1XX /
A9D0
INP1XX

REGION

PEXIT
PXIT36
LINKNSO
INTLST
ROMODX
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
TRPBIT
XSEM2

SETVAR

INPTT2

/INP2XX /

INP2XX

A320

A

PLOTBD
AXIS
DRWCHR
FNDPLT
IOPLOT
LINE
PLTSET
PRINT
SELCAM
SKPFRM
SGINO
STPLOT
SYMBOL
TIPE
TYPFLT
TYPINT
/CHARSW /
/CHRDRW /
/XXPARM /
/PLTDAT /
/SYMBLS /

LINE1
TYPE1
WPLT1

LINE2
TYPE2
WPLT2

AXIS3
LINE3
TYPE3
WPLT3

LINE4
WPLT4

LINE9
TYPE9
WPLT9

AXIS10
LINE10
TYPE10
WPLT10

DRAW

DPLOT
DRAW
DVECTR
ELELBL
FIND
FNDSET
GETDEF
GPTLBL
GPTSYM
HEAD
INTVEC
MINMAX
PARAM
PERPEC
PLOT
PLTOPR
PROCES
SHAPE
WRTPRT
/DRWDAT /
/RSTXXX /

/XXPLOT /

XXPLOT

18130

SEEMAT
MAPSET

/SEEMTX /

SEEMTX

13A00

XYPLOT
/XYPLIN /

/XYPLXX /

XYPLXX

LONGST

13C08

EJDUM2
/EJDUM2 /

LINK 02

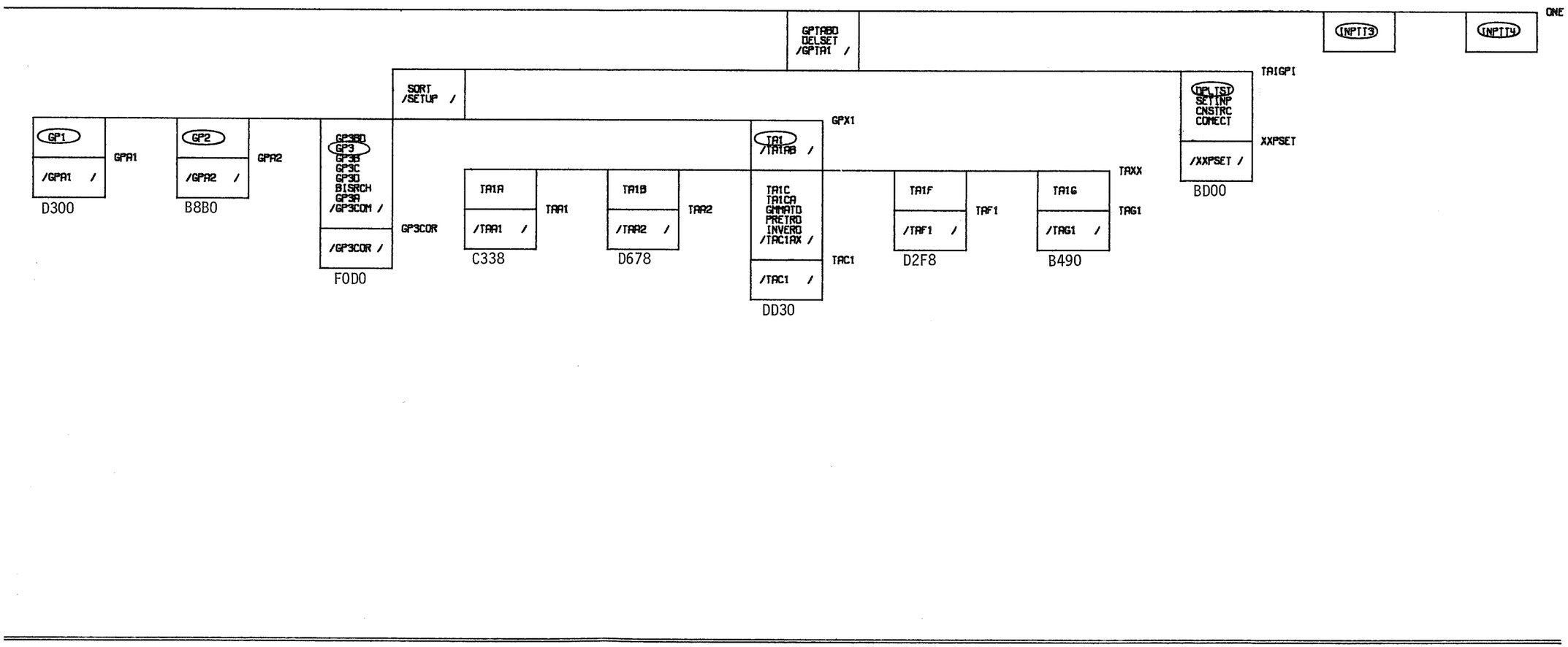
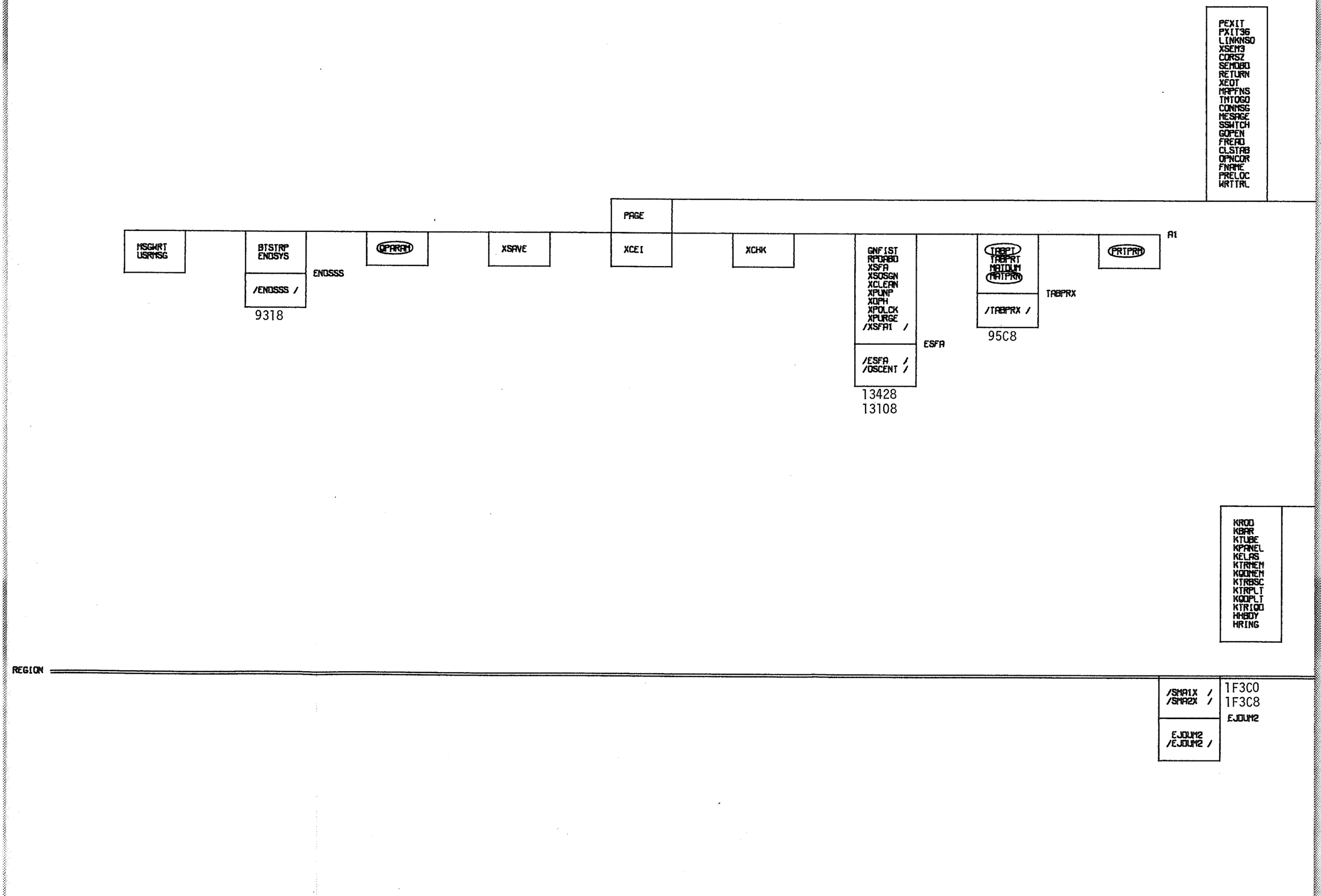


Figure 5. Overlay Structure for Link 02 on the IBM 360-370.


PEXIT
PXIT36
LINKNSO
XSEM3
CORSZ
SEMOBO
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
PAGE
XCEI
MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
9318
ENDSSS
QPARAM
XSAVE
XCHK
GNFIST
RPORBO
XSFA
XSOSGN
XCLEAN
XPUNP
XOPN
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
13428
13108
ESFA
TABPT
TABPRT
MAIOUM
MATPRM
/TABPRX /
95C8
TABPRX
PRTPRM
A1
KROO
KBAR
KTUBE
KPANEL
KELAS
KTRMEM
KQOMEM
KTRBSC
KTRPLT
KQOPLT
KTRIQO
HHBDY
HRING
REGION
/SMA1X /
/SMA2X /
1F3C0
1F3C8
EJOUM2
EJOUM2
/EJOUM2 /

LINK 03

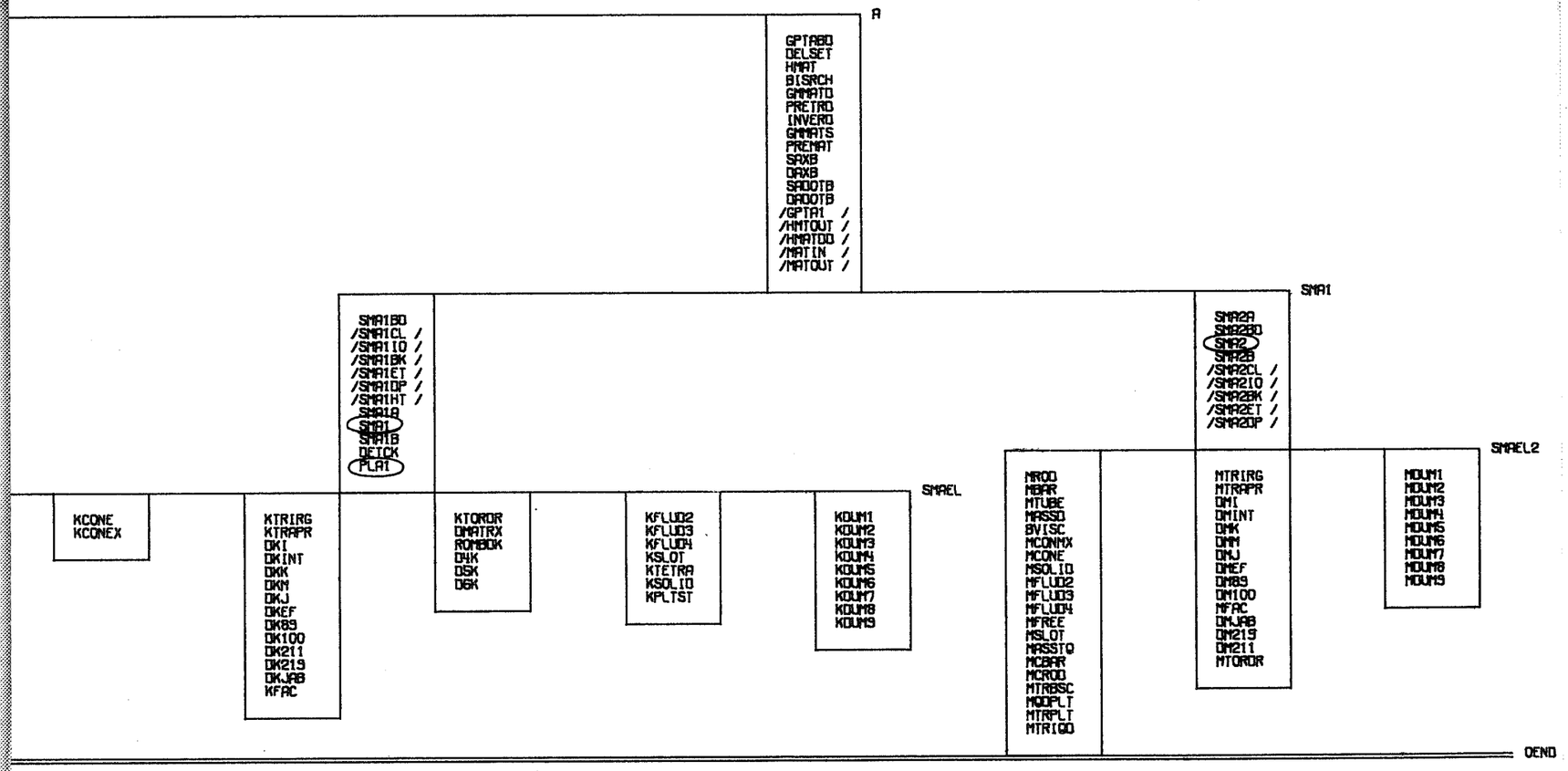
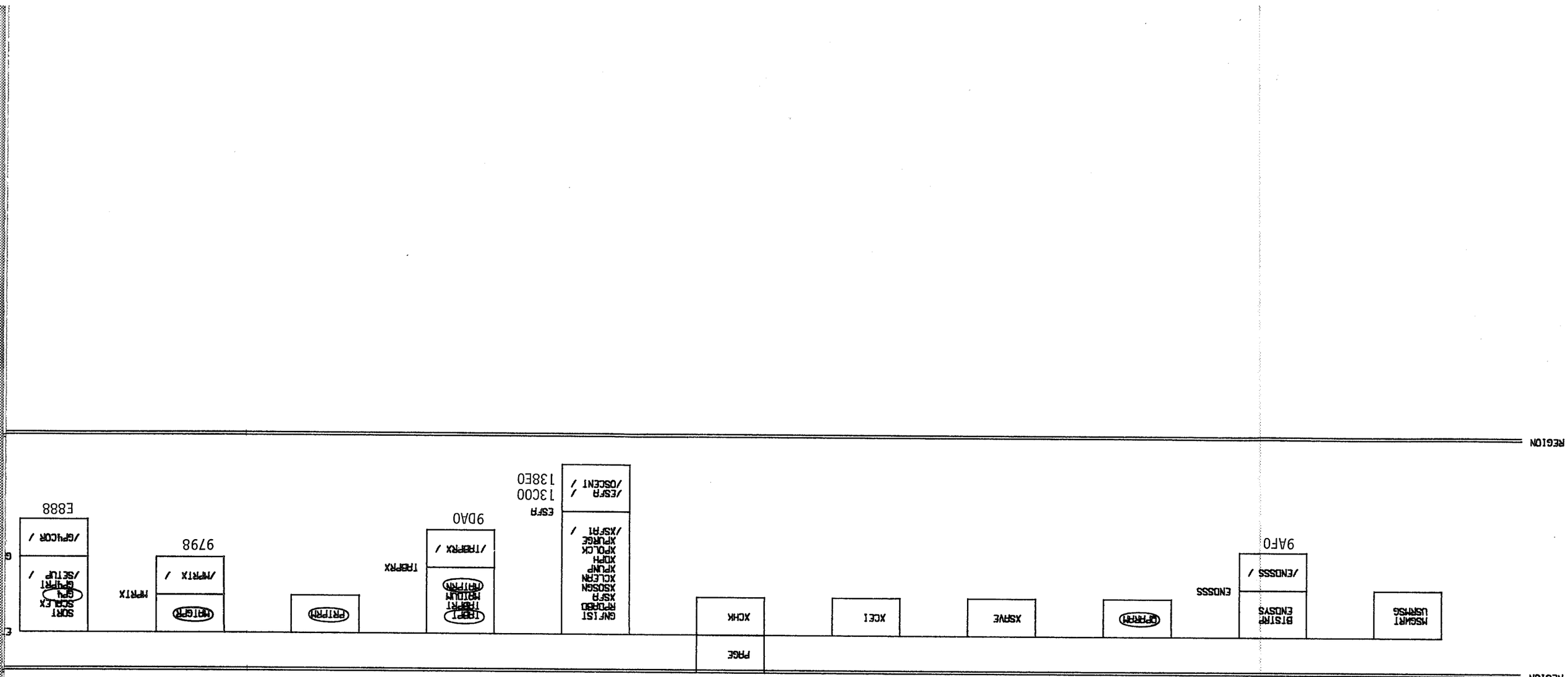
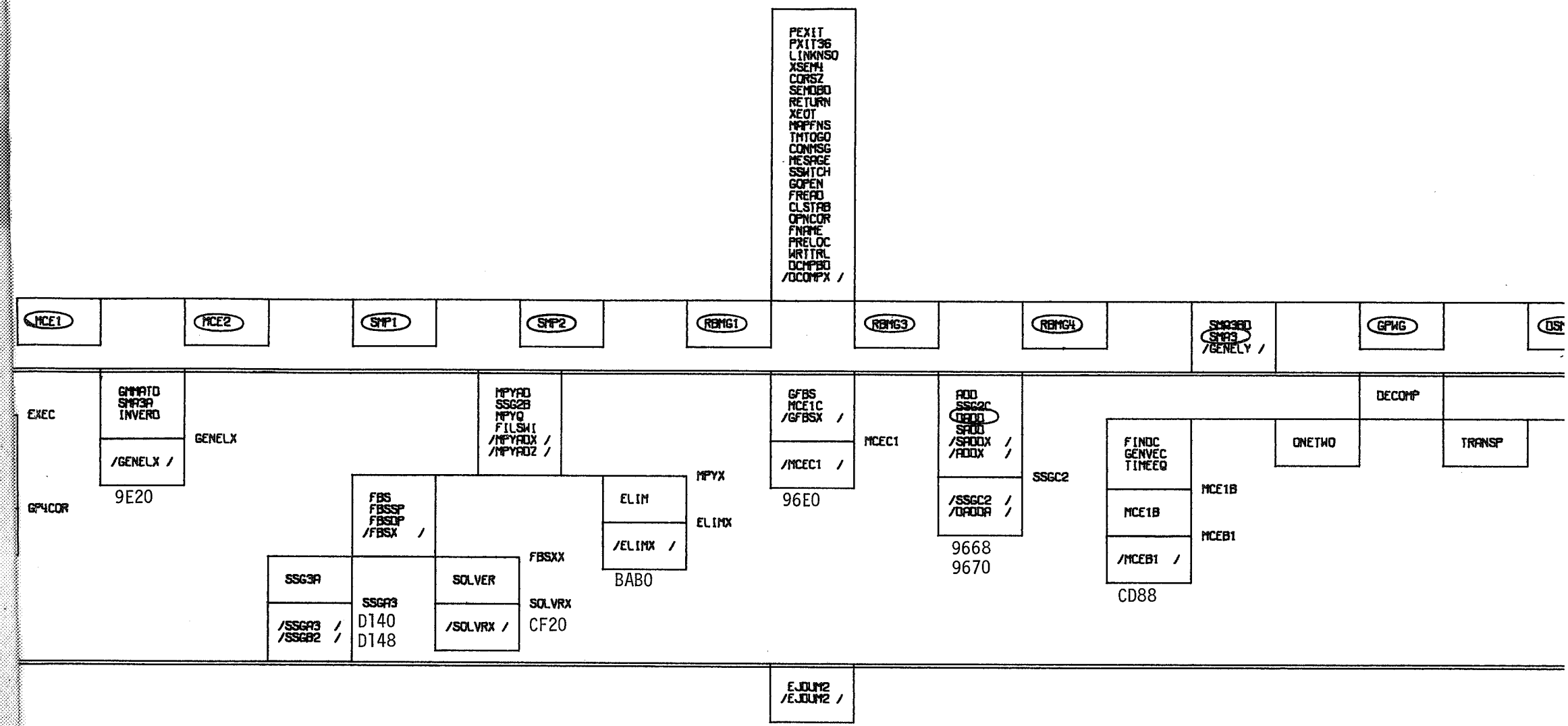


Figure 6. Overlay Structure for Link 03 on the IBM 360-370.

REGION


9AF0
/ENDSSS /
BISTRP
ENDSYS
MSGWRT
USRMSG
ENDSSS
XSRVE
XCE1
XCHK
PRGE
ESFR
13C00
13BE0
/ESFR /
/OSCENT /
GNFLST
RFDRBD
XSFR
XSOSGN
XCLEFN
XFLUNP
XFOLCK
XDPH
XFUGE
XFULCK
XSFR1
9DA0
/TRBFRX /
TRBFRX
TRBFRI
MBIUUM
MBIFRN
TRBFRX
9798
/MFRTX /
MBIGFR
MFRTX
PRIFRN
E888
/GPHCOR /
SORT
SCRLEX
GPH
GPHFRI
/SETUP /


PEXIT
PXIT36
LINKNSQ
XSEM4
CORSZ
SEMOBQ
RETURN
XEOT
MAPFNS
TMTOGQ
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
DCMPBQ
/DCOMPX /
MCE1
MCE2
SMP1
SMP2
RBMG1
RBMG3
RBMG4
SMA3BQ
SMP3
/GENELY /
GPWG
EXEC
GMMATD
SMA3A
INVERD
/GENELX /
GENELX
9E20
GP4COR
MPYAD
SSG2B
MPYQ
FILSWI
/MPYADX /
/MPYADZ /
MPYX
FBS
FBSSP
FBSDP
/FBSX /
FBSXX
ELIM
/ELIMX /
ELIMX
BABO
SSG3A
/SSGA3 /
/SSGB2 /
SSGA3
D140
D148
SOLVER
/SOLVRX /
SOLVRX
CF20
GFBS
MCE1C
/GFBSX /
/MCEC1 /
MCEC1
96E0
EJOUM2
/EJOUM2 /
ADD
SSG2C
DADD
SADD
/SADDX /
/ADDX /
/SSGC2 /
/DADDA /
SSGC2
9668
9670
DECOMP
ONETWO
TRANSP
FINDC
GENVEC
TIMEEQ
MCE1B
/MCEB1 /
MCEB1
CD88

A

DLOOP

DECOMP

UPART
SCE1
/UPARTX /

UPARTX

9D98

RULER
CALCV
PARTN
/PATX /
/PARMEG /

MCE1A
/MCEA1 /

PARTX

MCEA1

9A40

SDCOMP
LOOP
FACTOR
RBMG2
/SFACT /
/FACTRX /

FACTRX

C020

TRNSP
TRANP1
/TRNSPX /
/DTRANX /

DTRANX

9030

GPWG1A
/GPWGA1 /

GPWGA1

9850

PRETRS
GMMATS

GPWG1B
GPWG1C
/GPWGB1 /

GPWG

GPWGB1

A0F8

MCE1D
/MCED1 /

MCED1

8710

SMA3B
SMA3C
/SMAB3 /
/SMAC3 /

SMAB3

95D8
95E0

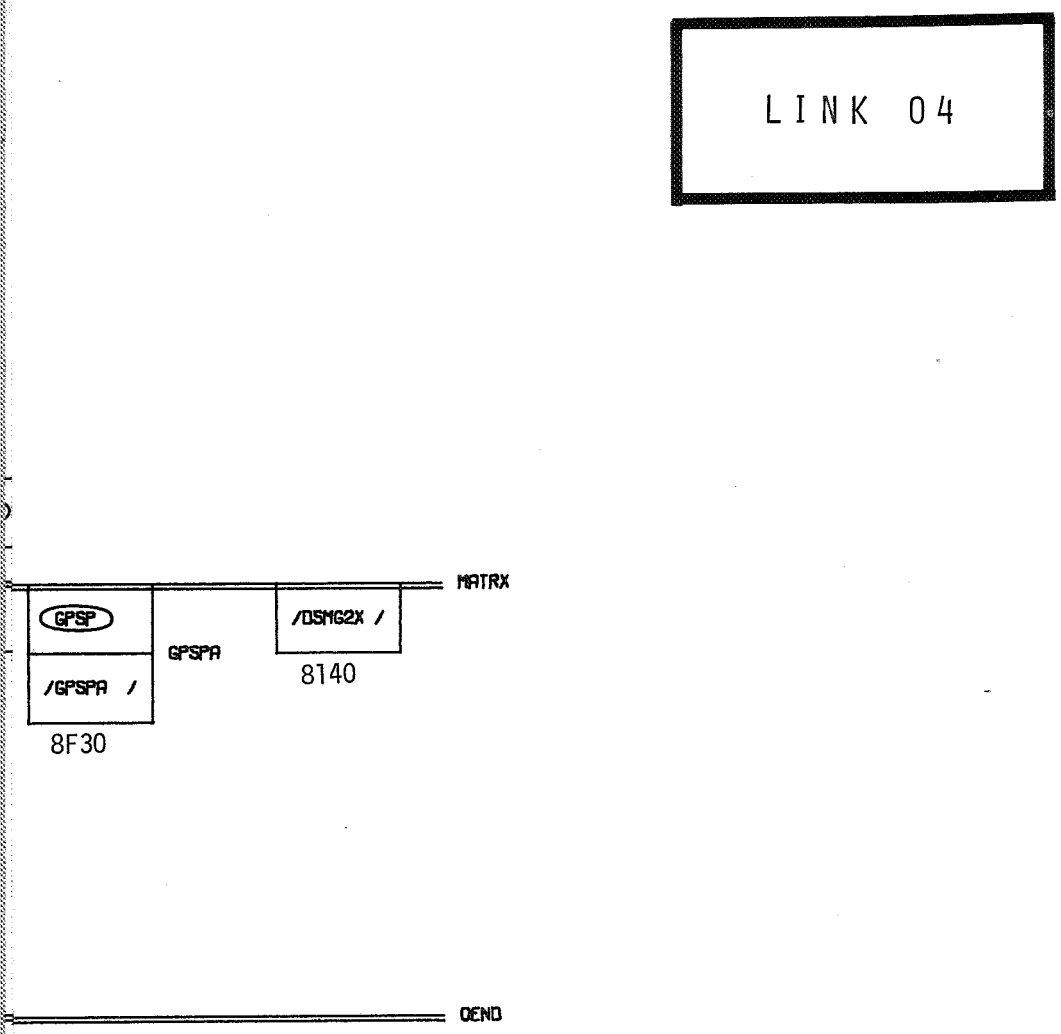


Figure 7. Overlay Structure for Link 04 on the IBM 360-370.

REGION

SSG1
/LOADX /

PAGE

MSGWRT
USRMSG

BTSTRP
ENDSYS

/ENDSSS /

ENDSSS

9C58

QPARAM

XSAVE

XCEI

XCHK

GNFIST
RPDABO
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
XPOLCK
XPURGE
/XSFA1 /

/ESFA /
/DSCENT /

ESFA

13D68
13A48

TABPT
TABERT
MATPRN
MATDUM

/TABPRX /

TABPRX

9F08

PRTPRM

REGION

LINK 05

PEXIT
PXIT36
LINKNSO
XSEMS
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL

SSG2 /PATX /

A

SSG4

MATRX

EXEC

MATGPR

MPRTX

/MPRTX /

9900

SSG2B
MPYAD
MPYQ
FILSWI
/MPYAQX /
/MPYAQZ /

SSG3
SSG3A
FBS
FBSSP
FBSDP
/FBSX /

SSGA3

/SSGA3 /

D408

MPYX

RULER
CALCV
PARTN
/PARMEG /

PARTX

MERGE
SDR1B

SDR1

/SDR1 /
/SSG2X /
/SSGB2 /

E5A8
E598
E5A0

SSG2A

SSGA2

/SSGA2 /

D2A8

SDCOMP
LOOP
FACTOR

FACTRX

/FACTRX /

C090

FNDPNT
BASGLB
MPYL
PERMUT
BISRCH
SAXB
/LODS /
/TRANX /
/XCSTM /

SSG1X

SSG1A
EXTERN
GRAVL1
GRAVL3
FPONT
COMBIN
GRAV
PLOAD
PRESAX
RFORCE
GRAVL2
GHBDY

SSGA1X

/SSGA1X /

10FC0

GPTABD
DELSET
EDTL
GMMATS
PREMAT
INVERS
SSGETD
SSGKHI
/FPT /
/GPTA1 /
/TRIMEX /
/MATIN /
/MATOUT /
/SSGTRI /
/SSGWRK /
/SSGETT /

SSGEL

CONE

DUM1
DUM2
DUM3
DUM4
DUM5
DUM6
DUM7
DUM8
DUM9

HBDY
BAR
TRIMEM
QDMEM
TETRA
SOLID
TRBSC
TRPLT
QDPLT
TRIQD
ROD

SSGB1X

/SSGB1X /

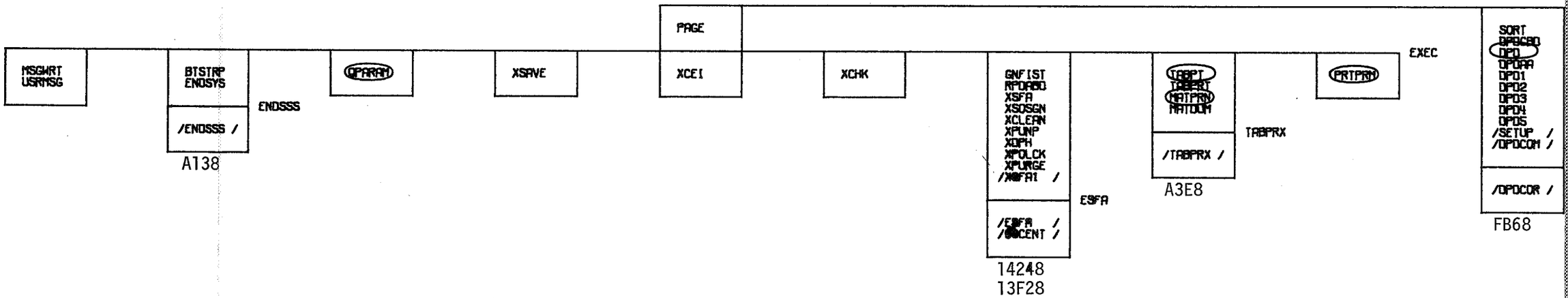
19F10

TIRIRG
TIRAPR
TTORDR
FCURL
AI
BINT
AK
AM
AJ
COEF
PRETRS
F85
FF1QD
IFAC
FJAB
F6219
F6211
ROMBER
F4
F5
F6

QEND

EJDUM2
/EJDUM2 /

Figure 8. Overlay Structure for Link 05 on the IBM 360-370.


MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
ENDSSS
A138
QPARAM
XSAVE
PAGE
XCEI
XCHK
GNFIST
RPDABD
XSFA
XSOSGN
XCLEAN
XPUNP
XOPH
XPOLCK
XPURGE
/XMFA1 /
/ESFA /
/XMCENT /
ESFA
14248
13F28
TABPT
TABERT
MATPRM
MATDUM
/TABPRX /
TABPRX
A3E8
PRTPRM
EXEC
SORT
QPSCBD
DPD
DPDAA
DPD1
DPD2
DPD3
DPD4
DPD5
/SETUP /
/DPDCOM /
/DPDCOR /
FB68

REGION

LINK 06

PEXIT
PXIT36
LINKNSO
XSEMG
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
A

READBD
REIG
/INVPWX /
/GIVN /
/REGEAN /
/REIGKR /

/REIGA /
8788

SSG2B
MPYAD
MPYQ
FILSWI
/MPYADX /
/MPYAD2 /
MPYX

RULER
CALCV
MERGE
/PATX /
/PARAMS /

OPDCOR

SDR1B
READ1
/READ1A /
/SDAD1 /
READ1A
EC50
EC48

PARTX
READ8
READ8
READ4
ORTCK
/READ8A /
/SSGD2 /
/INVP4X /
READ8A
107E0
107D8
107E8

INVPWR
DCMPBD
/INVPXX /
/DCOMPX /

ADD
INVP2
SADD
/SADDX /
/ADDX /
/SFACT /

GENVEC
TIMEE8
FINBC
ONETHO
TRANSP
DECOMP
DLOOP

DETDET
DETM
DETM1
DETM3
DETM4
DETM5
DETFBS
SUMM
SQRTM
ARRM
EADD
FOVECT
/DETMX /
DETOX
/DETOX /
140A8

/INVP2V /
DCMPX
10740

ADDXX

FACTOR
SDCOMP
LOOP
INVP1
/INVPX /
/INVP1X /
/INVP2X /
/FACTRX /
INVPX
E1D0
E1E8
E1D8
E1E0

INVFBS
INVP3
XTRNSY
MTIMSU
FBSINV
NORM1
SUB
/INFB6X /
INVY1

/INVP3X /
INVP3X
BF50

VALVEC
SMLEIG
TRIDI
SICOX
ROTAX
EMPCOR
FILCOR
QRITER
WILVEC
/XXVLVC /
XXVLVC
D138

INVERT
INVTR
/INVTRX /
/INVRTX /
INVRTX
A680

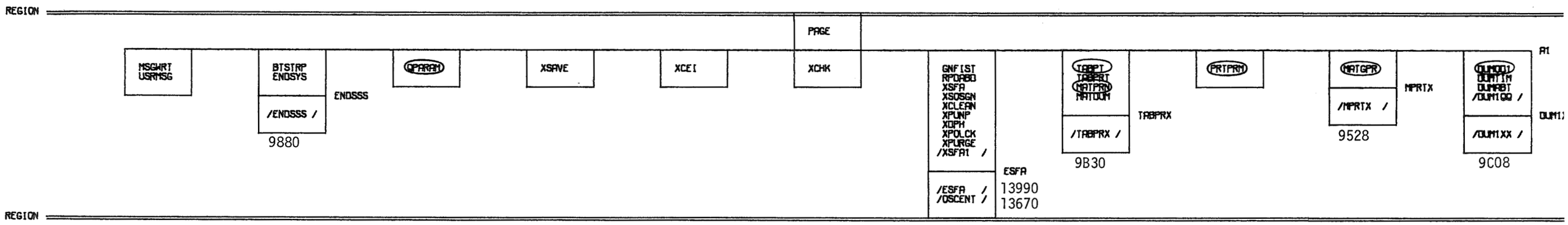
READ6
/READ6X /
READ6X
8C68

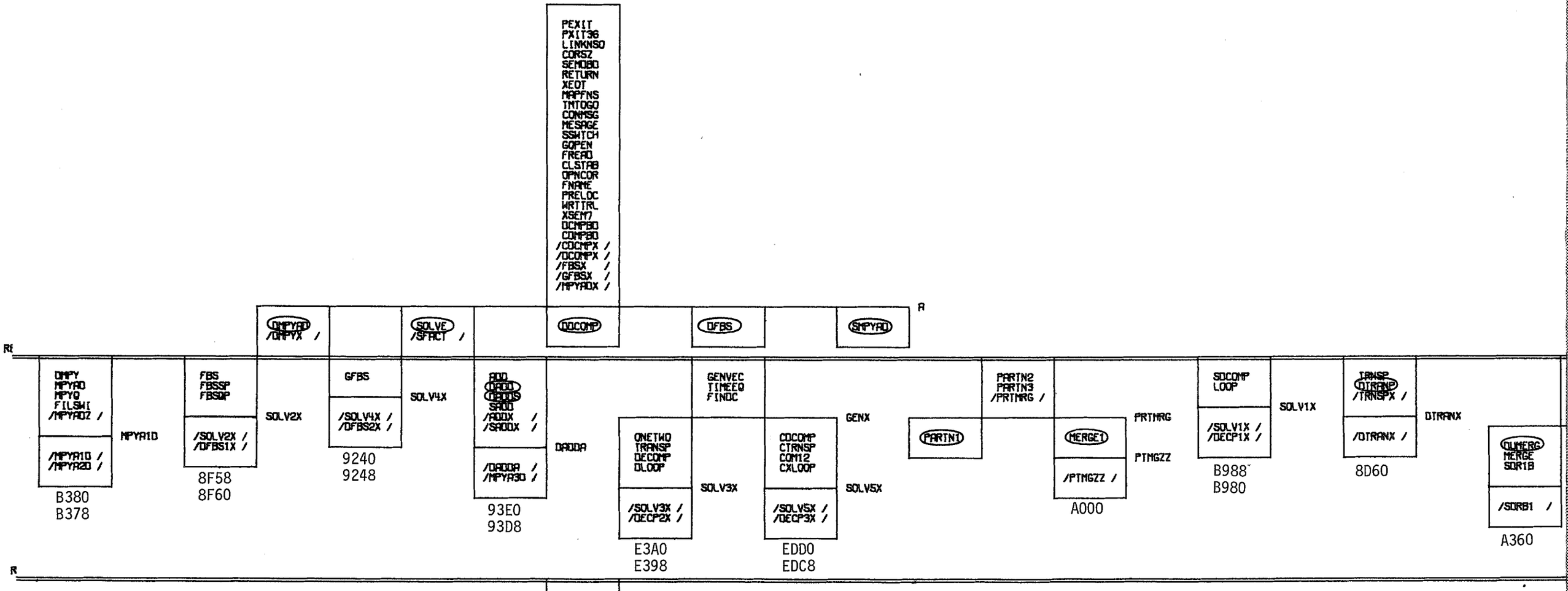
TRNSP
TRANP1
/TRNSPX /
/DTRANX /
MATRX
DTRANX
9678

OENO

EJOUM2
/EJOUM2 /

Figure 9. Overlay Structure for Link 06 on the IBM 360-370.


REGION
MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
9880
ENDSSS
QPARAM
XSAVE
XCEI
PAGE
XCHK
GNFIST
RPDABD
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
ESFA
13990
13670
TABPT
TABPRT
MATPRM
MATDDM
/TABPRX /
9B30
TABPRX
PRTPRM
MATGPR
/MPRTX /
9528
MPRTX
DUM001
DUMTIM
DUMABT
/DUM1QQ /
/DUM1XX /
9C08
A1
DUM1
REGION


PEXIT
PXIT36
LINKNSQ
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
XSEM7
DCMPBD
COMPBD
/CDCMPX /
/DCOMPX /
/FBSX /
/GFBSX /
/MPYADX /
DMPYBD
/DMPYX /
SOLVE
/SFACT /
DDCOMP
DFBS
SMPYAD
DMPY
MPYAD
MPYQ
FILSWI
/MPYAD2 /
/MPYA1D /
/MPYA2D /
MPYA1D
B380
B378
FBS
FBSSP
FBSDP
/SOLV2X /
/DFBS1X /
SOLV2X
8F58
8F60
GFBS
/SOLV4X /
/DFBS2X /
SOLV4X
9240
9248
ADD
(ADD)
SADD
(SADDS)
SADD
/ADDX /
/SADDX /
/DADDA /
/MPYA3D /
DADDA
93E0
93D8
EJOUM2
/EJOUM2 /
ONETWO
TRANSP
DECOMP
DLOOP
/SOLV3X /
/DECP2X /
SOLV3X
E3A0
E398
GENVEC
TIMEEQ
FINDC
CDCOMP
CTRNSP
COM12
CXLOOP
/SOLV5X /
/DECP3X /
GENX
SOLV5X
EDD0
EDC8
PARTN1
PARTN2
PARTN3
/PRTMRG /
MERGE1
/PTMGZZ /
PRTMRG
PTMGZZ
A000
SDCOMP
LOOP
/SOLV1X /
/DECP1X /
SOLV1X
B988
B980
TRNSP
(DTRANP)
/TRNSPX /
/DTRANX /
DTRANX
8D60
(NUMERG)
MERGE
SDR1B
/SDRB1 /
A360

LINK 07

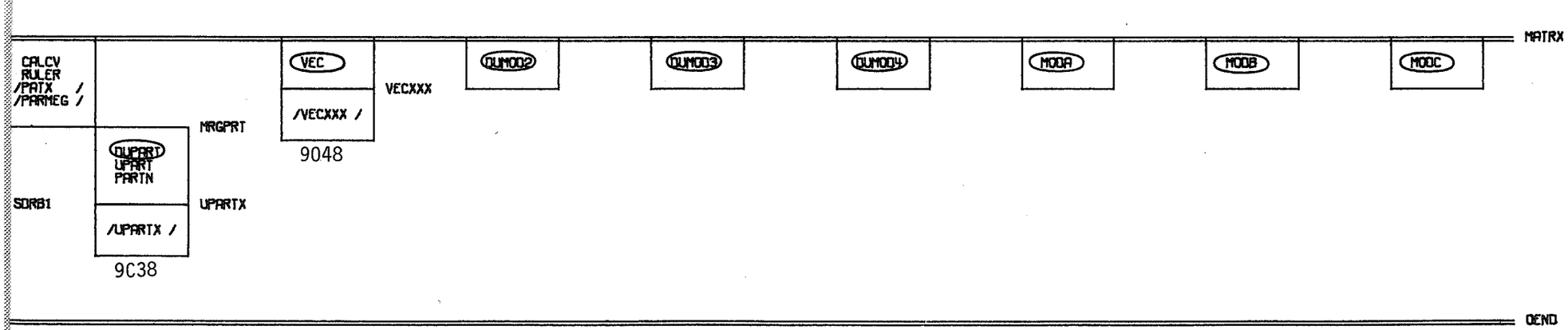
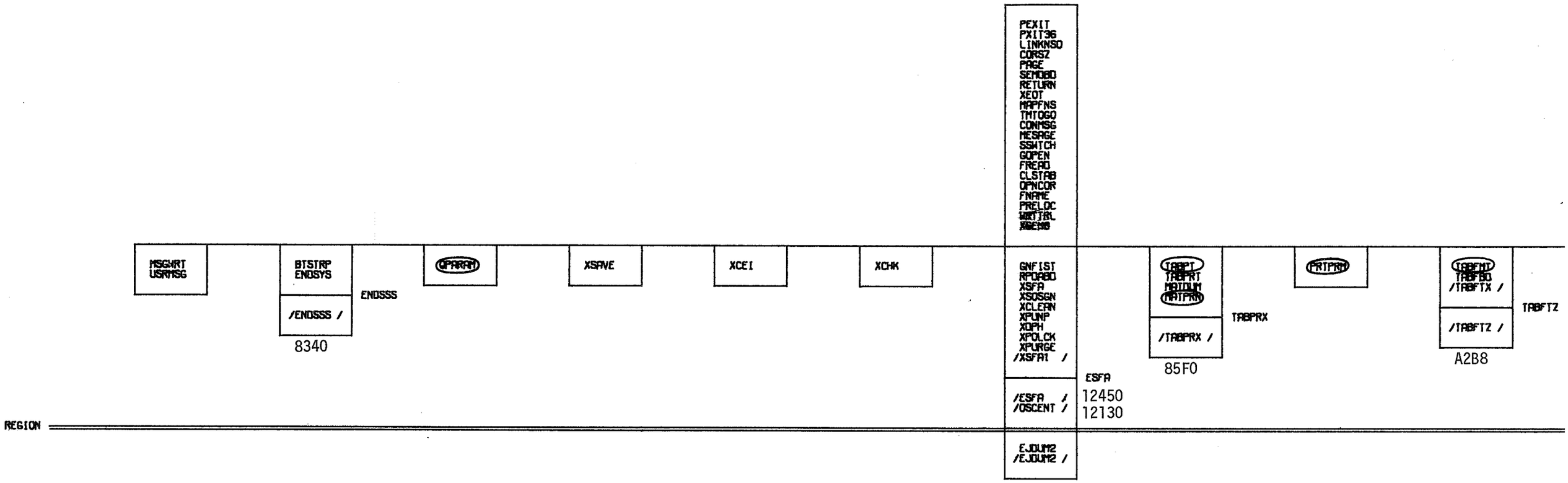


Figure 10. Overlay Structure for Link 07 on the IBM 360-370.


MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
ENDSSS
8340
QPARAM
XSAVE
XCEI
XCHK
PEXIT
PXIT36
LINKNSO
CORSZ
PAGE
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWITCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
GNFIST
RPORBD
XSFA
XSOSGN
XCLEAN
XPUNP
XOPN
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
ESFA
12450
12130
EJOUM2
/EJOUM2 /
TABPT
TABPRT
MAITOUM
MAITPRN
/TABPRX /
TABPRX
85F0
PRTPRM
TABFMT
TABFBD
/TABFTX /
/TABFTZ /
TABFTZ
A2B8
REGION

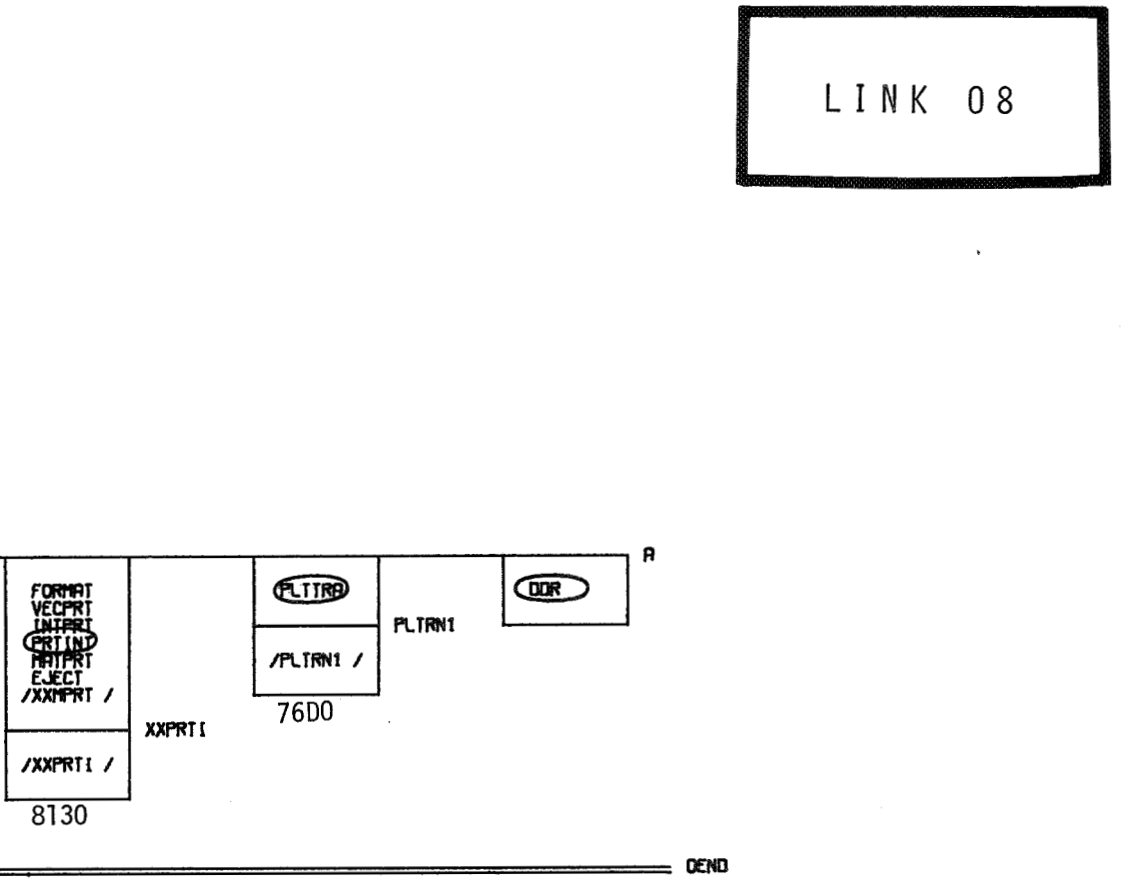


Figure 11. Overlay Structure for Link 08 on the IBM 360-370.

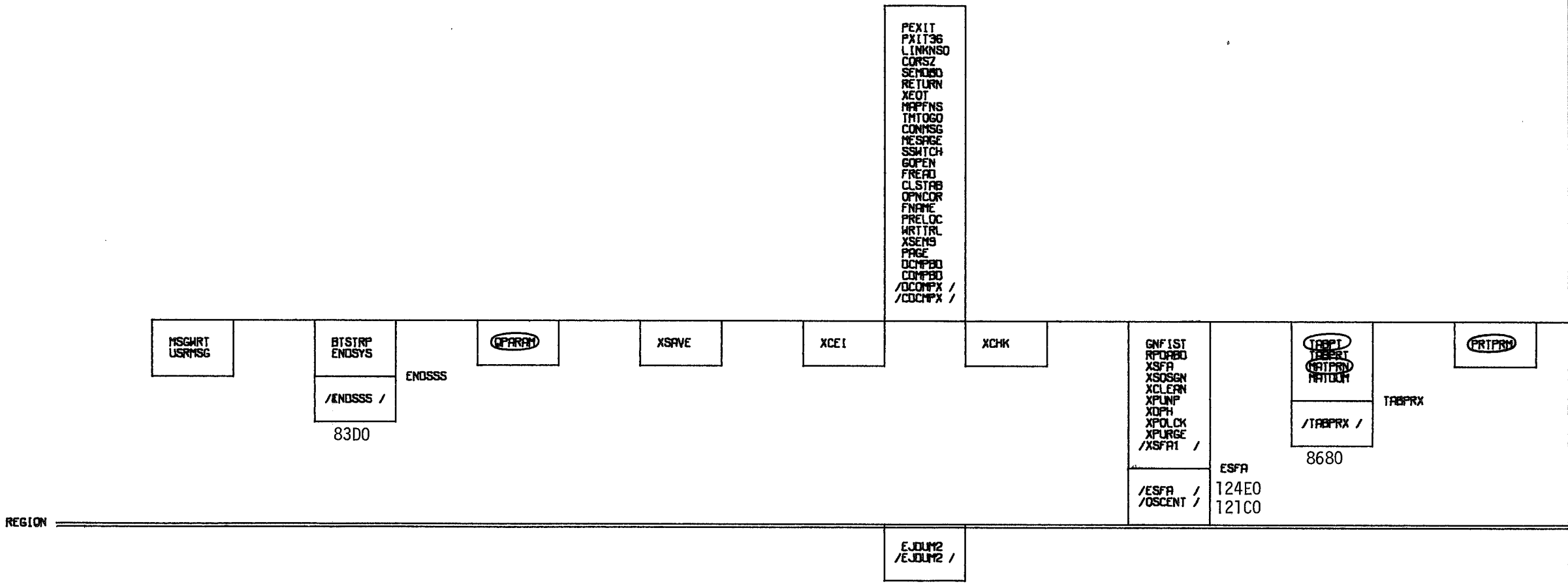
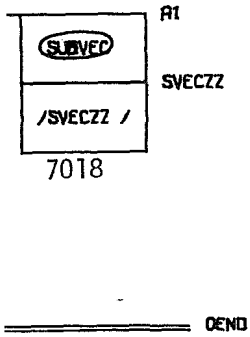


Figure 12. Ove

LINK 09



y Structure for Link 09 on the IBM 360-370.

PEXIT
PXIT36
LINKNS1
XSEM10
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
OCMPBD
COMPBD
/COCMPX /
/OCOMPX /

GKAD | GKAM

REGION

PAGE | PRETAB

MSCHRT
USRMSG

BTSTRP
ENDSYS
/ENDSSS /
99B8
ENDSSS

QPARAM

XSAVE

XCEI

XCHK

GNFIST
RPDRBD
XSFA
XSOSGN
XCLEAN
XPUNP
XOPN
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
13AC8
137A8
ESFA

TABPT
TABERT
MATPRM
MATBDM
/TABPRX /
9C68
TABPRX

PRTPRM

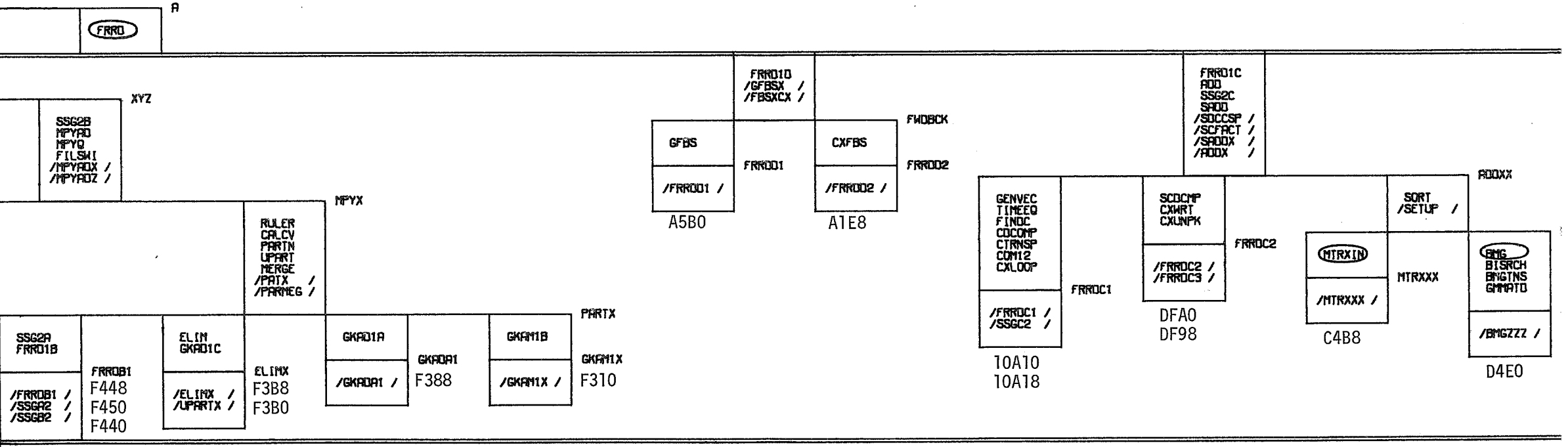
MATGPR
/MPRTX /
9660
A1
MPRTX

FRRD1A
/FRRDA1 /
A490
FRRDA1

GKAM1A

E.JOUN2
/E.JOUN2 /

REGION


A
FRRO
XYZ
SSG2B
MPYAO
MPYO
FILSWI
/MPYAOX /
/MPYAOZ /
MPYX
RULER
CALCV
PARTN
UPART
MERGE
/PATX /
/PARMEG /
PARTX
SSG2A
FRRO1B
/FRROB1 /
/SSGA2 /
/SSGB2 /
FRROB1
F448
F450
F440
ELIM
GKAO1C
/ELIMX /
/UPARTX /
ELIMX
F3B8
F3B0
GKAO1A
/GKAOA1 /
GKAOA1
F388
GKAM1B
/GKAM1X /
GKAM1X
F310
FRRO1O
/GFBSX /
/FBSXCX /
FWDBCK
GFBS
/FRROO1 /
FRROO1
A5BO
CXFBS
/FRROO2 /
FRROO2
A1E8
FRRO1C
ADO
SSG2C
SADO
/SDCCSP /
/SCFACT /
/SADOX /
/ADOX /
ADOXX
GENVEC
TIMEEQ
FINDC
COCOMP
CTRNSP
COM12
CXLOOP
/FRROC1 /
/SSGC2 /
FRROC1
10A10
10A18
SCDCMP
CXWRT
CXUNPK
/FRROC2 /
/FRROC3 /
FRROC2
DFA0
DF98
SORT
/SETUP /
MTRXIN
/MTRXXX /
MTRXXX
C4B8
BMG
BISRCH
BMGTNS
GMMATO
/BMGZZZ /
D4E0

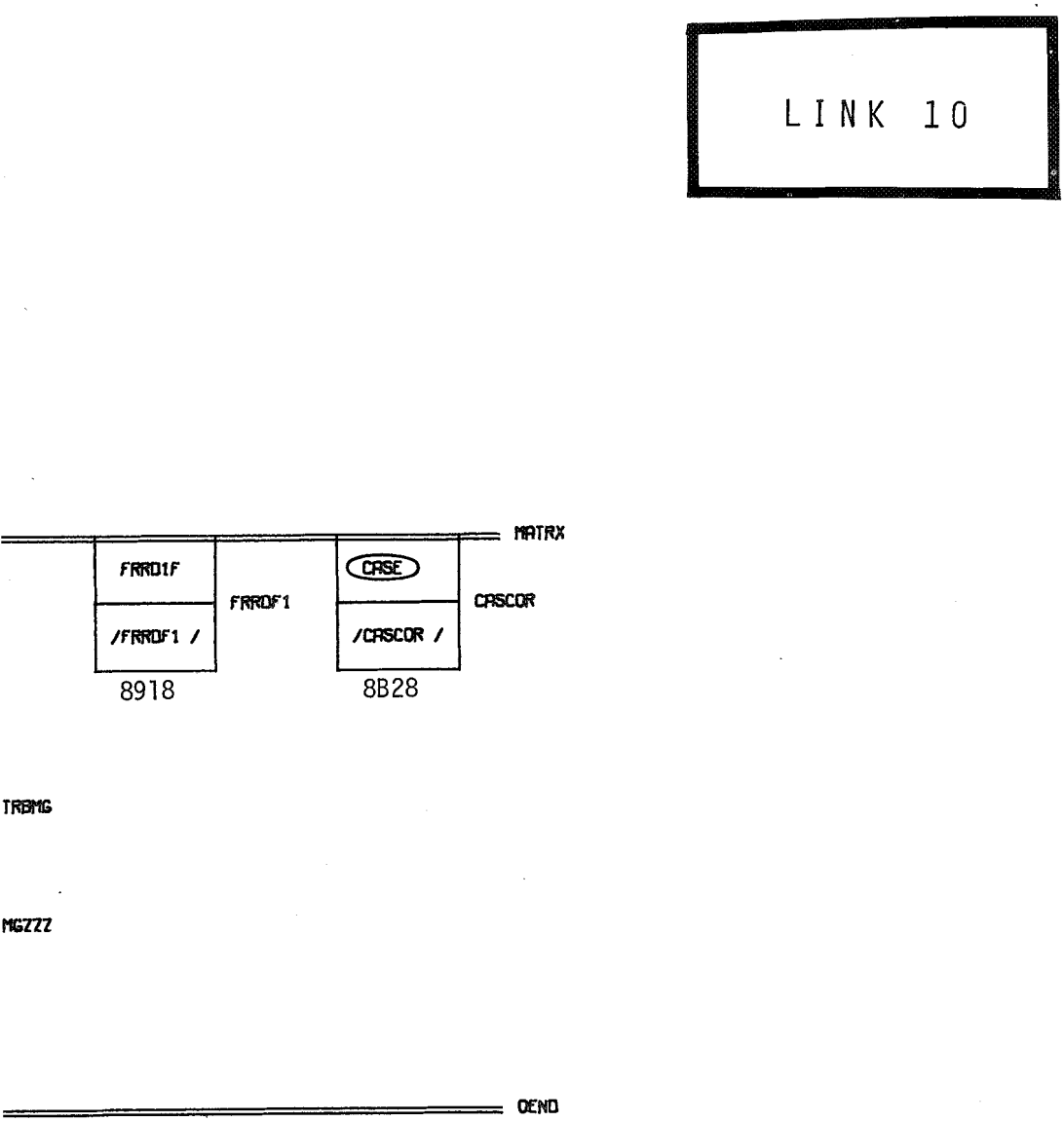


Figure 13. Overlay Structure for Link 10 on the IBM 360-370.

REGION

/CERO1X /
8410

/TRO1X /
8410

MSGWRT
USRMSG

BTSTRP
ENDSYS
/ENDSSS /
9DC0
ENDSSS

QPARAM

XSAVE

PAGE
XCEI

XCHK

GNFIST
RPORBO
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
13ED0
13BB0
ESFA

TABPT
TABERT
MATPRN
MATDUM
/TABPRX /
A070
TABPRX

CERO
/CINVPX /

REGION

LINK 11

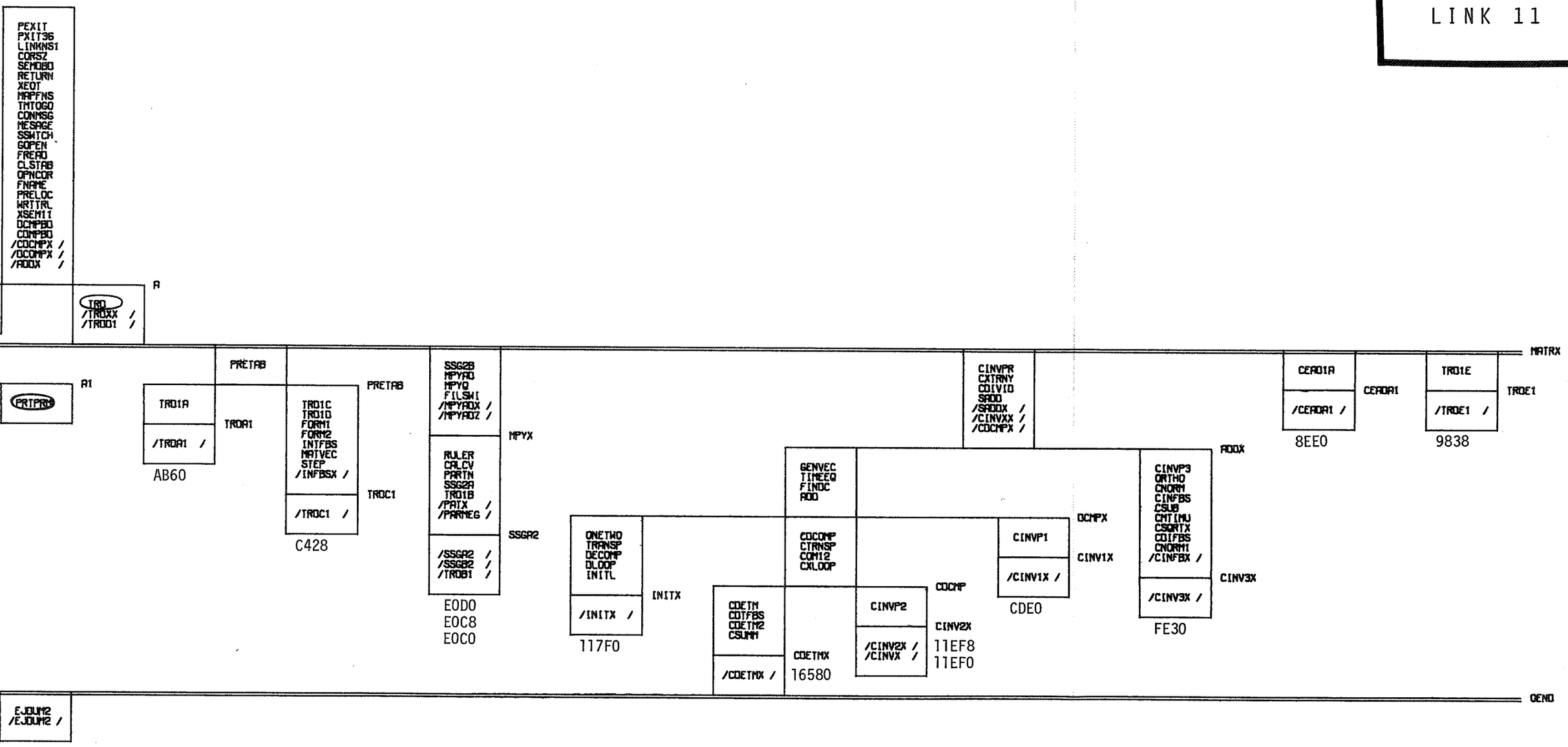
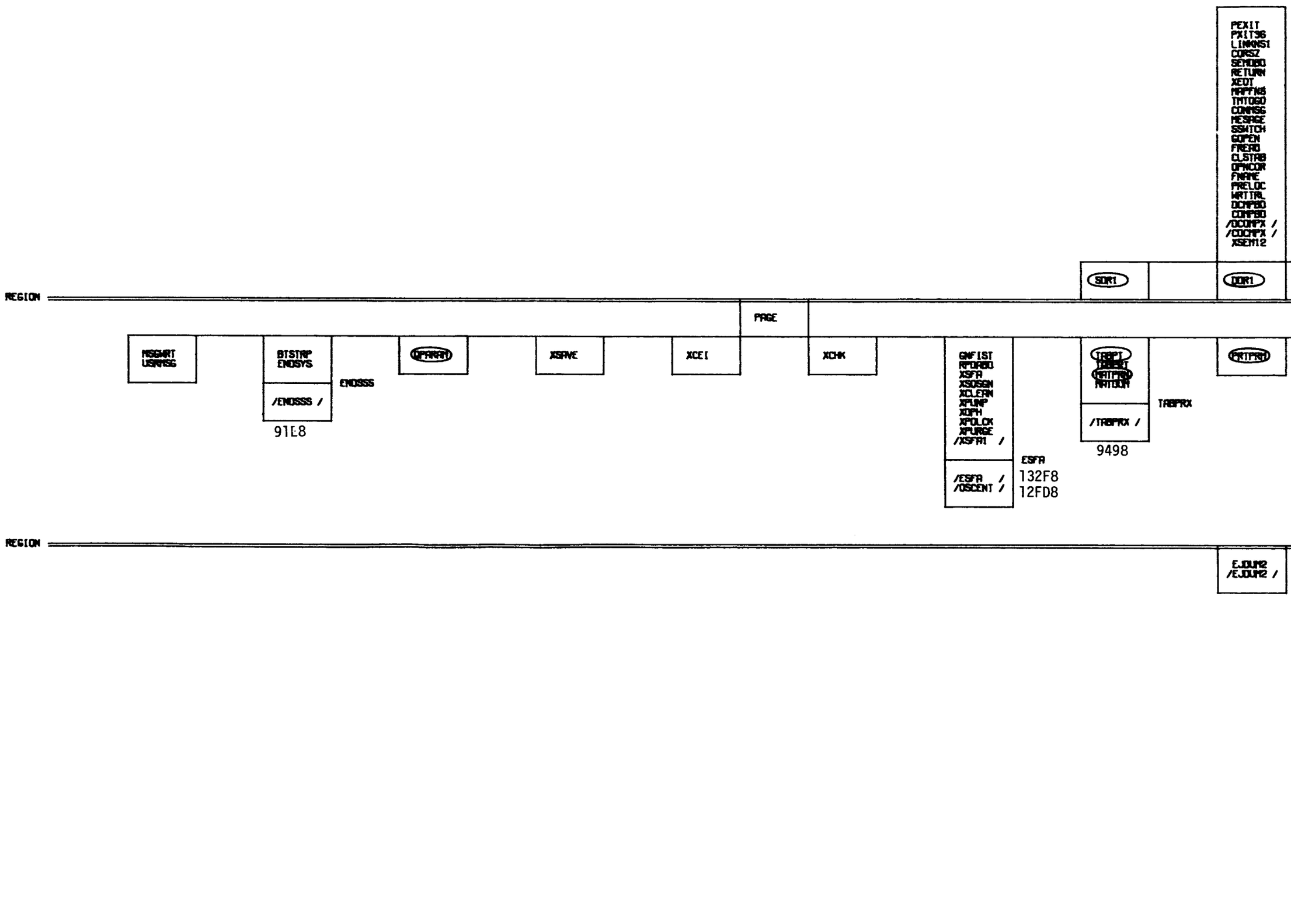


Figure 14. Overlay Structure for Link 11 on the IBM 360-370.


PEXIT
PXITS6
LINKNS1
CORSZ
SEMOBO
RETURN
XEDT
MAPFNS
TMTOSO
CONMSG
MESAGE
SSWITCH
GOPEN
FREAD
CLSTAB
OPNCOR
FWAPE
FRELOC
WRTTAL
DCMPSO
COMPSO
/DCOMPX /
/COCMPX /
XSEM12
SDR1
DDR1
REGION
PAGE
MSGMRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
ENDSSS
91E8
DPARRT
XSAVE
XCEI
XCHK
GNFLIST
RMDABO
XSFA
XSOSGN
XCLEAN
XPUMP
XOPN
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
ESFA
132F8
12FD8
TRBPT
TRBRT
TRTPRO
RATOUT
/TRBPRX /
TRBPRX
9498
PRTPRO
REGION
EJOUM2
/EJOUM2 /

LINK 12

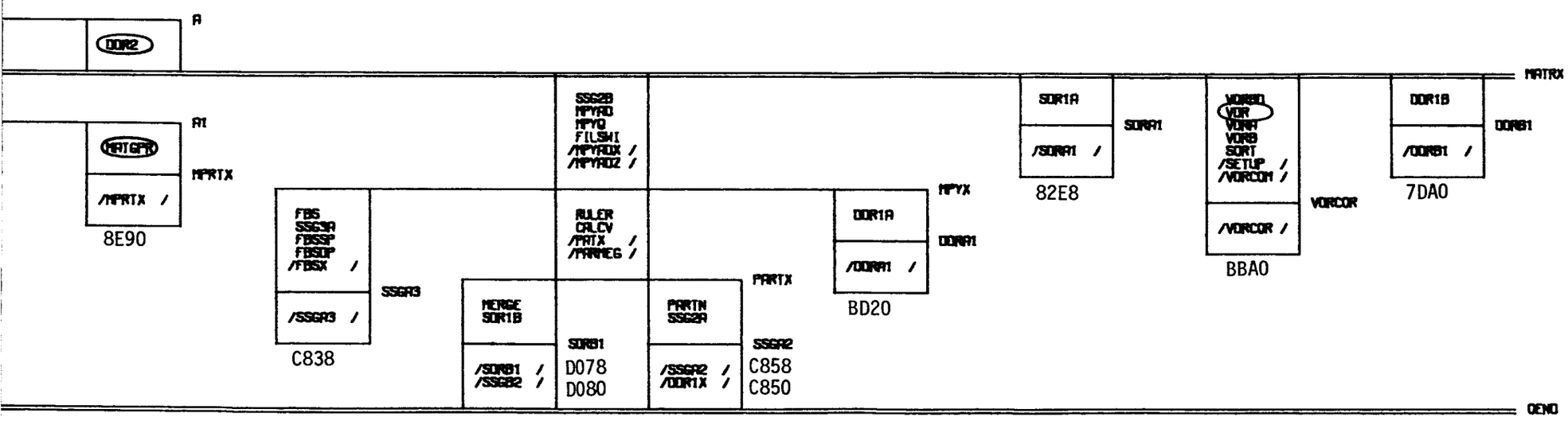


Figure 15. Overlay Structure for Link 12 on the IBM 360-370.

REGION

MSGWRT
USRMSG

BTSTRP
ENDSYS

/ENDSSS /

ENDSSS

A598

QPARAM

XSAVE

PAGE

XCEI

XCHK

GNFIST
RPDABD
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
XPOLCK
XPURGE
/XSFA1 /

/ESFA /
/OSCENT /

ESFA

146A8
14388

TABPT
TABPRT
MATPRN
MATDUM

/TABPRX /

TABPRX

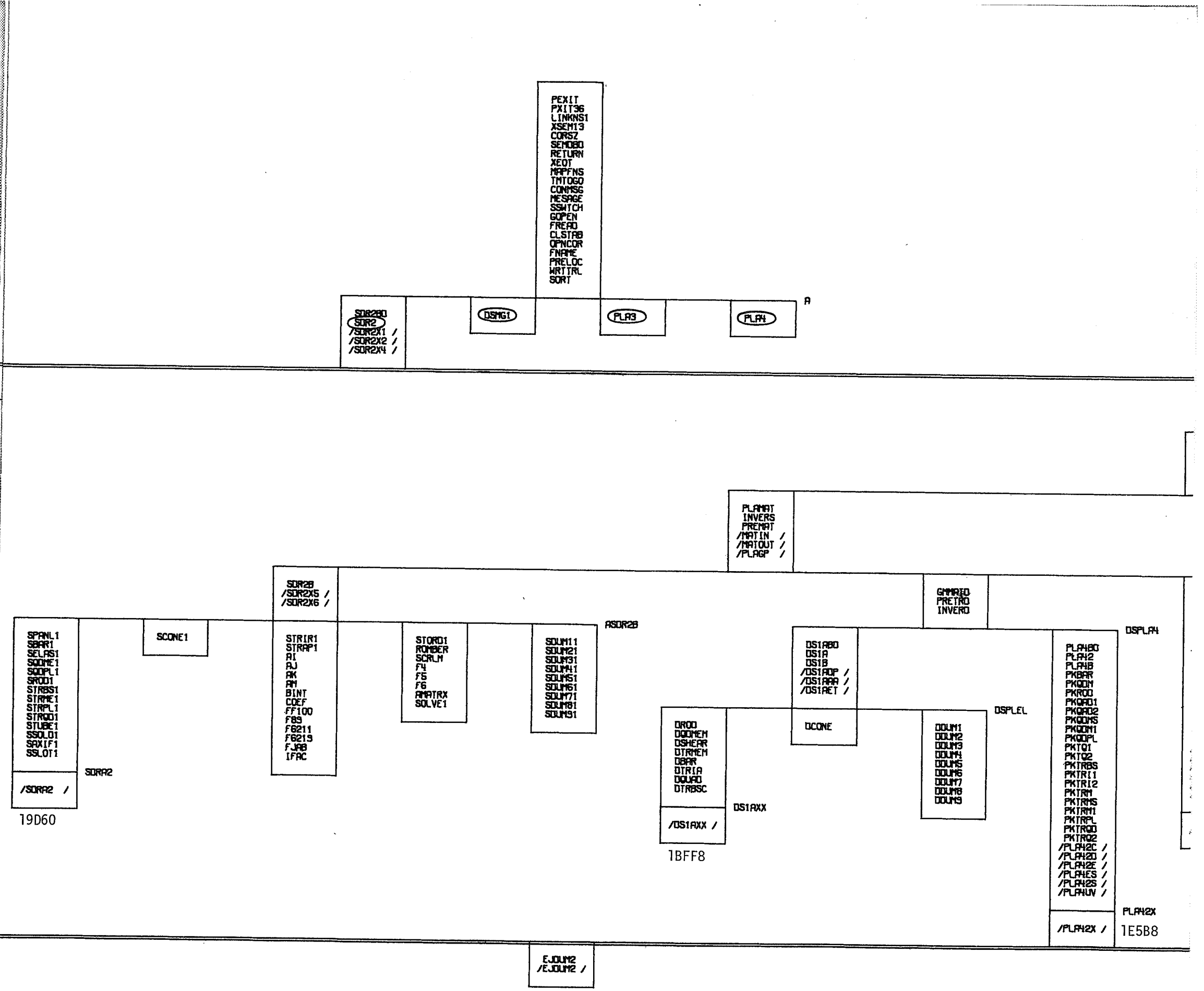
A848

PRTPRM

A1

SDR2AA
SDR2A
/SETUP /

REGION


PEXIT
PXIT36
LINKNS1
XSEM13
CORSZ
SEMOBO
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
SORT
SDR2BO
SDR2
/SDR2X1 /
/SDR2X2 /
/SDR2X4 /
DSMG1
PLA3
PLA4
A
PLAMAT
INVERS
PREMAT
/MATIN /
/MATOUT /
/PLAGP /
SDR2B
/SDR2X5 /
/SDR2X6 /
GMMAIO
PRETRO
INVERO
SPANL1
SBAR1
SELAS1
SQDME1
SQDPL1
SROD1
STRBS1
STRME1
STRPL1
STRQD1
STUBE1
SSOLD1
SAXIF1
SSLOT1
/SDRA2 /
SDRA2
19D60
SCONE1
STRIR1
STRAP1
AI
AJ
AK
AM
BINT
COEF
FF100
F89
F6211
F6213
FJAB
IFAC
STORD1
ROMBER
SCALM
F4
F5
F6
AMATRX
SOLVE1
SDUM11
SDUM21
SDUM31
SDUM41
SDUM51
SDUM61
SDUM71
SDUM81
SDUM91
ASDR2B
DS1ABO
DS1A
DS1B
/DS1AOP /
/DS1AAA /
/DS1AET /
DCONE
DROD
DQOMEM
DSHEAR
DTRMEM
DBAR
DTRIA
DQUAD
DTRBSC
/DS1AXX /
DS1AXX
1BFF8
DSPLEL
DDUM1
DDUM2
DDUM3
DDUM4
DDUM5
DDUM6
DDUM7
DDUM8
DDUM9
DSPLA4
PLA4BO
PLA42
PLA4B
PKBAR
PKQDM
PKROD
PKQAD1
PKQAD2
PKQDMS
PKQDM1
PKQDPL
PKTQ1
PKTQ2
PKTRBS
PKTRI1
PKTRI2
PKTRM
PKTRMS
PKTRM1
PKTRPL
PKTRQD
PKTRQ2
/PLA42C /
/PLA42D /
/PLA42E /
/PLA4ES /
/PLA42S /
/PLA4UV /
/PLA42X /
PLA42X
1E5B8
EJDUM2
/EJDUM2 /

GPTA80
DELSET
/GPTA1 /

PLA2
/PLA2X /
PLA2X
93A8

PLA31
/PLA31X /
PLA31X
9600

PRETRS
GMMATS
SAXB
SADOTB

DS1
BISRCH
/DS1X /
DS1X
SDR2X
BFA8

A3

SDR2C
/SDRC2 /
SDRC2
DB80

SDR2E
SDR2D
MAGPHA
SDRETD
/SDRETT /
/SDR2DE /
/SDR2X7 /
/SDR2X8 /

A4

PLA32
PSROD
PSBAR
PSODM
PSOAD1
PSOAD2
PSODM1
PSOPL1
PSTPL1
PSTQ1
PSTQ2
PSTRB1
PSTRI1
PSTRI2
PSTRM
PSTRM1
PSTRQ2
/PLA32C /
/PLA32E /
/PLA3ES /
/PLA32S /
/PLA3UV /
/SOUT /
PLA32X
/PLA32X /
1A150

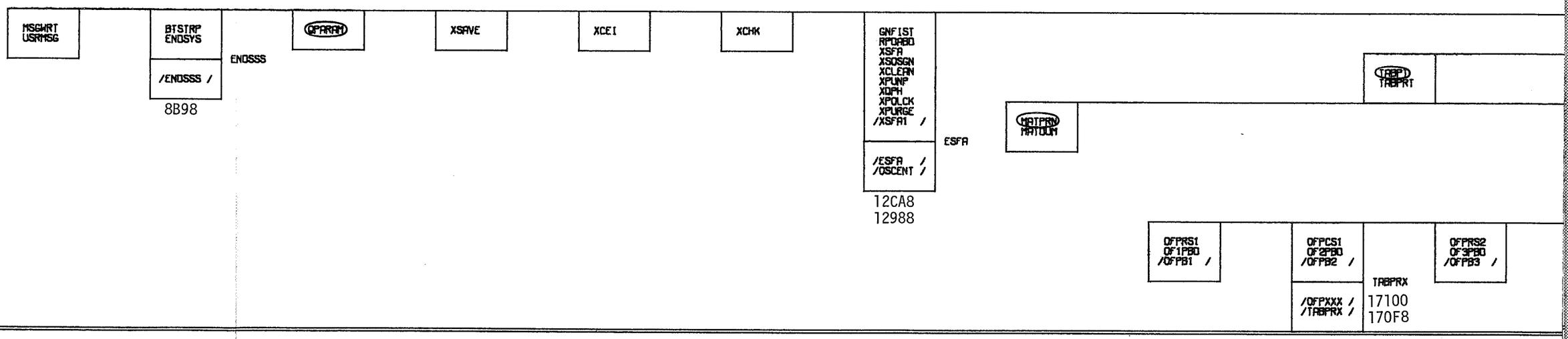
SSOLD2
SAXIF2
SSLOT2
SBAR2
SBSPL2
SELAS2
SPANL2
SROD2
STONE2
STROD2
SDR2XX
/SDR2XX /
12FF8

SCONE2
SCONE3

STORD2
STRAP2
STRIR2

ASDR2E
SDUM12
SDUM22
SDUM32
SDUM42
SDUM52
SDUM62
SDUM72
SDUM82
SDUM92

Figure 16. Overlay Structure for Link 13 on the IBM 360-370.


MSGWRT
USRMSG
BTSTRP
ENDSYS
/ENDSSS /
ENDSSS
8B98
QPARAM
XSAVE
XCEI
XCHK
GNFIST
RPQABD
XSFA
XSOSGN
XCLEAN
XPUNP
XQPH
XPOLCK
XPURGE
/XSFA1 /
/ESFA /
/OSCENT /
ESFA
12CA8
12988
TABPT
TABPRT
MATPRN
MATDUM
OFPRS1
OF1PBD
/OFPB1 /
OFPCS1
OF2PBD
/OFPB2 /
/OFPXXX /
/TABPRX /
TABPRX
17100
170F8
OFPRS2
OF3PBD
/OFPB3 /
REGION

PAGE
TAPBIT

SQR3

PRTPRM

SQR3A

/SQR3ZZ /

A2

SQR3ZZ

93E0

SQR1
XYTRAN
/SETUP /
/XYWORK /

XYPRPL
XYCHAR
XYGRAF
/XYPPPP /

TABPTX

OFP
OFPPUN
OFP1
OFP1A
OFP1BD
OFPSBD
/OFPBD1 /
/OFPBD5 /
/OFPCOM /

OFP

OFPCS2
OF4PBD
/OFPB4 /

OFPRF1
OF5PBD
/OFPB5 /

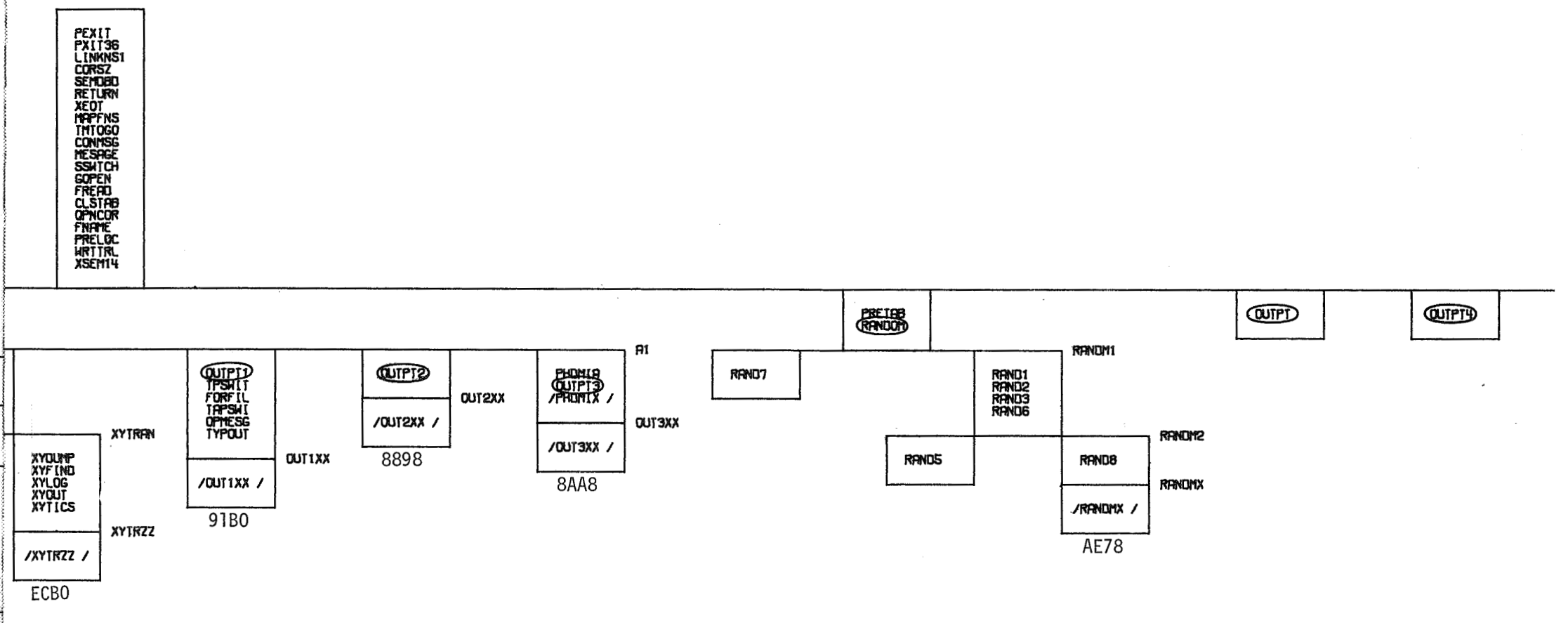
OFPCF1
OF6PBD
/OFPB6 /

OFPRF2
OF7PBD
/OFPB7 /

OFPCF2
OF8PBD
/OFPB8 /

OFPMIS
OF9PBD
/OFPB9 /

EJOUM2
/EJOUM2 /


PEXIT
PXIT36
LINKNS1
CORSZ
SEMOBD
RETURN
XEOT
MAPFNS
TMTOGO
CONMSG
MESAGE
SSWTCH
GOPEN
FREAD
CLSTAB
OPNCOR
FNAME
PRELOC
WRTTRL
XSEM14
PREIOB
RANDOM
OUTPT
OUTPT4
XYTRAN
XYOUMP
XYFIND
XYLOG
XYOUT
XYTICS
/XYTRZZ /
XYTRZZ
ECB0
OUTPT1
TPSWIT
FORFIL
TAPSWI
OPMESG
TYPOUT
/OUT1XX /
OUT1XX
91B0
OUTPT2
/OUT2XX /
OUT2XX
8898
PHONIO
OUTPT3
/PHONIX /
/OUT3XX /
OUT3XX
8AA8
A1
RAND7
RANDM1
RAND1
RAND2
RAND3
RAND6
RAND5
RAND8
RANDM2
/RANDMX /
RANDMX
AE78

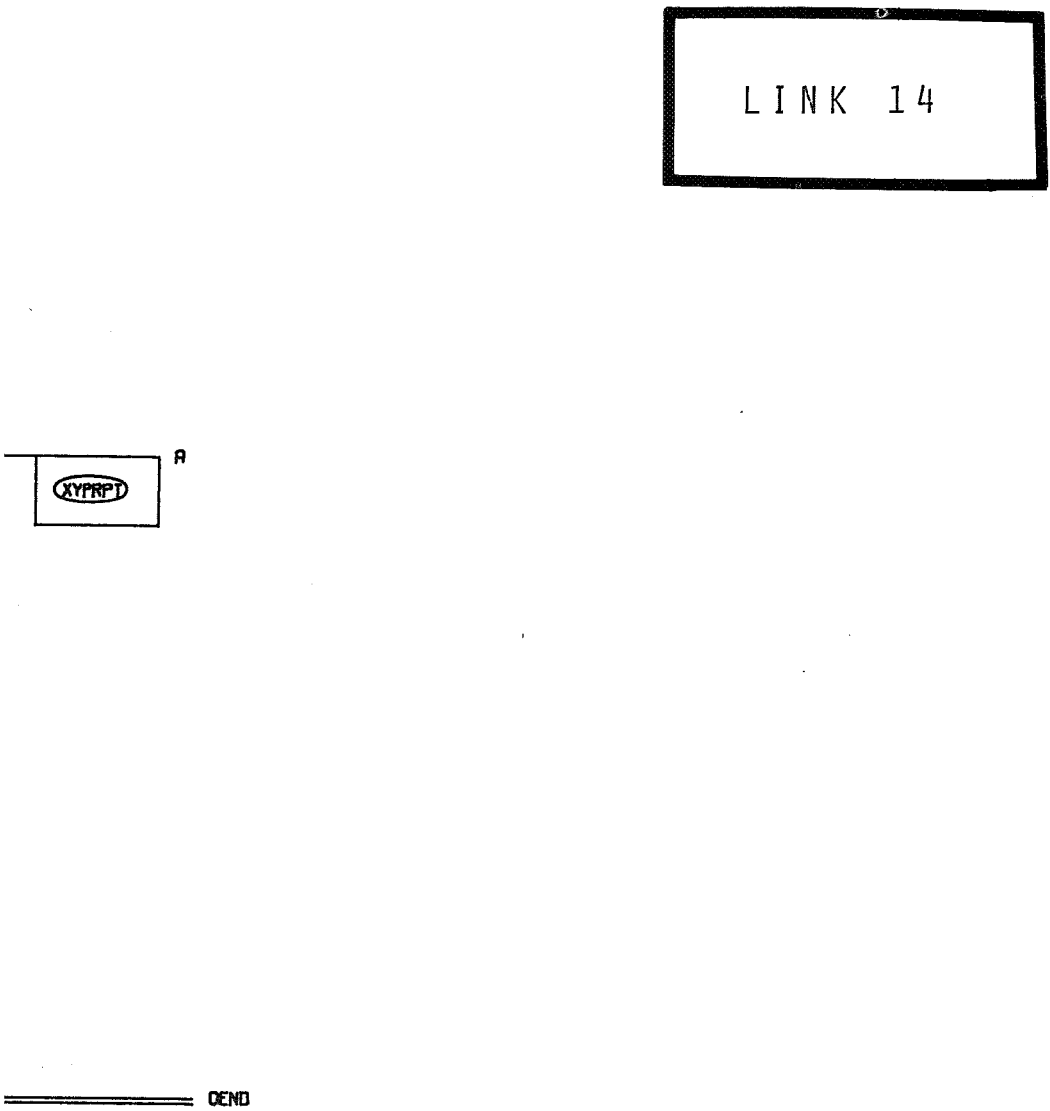


Figure 17. Overlay Structure for Link 14 on the IBM 360-370.

5.4 NASTRAN ON THE UNIVAC 1108 (EXEC 8)

5.4.1 Introduction

The purpose of this section is to describe the unique operating features of NASTRAN on the UNIVAC 1108 computer under the Exec 8 operating system.

This section contains much material of interest to both the serious user of NASTRAN and the support programmer. Of particular interest to the user are the following sections:

Number	User
5.4.2	Mass storage estimates and maximum file sizes.
5.4.4	Control of open core sizes and the generation of smaller NASTRAN's.
5.4.5	Execution deck set-ups.
5.4.9.3	Catalog the executable procedure (or copy in each time).
5.4.12	External names of user tapes (ØPTP, NPTP, PLT2, etc.).
5.4.14	Description of the UMF runs.
5.4.15	UMF times and problem numbers for the demonstration problems.
5.4.18	1108 time estimation.

The choice of Exec 8 over Exec II as the 1108 Executive System was made due to the added flexibility obtainable in the control language. The size and complexity of the NASTRAN system necessitates the use of a system allowing open-ended expansion.

Much of the final checkout and validation of NASTRAN was done under Exec 8. The use of catalogued files for the source, object, and absolute program files simplified the task of modifying and updating the NASTRAN system.

NASTRAN operates as a single job on UNIVAC 1108 computers under Exec 8. NASTRAN is created as 14 separate absolute programs, with each program containing the structure and content of a NASTRAN link. These links are executed serially (usually) by the use of 'XQT' cards.

5.4.2 Input/Output

The machine dependent I/Ø routines in NASTRAN can be classified into three categories: 1) obtaining the logical files, 2) performing the actual I/Ø (other than plot output), and 3) generating the plot tapes.

GNFIAT is the subroutine responsible for identifying the logical files available for use by NASTRAN. For the UNIVAC 1108, it is written in FØRTRAN. Its functional description can be found in Section 3. Under Exec 8, GNFIAT operates in conjunction with the system routine NTAB$. NTAB$ was reassembled for NASTRAN to allow access to logical units 1-40. Correspondingly, a table is generated in GNFIAT to indicate the status of each of these units. The status code of 1 implies the unit is unconditionally available for insertion into the FIAT Executive Table. A code of 2 means the unit can be used if it is not set up as a tape. A status code of 3 means the unit is unavailable for the FIAT, but is available for XFIAT. A status code of 4 means the unit is not to be assigned by NASTRAN. Any units with status codes of 1, 2, or 3 will be dynamically assigned by NASTRAN unless they have been previously assigned by user-supplied assign cards. GNFIAT searches this table and inserts the available logical units into the FIAT.

The following table indicates the status of the 40 units:

FØRTRAN Unit No.	Status Code	External Name
1	4	None
2	3	2
3	1	3
4	1	4
5	4	None (Input File)
6	4	None (Print File)
7	3	PØØL
8	3	ØPTP
9	3	NPTP
10	2	UMF
11	2	NUMF
12	3	PLT1
13	3	PLT2
14	2	INPT
15	2	INPT1
16	2	INPT2
17	2	INPT3
18	2	INPT4

FØRTRAN Unit No.	Status Code	External Name
19	2	INPT5
20	2	INPT6
21	2	INPT7
22	2	INPT8
23	2	INPT9
24	1	24
25	1	25
26	1	26
27	1	27
28	1	28
29	1	29
30	1	30
31	1	31
32	1	32
33	1	33
34	1	34
35	1	35
36	1	36
37	1	37
38	1	38
39	1	39

FØRTRAN unit numbers 7 through 23 are attached to their external names by the use of @USE cards which are added internally. Note that this requires assignments be made by the external name, rather than the FØRTRAN unit number, as was done in the past. Dynamic assigns for all units not assigned by the user (up to MAXFIL units (System (29)) will be of the following form @ASG,T XX,F17//PØS/30. This assign card allows a maximum of 2,000 tracks, or approximately 3,500,000 words, for each file. The F17 requests mass storage as available from first FH1782's, second FH880's, and third FASTRAND model II. PØS requests that 64 contiguous tracks be assigned at once. 30 will terminate the run if more than 30 x 64 tracks of data are written on any one file.

In addition to the expanded NTAB$, NTRAN$ was assembled with the number of packets increased to 30. This was necessary, due to the number of files used in NASTRAN at any one time.

The actual I/Ø on the UNIVAC 1108 is controlled through a blocked I/Ø package, consisting of GINØ and its associated routines. The physical I/Ø directives are restricted to GINØIØ. Physical records of size BUFFSIZE-3 (System (1)) words are written on all units. BUFFSIZE is currently set to 871. Under Exec 8, NTRAN is used exclusively for I/Ø. The reader should consult the subroutine descriptions for GINØ and GINØIØ in Section 3 for more information.

The final I/Ø dependent routine is SGINØ, whose responsibility is to generate the unformatted BCD and binary tapes for the plotters. The restriction in SGINØ is that the output records must be free of any NASTRAN or system control words. NTRAN satisfies these requirements and is used to perform the I/Ø.

5.4.3 Link Switching

A link on the UNIVAC 1108 consists of a main program, MAINi, that calls subroutine XSEMi, which in turn has calls to the subroutines corresponding to the modules residing in that link. Thus, a link is, in itself, a complete executable program.

The problem of link switching reduces to the problem of selectively controlling the execution of the various programs (links). This is accomplished under Exec 8 by virtue of the TEST control card and by the executive request (ER) SETC$.

The option to either execute or skip a link is achieved by the following two system control cards:

```
@TEST                TNE/i/S6
@XQT                 *NASTRAN.LINKi
```

The right sixth of the condition word which is tested by the TEST command is set by an ER to SET$. By setting this sixth of the word to the value i, LINKi will be executed. If the value of the word is not i, the XQT instruction will be skipped.

A packet of these control cards consisting of TEST and XQT cards for each link gives the user the flexibility he desires. However, due to the capability of looping in NASTRAN, many of these packets are usually put on a catalogued file such that one ADD card can redirect the control card stream to the proper file. Two such packets are supplied with the Level 15 NASTRAN: CØNTRL,

which results in a NASTRAN user region of 65K decimal words and CØNTRL 42K, which results in a NASTRAN user region of 42K decimal words.

The above description gives the external controls required for link switching. Internally, NASTRAN uses subroutines ENDSYS and SEARCH to direct the link switch. Their functional descriptions can be found in Section 3. ENDSYS is used mainly for saving information required across links. SEARCH, however, is the routine which controls the link switch. Under EXEC 8, this consists simply of setting the condition word to the value of the desired link, and terminating the execution of the current link. SEARCH on the 1108 will also free (after link one) the UMF, the NUMF, or the ØPTP if they are assigned to tape.

Upon initiation of a new link, BGNSYS is called to restore previous information. An additional function of BGNSYS on the UNIVAC 1108, controlled by a branch on machine type, is to restore drum pointers for all files off the load point. Since GINØ maintains a table of file positions, this table can be used to update the system drum pointers.

5.4.4 Overlay Considerations and Implementation of Open Core

The complex nature of the NASTRAN overlay picture and the pecularities of the Exec 8 loader pose some special problems on the 1108. The loader under Exec 8 is a "block" or "segment" loader. A segment is loaded only when a subroutine within that segment is called. Also, when a segment is loaded, local data and common blocks are set to zero.

The implications of these features of the loader can be seen in the following overlay example, given in Table 1 and Figure 1. If common block /XX/ is initialized by the Block Data subprogram E, and subroutine A calls D directly, then D cannot reference the data in /XX/, since that segment has not been loaded. Also, if subroutine A stores data in /YY/, and subsequently calls subroutine C, /YY/ will be reset to zero as it is loaded.

As seen in Table 1 and Figure 1, some common blocks will have to be repositioned higher (in lower order core) in the overlay on the UNIVAC 1108 than on the IBM 360 or CDC 6600 to protect NASTRAN from the loader.

The implementation of open core on the UNIVAC 1108 consists of defining a common block (/DFCØR/) in subroutine DEFCØR and using the executive request (ER) to MCØRE$ to reserve core from the first cell of the common block to 177770_8. This will define a 65K NASTRAN system. Smaller NASTRAN versions can be defined by shortening the length of open core as follows:

Table 1. Example of Input to the MAP Processor for a NASTRAN Overlay on the UNIVAC 1108.

@MAP,1	Sample
SEG	AA
IN	A
SEG	BB*,AA
IN	B,XX
SEG	CC*,BB
IN	C,YY
SEG	DD*,(CC)
IN	D
SEG	CORE*,BB
IN	DEFCØR,DFCØR

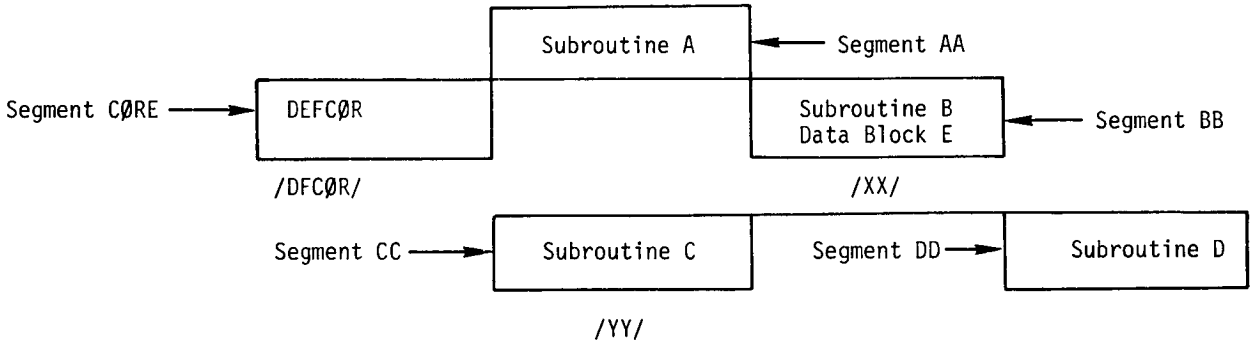


Figure 1. Example of NASTRAN Overlay on the UNIVAC 1108

Open core can be shortened by two methods: (1) The number 177770_8 in subroutine ZCØRSZ (MPAFNS) can be changed to a smaller number with 40K being the minimum. This method requires regenerating all the absolute elements. (2) Options can be added to the XQT cards. The options will turn bits on corresponding to the letter in the alphabet (i.e., A = 26^{th} bit - Z = 0^{th} bit) in a word. This word will then be subtracted from the number 177770_8 in subroutine ZCØRSZ before the ER to MCØRE$. Execute cards of the form @XQT,LM will make NASTRAN approximately 42K in length.

5.4.5 Execution Deck Set-Up

The following table gives a typical deck set-up for NASTRAN on the 1108.

Table 2. Execution Deck Set-Up for NASTRAN on the UNIVAC 1108

```
@RUN                                                          001
@ASG,T     2,F//PØS/30                                        002
@ASG,T     3,F//PØS/30                                        003
@ASG,T     4,F//PØS/30                                        004
@ASG,T     PØØL,F//PØS/30              . PØØL                 005
@ASG,T     ØPTP,F//PØS/30              . ØPTP                 006
@ASG,T     NPTP,F//PØS/30              . NPTP                 007
@ASG,T     UMF,F//PØS/30               . UMF                  008
@ASG,T     NUMF,F//PØS/30              . NUMF                 009
@ASG,T     PLT1,F//PØS/30              . PLT1                 010
@ASG,T     PLT2,F//PØS/30              . PLT2                 011
@ASG,T     INPT,F//PØS/30                                     012
   .          .                                                .
   .          .                                                .
   .          .                                                .
@ASG,T     39,F//PØS/30                                       037
@HDG,N                                                        038
@XQT       *NASTRAN.LINK1                                     039
NASTRAN DATA DECKS (Executive Control Deck, Case
                    Control Deck, Bulk Data Deck)
@TEST      TNE/1/S6                                           040
@XQT       *NASTRAN.LINK1                                     041
@TEST      TNE/2/S6                                           042
@XQT       *NASTRAN.LINK2                                     043
   .          .                                                .
   .          .                                                .
   .          .                                                .
@TEST      TNE/14/S6                                          052
@XQT       *NASTRAN.LINK12                                    053
@TEST      TNE/17/S6                                          054
@JUMP      END                                                055
@END:PMD,EB                                                   056
```

The following comments explain particular cards or groups of cards:

1. Card 001 consists of the standard RUN card required by the installation.
2. Cards 002-037 assign the logical files to FASTRAND or some other auxiliary storage device. These assign cards allow a maximum of 2,000 tracks or approximately 3,500,000 words for each file. This assignment can vary per run or per device used.
3. Cards 005-011 have a dual usage and can be used as user tapes. If a checkpoint is required, then card 007 must be replaced with

   @ASG,T NPTP,T,TAPE#
4. Depending upon the devices available, the assign cards can reference FASTRAND, drum, disk, or tape.
5. Card 038 turns off the standard system heading.
6. Card 039 initiates execution of LINK1.
7. The NASTRAN data decks are inserted between cards 039 and 040.
8. Cards 040 to 050 constitute a packet of NASTRAN control cards. Many of these packets may be required for one run.
9. For user convenience, 002-037 are automatically generated by NASTRAN, except for any assignment supplied by the user (usually just tapes). Cards 038-039 can be catalogued as the file ASGCRDS, and 100 packets of the cards 040-056 can be catalogued as the file CØNTRL (or the file CØNTRL42K for the same cards, but with the L and M option on the XQT cards).

The execution deck set-up can then consist of:

```
@RUN                                    @ASG (option tape assignment)
@ADD     ASGCRDS .
 NASTRAN DATA CARDS
@ADD     CØNTRL .    or                 @ADD  CØNTRL42K. (for smaller NASTRAN)
@FIN
```

5.4.6 Description of NASTRAN Physical Items and Generation of the NASTRAN Executable System

1. Symbolic Tape

This physical item includes a physical tape and an element list (TØC). The UNIVAC 1108 NASTRAN source library tape consists of a 2-file, 800-BPI tape containing approximately 900 separate symbolic elements in FUR/PUR format. The elements are ordered on the tape alphabetically. The element names and the order are shown on the element list. File 1 consists of the machine independent decks. File 2 consists of the 1108 machine dependent decks.

2. Relocatable and Demonstration Problem Tape

This physical item includes a physical tape and an element list (TØC). The tape is a two-file, 800-BPI tape in FUR/PUR format which contains the relocatable elements from the source compiles, 14 symbolic MAP decks, and FØRTRAN source of locally modified decks. The MAP decks were placed on the relocatable tape, so that an executable tape could be generated with just the relocatable tape file catalogued. The names and order of the relocatable elements are shown on the element list. File 1 consists of the relocatable elements from the machine independent and dependent libraries. File 2 contains run setups for executing demonstration problems.

There are 50 NASTRAN demonstration problem decks. They have been set up with all the control cards including the "RUN" card necessary to run the demonstration problems on the UNIVAC 1108 Exec 8. A description of one of the decks is shown in Section 5.4.14. In addition to being necessary for running the demonstration problems, they are useful as sample problem decks for new NASTRAN users.

3. Executable and UMF Tape

This physical item is a five-file, 800-BPI tape in FUR/PUR format. The first file contains the NASTRAN executable elements or absolute program, and the executable program for PRTVEC. The second file contains a program file called ASGCRDS., the third file contains a program file called CØNTRL., the fourth file contains a program file called CØNTRL42K, and the fifth file is the User Master File (UMF).

The NASTRAN absolute program consists of 14 executable elements. These elements appear to the UNIVAC 1108 Exec 8 system as 14 separate programs. The execution sequence of these programs, for any problem, is controlled by the file CØNTRL. or CØNTRL42K.

The file ASGCRDS is a control card file which contains the control card to turn off the system heading and the control card to execute the first executable element. This file as well as the CØNTRL file are described in more detail in Sections 5.4.12 and 5.4.13, respectively.

The UMF file must be copied to another tape as the only file. This single file is used to store NASTRAN Bulk Data Decks so that the input card deck will be smaller. Each UMF tape has a tape and problem number associated with each Bulk Data Deck; the numbers are used by NASTRAN to retrieve the appropriate deck. The UMF tape file delivered contains the Bulk Data Deck for the NASTRAN demonstration problems. The tape and problem numbers are given in Section 5.4.15. The BUFFSIZE used to generate this tape was 871 (the default value).

4. Sample Utility Procedure Deck

This physical item includes a family of sample decks (procedures) which have been used during the NASTRAN project. Included are decks to:

a. Copy the four system tapes (see Section 5.4.8).

b. Catalogue the source, relocatable, and executable tapes (see Section 5.4.9).

c. Update the system (see Section 5.4.10).

d. Regenerate the executable tape (see Section 5.4.11).

The tape copy procedure should be used to provide backup copies of the NASTRAN tapes delivered.

The catalogue procedures should be used when doing system maintenance. In addition, the catalogue procedure for the executable tape must be used before running a NASTRAN problem.

The update shows one way of setting up a compile and executable regeneration for system maintenance or temporary check out of updates.

The deck to regenerate the executable tape contains the cards necessary to make a new executable tape from the relocatable tape.

5.4.7 Machine Dependent Routines

The routines discussed in this section consist of those programs unique to the UNIVAC 1108 or those which are implemented differently from other machines. The language for each deck is indicated by an F (FØRTRAN) or S (SLEUTH) following the deck name. GINØ is discussed in Section 5.4.16, matrix packing is discussed in Section 5.4.17, and single precision decks are discussed in Section 5.4.18.

1. MAINi (F)

   MAINi is the main program for LINKi. Its sole function is to call DEFCØR and XSEMi.

2. DEFCØR (F)

   DEFCØR is responsible for calling ZCØRSZ to reserve core for NASTRAN. The last location of this segment is saved as the end of open core.

3. MAPFNS (S)

   In addition to the standard functions described in Section 3, the following functions were added:

   a. SETC(I) - Sets the condition word to I.

   b. FACIL(UNIT,ID) - Sets ID = 0 if UNIT is assigned to FASTRAND.
      Sets ID = 1 if UNIT is assigned as a tape.
      Sets ID = 2 if UNIT is not assigned.

   c. XDATE(DATE) - Return the date in a four-word array DATE.
      DATE(1) = MONTH
      DATE(2) = DAY
      DATE(3) = YEAR
      DATE(4) = time in elapsed wall clock seconds from midnight

   d. ZCØRSZ(X(1),LENGTH) - Reserves core between X(1) and the 65K (less if options on the XQT card are used) and return the length in LENGTH.

   e. SEC(t) - Return CPU time used in T.

   f. LOGFIL(I(1),WØRDS) - Writes the number of words in WØRDS starting with I(1) on the run log file.

   g. ELAPSE(T) - Return in T the wall clock time used.

   h. TSWAP(ID) - Unloads a unit (ID) and mounts another tape on that unit.

i. ADDCRD(IMAGE,LENGTH) - Add a control card image of length LENGTH to the control stream.

j. CØM(IMAGE,LENGTH) - Type an image of length LENGTH on the operator console.

k. ZCØRSZ - Perform the function of CØRSZ.

4. UTIL (F)

a. SECØND(T) - Returns the CPU time in floating point seconds by calling SEC.

b. TDATE(II) - Returns the date in the first three words of II and zero in the fourth word of II by calling XDATE. It also initializes STIME (SYSTEM(32)) to the elapsed wall clock seconds from midnight.

c. KLØCK(I) - Returns the current CPU time used in integer seconds.

d. CONMSG(IX,IY,IZ) - Writes a message of length IY words from the first IY words of IX. This message is displayed on the operator's console if IZ $\neq$ 0 (controlled by DIAG 5 and 6). The messages are normally stored in the log file. The number of messages previously written is accumulated in SYSTEM (7). If SYSTEM (7) > 100, messages are included into the normal print file.

e. XTRACE - Is a print routine for a trace back routine.

f. WALTIM(I) - Returns the elapsed wall clock seconds from midnight.

5. XEØT (F)

XEØT causes reels to be swapped for multireel old and new problem tapes.

6. NTRAN$ (S)

NTRAN$ is a standard 1108 NTRAN reassembled to include 30 packets. NTRAN$ varies from Exec 8 release to release. If the NTRAN$ supplied with NASTRAN will not collect without errors, the standard version may be obtained, the number of packets changed to 30, and used.

7. NTAB$ (S)

NTAB$ is a standard 1108 NTAB reassembled to allow up to 40 files.

8. RWUNLD (F)

RWUNLD will, given a GINØ file name for a permanent entry, determine its internal (1108) file name and call TSWAP to switch to another physical reel. It is used by XCHK to manipulate the ØPTP and NPTP and by TPSWIT to manipulate the user tapes (INPT, etc.).

9. TPSWIT (F)

TPSWIT calls RWUNLD to obtain another user tape and prints a message.

10. PEXIT (F)

PEXIT performs normal (machine dependent) termination procedures and also sets the condition code (15) for final termination.

11. SEARCH (F)

SEARCH frees the ØPTP, UMF, and NUMF at the conclusion of LINK1 if these files reside on a tape. In addition, SEARCH sets the condition code for the next link to be executed.

12. SGINØ (F)

SGINØ performs physical I/Ø on the plot tapes (PLT1 and PLT2).

a. SØPEN ($N, PLTTP, BUF, BUFSIZ) - Establishes a buffer for PLTTP of length BUFSIZ at location BUF. It also sets the parity of the file, depending on whether PLTTP = PLT1 or PLT2.

b. SWRITE (PLTTP,A,N,EØR) - Writes N characters from N words starting at A(1) into the plot buffer.

c. SCLØSE (PLTTP) - Flushes the plot buffer, places a physical end-of-file on the plot tape, and backspaces over it.

d. SEØF (PLTTP) - Places a physical end-of-file on PLTTP.

13. CØRSZ (F)

CØRSZ provides for the display of the open core length (on DIAG 13) obtained from the SLEUTH subroutine ZCØRSZ.

14. MPYQ (S)

MPYQ is a SLEUTH deck written to increase the speed of MPYAD's inner loops. The documentation for MPYQ is machine independent, and is in Section 3 as an auxiliary routine to MPYAD.

15. PPDUMP (F)

Supplies entry points DUMP, PDUMP, and PPDUMP.

PPDUMP was to capture control after a guard mode interrupt. This feature never was implemented. DUMP and PDUMP dump open core beyond the allocated limit. DUMP will do this unconditionally and PDUMP will do it if DIAG 1 was set by the user. Note that PDUMP will force a trace back via YTRACE if NO dump is taken. An element dump is given via an illegal computed goto statement to provide a "nicely" formatted dump and a trace back for normal dumps. Since control cannot be recaptured after such dumps, any messages will have to be decoded from common block /MSGX/ by the user.

16. YTRACE (S)

YTRACE provides a walk back trace to XSEMi from the calling routine to aid in subroutine debugging.

5.4.8 Procedure to Copy the Three System Tapes

5.4.8.1 Source Tape

1. Tape assign @ASG statement - assign the input source tape to a tape unit giving its tape number and a file name.

```
@ASG,T SØURCE,T,XXXX
    (file name, to tape, numbers)
```

2. Tape assign @ASG statement - Assign the output source tape giving it a file name and number.

```
@ASG,T NEWSØU,T,XXXX
```

3. Tape copy @CØPY,M statement - Copy the input source files to the output source files.

```
@CØPY,M SØURCE.,NEWSØU.,2
```

4. Free file @FREE statement - Release the input source file from the job stream.

```
@FREE SØURCE
```

5. Free file @FREE statement - Release the output source file.

   @FREE NEWSØU

5.4.8.2 Relocatable and Demonstration Problem Tape

1. Assign the input relocatable tape

   @ASG,T ØBJECT,Txxxxx

2. Assign the output relocatable tape.

   @ASG,T NEWØBJ,T,xxxxx

3. Copy two files from the input tape to the output tape.

   @CØPY,M ØBJECT.,NEWØBJ.,2

4. FREE the input relocatable tape.

   @FREE ØBJECT

5. FREE the output relocatable tape.

   @FREE NEWØBJ

5.4.8.3 Executable and UMF Tape

1. Assign the input executable tape.

   @ASG,T ABSTAP,T,xxxxx

2. Assign the output executable tape.

   @ASG,T NEWABS,T,xxxxx

3. Copy five files from the input tape to the output tape.

   @CØPY,M ABSTAP.,NEWABS.,5

4. Free the input executable tape.

   @FREE ABSTAP

5. Free the output executable tape.

   @FREE NEWABS

5.4.8.4 Demonstration Problem Input Data Tape (UMF)

1. Assign the input executable and UMF tape.

   @ASG,T ABSTAP,T,xxxx

2. Position to the UMF file.

   @MØVE ABSTAP.,7

3. Assign the output UMF tape.

   @ASG,T NEWUMF,T,xxxxx

4. Copy one file from the input UMF to the output UMF tape.

   @CØPY,M ABSTAP.,NEWUMF.

5. Free the input executable and UMF tape.

   @FREE ABSTAP

6. Free the output UMF tape.

   @FREE NEWUMF

5.4.9 NASTRAN Tapes (Files) Catalogue Procedure

5.4.9.1 Source Catalogue Procedure

1. Delete @DELETE statement - Delete a file if it exists, but proceed with the run if it does not exist (C-option).

   @DELETE,C SØU.

      (name to be assigned to the machine independent source FASTRAND file)

   @DELETE,C MDSØU.

      (name to be assigned to the machine dependent source FASTRAND file)

2. Assign a FASTRAND file @ASG statement - Assign a FASTRAND file name for the source elements making it permanently assigned, regardless of the manner of termination of the run (U-option), making it public (P - option), and making it read only (R - option).

   @ASG,UPR SØU,F///1500

      (file name, assign to FASTRAND with 1500 tracks as a maximum size)

   @ASG,UPR MDSØU,F///500

      (file name assign to FASTRAND with 500 tracks as a maximum size)

3. Assign the input source tape.

   @ASG,T SØURCE,T,xxxxx

4. Copy an element file from one unit to another @CØPY statement - Copy the input machine independent and machine dependent source tape to a FASTRAND file.

   @CØPY,G SØURCE.,SØU.

   @CØPY,G SØURCE.,MDSØU.

5. Free the input source tape.

   @FREE SØURCE

5.4.9.2 Relocatable Catalogue Procedure

1. Delete a file if it exists, but proceed with the run if it does not exist.

   @DELETE,C ØBJ.

2. Assign a FASTRAND file for the relocatable tape. Note: do not use the R - option if this file is to be updated.

   @ASG,UPR ØBJ,F///1500

3. Assign the input relocatable tape.

   @ASG,T ØBJECT,T,yyyyy

4. Copy the input relocatable tape to the FASTRAND file assigned.

   @CØPY,G ØBJECT.,ØBJ.

5. Prepare an entry point table @PREP statement - Make a table of entry points so subsequent processors can find the relocatable's entry points.

   @PREP ØBJ.

6. Free the input relocatable tape.

   @FREE ØBJECT

5.4.9.3 Executable Catalogue Procedure

1. Delete a file if it exists, but continue the run if it does not (C-option).

   @DELETE,C NASTRAN.

2. Assign a FASTRAND file for the NASTRAN executable elements. Note: do not use the R-option if this file is to be updated.

   @ASG,UPR NASTRAN,F///1000

3. Delete a file if it exists, but continue the run if it does not exist.

   @DELETE,C ASGCRDS.

4. Assign a FASTRAND file for the program file ASGCRDS.

   @ASG,UPR ASGCRDS,F///10

5. Delete file if it exists, but continue the run if it does not exist.

   @DELETE,C CØNTRL.

6. Assign a FASTRAND file for the program file CØNTRL.

```
@ASG,UPR  CØNTRL,F///10
```

7. Delete file if it exists, but continue the run if it does not exist.

```
@DELETE,C  CØNTRL42K.
```

8. Assign a FASTRAND file for the program file CØNTRL42K.

```
@ASG,UPR  CØNTRL42K,F///10
```

9. Assign the input executable tape.

```
@ASG,T  ABSTAP,T,zzzzz
```

10. Copy the executable element file from tape to the FASTRAND file NASTRAN.

```
@CØPY,G ABSTAP.,NASTRAN
```

11. Copy a program file @CØPY,F statement - Copy the ASGCRDS file from tape to FASTRAND. Note program files (files with control cards as part of the file) must be copied in a different manner than element files. In addition, the @CØPY,F statement does not position a tape past the tape end-of-file when used to read a file in.

```
@CØPY,F  ABSTAP.,ASGCRDS.
```

12. Move a tape past an end-of-file mark @MØVE statement - Move the input tape past an end-of-file so the tape will be positioned properly for the next file.

```
@MØVE  ABSTAP.,1
```

13. Copy the program file CØNTRL from tape to FASTRAND.

```
@CØPY,F  ABSTAP.,CØNTRL.
```

14. Move a tape past an end-of-file.

```
@MØVE  ABSTAP.,1
```

15. Copy the program file CØNTRL42K from tape to FASTRAND.

```
@CØPY,F  ABSTAP.,CØNTRL42K.
```

16. Free the input executable tape.

```
@FREE ABSTAP
```

5.4.10 NASTRAN Update Procedure

1. Catalogue the executable tape (@ASG,UP NASTRAN,F///1000).

2. Catalogue the relocatable tape (@ASG,UPR ØBJ,F///1500).

3. Catalogue the source tape.

   @ASG,UPR SØU,F///1500

   (@ASG,UPR MDSØU,F///500)

4. Add a heading for the compile. This makes the deck easier to find in the output.

   @HDG deckname

5. Compile the deck (see note).

   @FØR,S SØU.deckname,deckname

   NOTE: If a machine dependent deck is to be compiled use

   @FØR,S MDSØU.deckname,deckname

6. Adding a heading for the executable element to be updated.

   @HDG LINKxx

7. Prepare an entry point table.

   @PREP ØBJ.

8. Map (regenerate) the executable element(s) in which the deck compiled resides. Note the map symbolics are on the relocatable file.

   @MAP,S ØBJ.LINKxx,NASTRAN.LINKxx

9. Run a problem.

   @ADD ASGCRDS.

5.4.11 Regenerate the Executable Tape

1. The relocatable tape must be catalogued.
2. The file ASGCRDS must be catalogued.
3. The file CØNTRL must be catalogued.
4. Delete a file, but continue the run if it does not exist.

   @DELETE,C NASTRAN

5. Assign the name NASTRAN to a FASTRAND file.

   @ASG,UP NASTRAN,F///1000

6. Add a heading for each executable element.

   @HDG LINK1

7. Add a message for each link (only useful if you are attending the run)

   @MSG LINK1

8. Map (regenerate) the executable element.

   @MAP,S ØBJ.LINK1,NASTRAN.LINK1

9. Repeat steps 6 through 8 for all links (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14).

10. Print the element list (TØC) for the NASTRAN file.

    @PRT,T NASTRAN

11. Assign an output executable tape.

    @ASG,T ABSTAP,T,xxxx

12. Copy the executable elements to tape.

    @CØPY,GM NASTRAN.,ABSTAP.

13. Copy the ASGCRDS program file to tape. Note @CØPY,F writes an end-of-file when used for output tape.

    @CØPY,F ASGCRDS.,ABSTAP.

14. Copy the CØNTRL program file to tape.

    @CØPY,F CØNTRL.,ABSTAP.

15. Copy the CØNTRL42K program file to tape.

    @CØPY,F CØNTRL.,ABSTAP.

16. Assign the input executable and demonstration input date tape (UMF).

    @ASG,T ØLDABS,T,xxxx

17. Position to UMF file on the executable tape.

    @MØVE ØLDABS.,7

18. Copy the UMF file to the end of the new executable tape.

    @CØPY,M ØLDABS.,ABSTAP.

19. Free the output executable tape.

    @FREE ABSTAP

NOTE: Alters to the map symbolics may be made by placing the alter cards after the appropriate MAP card.

5.4.12 The ASGCRDS Program File

The ASGCRDS program file contains a card to turn the system heading off because NASTRAN writes its own heading and an execute card for the first executable element LINK1 (the NASTRAN preface).

The heading-off statement is as follows:

```
@HDG,N
```

The next card is a @XQT card for the first element:

```
@XQT  *NASTRAN.LINK1
```

Note the use of the '*' before NASTRAN. This symbol is used because of the way the UNIVAC 1108 Exec 8 reference files (or elements). A complete element reference has the following form:

```
QUALIFIER*FILENAME.ELEMENTNAME
```

The qualifier is normally the name in the project field of the run card. If a user with a different qualifier should want to run a problem and the executable tape was catalogued in a run with the above qualifier, then the user would have to include a @QUAL statement as the first card (after the run card) in this deck. The @QUAL card would have the following form:

```
@QUAL  XXXXX (project field of run which catalogued the files)
```

With this card, all files that have a '*' before their name will reference files catalogued with the above qualifier. Note the @ADD ASGCRDS. and @ADD CØNTRL. statements should be changed to @ASG *ASGCRDS. and @ADD *CØNTRL. if the executable tape was catalogued under a different qualifier.

The ASGCRDS file is added to the control card stream with an @ADD statement of the form:

```
@ADD  ASGCRDS.
```

This statement causes the @ADD card to be replaced in the control stream with the file named ASGCRDS.

Since all the files are assigned to FASTRAND by NASTRAN, some way of assigning a tape is needed. Tape assignments are made by assigning a tape to a file before the @ADD ASGCRDS statement is reached. For example, an assignment for file (unit) 30 @ASG,T 30,T,XXX will assign unit 30 to tape. Matricies may be routed to this tape by the DMAP command FILE.

In NASTRAN, any unit may be assigned to tape if the user thinks it is necessary, but some units have specific functions. These specific functions and the units involved are as follows:

Unit		Function
7	(PØØL)	NASTRAN PØØL Tape (Temporary NASTRAN data block storage)
8	(ØPTP)	OLD PROBLEM Tape (Previous checkpoint tape restart)
9	(NPTP)	NEW PROBLEM Tape (Checkpoint Tape)
10	(UMF)	USER MASTER FILE Tape (Bulk data input from tape)
11	(NUMF)	NEW USER MASTER FILE Tape (Used when building a UMF)
12	(PLT1)	PLØT Tape for the EAI and Benson Lehner plotters
13	(PLT2)	PLØT Tape for the SC4020, CalComp and DD80 plotters
14 - 23	(INPT)	User tapes for substructuring

The most common tape assignments for NASTRAN problems are the checkpoint, restart, and/or PLT2. Note all named files must be assigned by their external names.

5.4.13 The CØNTRL or CØNTRL42K Program File

The CØNTRL program file consists of a series of @TEST and @XQT cards. The @TEST card allows the option of either skipping a control card or not skipping a control card, depending on the value of the test control word. The lower sixth of this word is set by the executive request SETC$. The NASTRAN executable element that is in core during a run will set the control word to the element number which is to get control next (i.e., LINK2 = 2, LINK14 = 14). The @TEST TNE/i/S6 statements will cause the appropriate link to execute when the control word is equal to i. The file contains the following cards:

```
@TEST     TNE/1/S6
@XQT      *NASTRAN.LINK1
@              .
               .
               .
@TEST     TNE/14/S6
@XQT      *NASTRAN.LINK14
@TEST     TNE/17/S6
@JUMP     END'
               .
               .
               .
```

```
the above stream repeated 100 times
          .
          .
          .
@END:PMD,EB
```

To exit, the control word is set to 17 and the @JUMP instruction will be executed. This will jump to the @END:PMD,EB statement for a possible post mortem dump.

The CØNTRL42K file differs from the CØNTRL file by having options on the @XQT cards (i.e., @XQT,LM *NASTRAN.LINK1). The options are LM. This will make a 42K NASTRAN system. Other size systems can be made by varying the options used (i.e., making another control file).

5.4.14 Description of a Demonstration Problem Starter Deck

In order to obtain a listing of the demonstration problem starter decks the following is executed:

1. Assign relocatable and problem demonstration tape.

   ```
   @ASG,T ØBJECT,T,xxxx
   ```

2. Position to the demonstration deck file.

   ```
   @MØVE ØBJECT.,1
   ```

3. Assign FASTRAND onto which demonstration problem starter decks are to be copied.

   ```
   @ASG,CP DEMØRUNS,F///100
   ```

4. Copy demonstration problem starter decks.

   ```
   @CØPY,G ØBJECT.,DEMØRUNS.
   ```

5. Release relocatable and problem demonstration tape.

   ```
   @FREE ØBJECT
   ```

6. List demonstration problem starter deck.

   ```
   @ELT,LD DEMØRUNS.X,,
   @END
   ```

The following will describe in detail the necessary steps for executing demonstration problem 1-1 on the UNIVAC 1108 using Exec 8.

1-5. Use first five steps of previous setup that was used to obtain a numbered listing of driver decks.

6. Extract demonstration problem 1-1 by updating the demonstration problem starter deck, placing the result in element Y.

```
@ELT,LD DEMØRUNS.X,.Y,
-1,7
-36,4287
@END
```

7. Assign the new problem tape (checkpoint tape) to a scratch tape on unit 9.

```
@ASG,T NPTP,T, SCRTCH . NPTP
```

8. Assign the demonstration problem input data tape (xxx) to unit 10.

```
@ASG,T UMF,T,xxx . UMF
```

9. Add the file containing the demonstration problem deck.

```
@ADD DEMØRUNS.Y
```

The following is a description of the control stream contained in the DEMØRUNS.Y element.

Add the file ASGCRDS. This will assign all the files except 9 and 10 which have already been assigned.

```
@ADD ASGCRDS.
```

The beginning of the NASTRAN data deck. The NASTRAN data deck has three parts -- Executive Control Deck, Case Control Deck, and Bulk Data Deck.

ID	DEM101,NASTRAN	(State of Executive Control Deck)
UMF	1972 110101	(Tape and problem number so the correct bulk data will be processed from the UMF tape)
CHKPNT	Yes	(Unit 9 must be assigned to tape when checkpointing)
TIME	5	(Should be approximately two minutes less than maximum time on job card)

.
.
.

CEND (End of Executive Control Deck and start of Case Control Deck)

.
.
.

BEGIN BULK (End of Case Control Deck and start of Bulk Data Deck)

(The Bulk Data Deck will be input from the UMF tape)

ENDDATA (End of Bulk Data Deck)

Add the file CØNTRL so that the other executable elements can be executed.

@ADD CØNTRL42K.

10. End of job.

@FIN

5.4.15 Tape and Problem Numbers for the NASTRAN Demonstration Problem Input Data Tape

External Problem Numbers	1108 Run Time	Tape Number	UMF Tape Problem Number
1-1	30	1972	101010
1-2	55		201020
1-3	86		2401030
1-4	510		2301042 (2601041)
1-5	477		301050
1-6	22		401060
1-7	115		501070
1-8	47		1301080
1-9	76		1401090
1-10	18		601100
1-11	83		150110
2-1	24		702010
3-1	422		2403011 (3103012)
3-2	405		1603020
3-3	354		1703030
4-1	102		1804010
5-1	287		805010
6-1	1361		1906010
7-1	188		2707010
7-2	765		2007021
8-1	115		2208011 (2808012)
9-1	24		909010
9-2	318		2909020
9-3	422		2109030
10-1	54		1010010
11-1	70		1111010
11-2	495		3011020
12-1	167		1212010

The tape number and problem number go on the UMF card in the NASTRAN Executive Control Deck. Note the name "tape number" used in the above table is not an external tape number, but is really a label written by NASTRAN.

5.4.16 GINØ (Generalized Input/Output for NASTRAN)

5.4.16.1 GINØ Data Flow

GINØ provides a common internal format for all NASTRAN data blocks. It also provides an increased set of I/Ø commands over those usually available to the FØRTRAN programmer. The functions provided are:

1. ØPEN($N,FILEA,BUFF,ØP)

   Opens GINØ file named FILEA into BUFF according to ØP.

2. CLØSE(FILEA,ØP)

   Closes FILEA according to ØP.

3. READ($N1,$N2,FILEA,IZ,NA,EØR,LEN)

   Reads NZ words from FILEA into IZ.

4. WRITE(FILEA,IZ,NA,EØR)

   Writes NZ words onto FILEA from IZ.

5. EØF(FILEA)

   Writes a logical end-of-file on FILEA.

6. REWIND(FILEA)

   Rewinds FILEA.

7. BCKREC(FILEA)

   Backspaces FILEA on record.

8. FWDREC($N,FILEA)

   Forward spaces FILEA on record.

9. SKPFIL(FILEA,IN)

   Forward or backward skip FILEA IN files.

The above entry points may be called by any NASTRAN programmer and their exact functions are detailed in Section 3 of the Programmer's Manual. In addition, there is one executive function:

10. RWUNLD(FILEA)

Rewinds FILEA, dismounts the tape assigned to it, and requests a second reel to be mounted. This function is unique to the 7094 and 1108 versions of GINØ.

The manner in which these user-requested I/Ø functions are performed is highly machine dependent, but the basic strategy is similar on all machines. The programming language may be computer dependent or all FORTRAN (as is the case on the 1108, except for NTRAN$ functions).

The basic data flow can be traced as follows:

Write Data

The user calls ØPEN, supplying a GINØ file name (201-299, 301-399) and a buffer allocated from his subroutine's open core of length given by the first word (SYSBUF) in the common block /SYSTEM/. ØPEN searches the FIST (located in common block /XFIST/ to find a pointer into the FIAT (located in common block /XFIAT/. The FIAT supplies the internal file name (FILE). (On the 1108, this is a FØRTRAN logical unit number such as 21.) This number is used as a file identification number. The buffer location is adjusted to the beginning of the common block /XNSTRN/ and is stored in the array BUFADD(FILE). A check is made to insure that this buffer does not overlap any other currently opened buffers. ØPEN then initializes the buffer area (it stores the word 'WRIT' in BUFF(1) and returns awaiting further commands). It might be useful to review the naming conventions for data in NASTRAN. A collection of data is being written by the current module on the first output file (known to the module writer as 201). The DMAP compiler assigns to this collection of data the Data Block Name EST as this symbol was the first Alpha string in the DMAP output section for this module. The file allocator has allocated the internal FØRTRAN file 21 to this data block. Physically, all writes will take place onto unit 21. On the 1108, this unit may also have an external name attached via the @USE card. Thus the New Problem Tape, which is FØRTRAN unit No. 9, has the external name NPTP.

The user now calls WRITE for this file. WRITE again finds the internal file number via the FIST and FIAT. It checks to be sure the file is open to write and retrieves the buffer address from BUFADD in common block /GINØX/. Data is stored in the buffer by this and

perhaps subsequent WRITE calls until the entire buffer is filled. WRITE then calls GINØIØ to cause the physical write to occur. GINØIØ calls NTRAN in the synchronous mode. Finally, the programmer calls CLØSE and the current buffer is flushed and a physical end-of-file is placed at the end of the GINØ blocks.

Read Data

The data read sequence is quite parallel to the data write sequence.

5.4.16.2 GINØ Subroutine Organization

The GINØ package consists of the following decks:

ØPEN	FWDREC	XEØT
CLØSE	EØF	GINØ
READ	SKPFIL	GINØIØ
WRITE	RWUNLD	NTRAN$
BCKREC	XGINØ	REWIND

The calling sequence for ØPEN, CLØSE, READ, WRITE, FWDREC, BCKREC, REWIND, EØF, SKPFIL, XGINØ, GINØ, and XEØ are discussed in Section 3 of the Programmer's Manual. RWUNLD is described in Section 5.4.16.1. XGINØ is a GINØ utility subroutine to perform the look-up associated with the GINØ file name to internal number conversion. XEØT is called by RWUNLD and communicates with the operator in mounting and demounting multireel tapes.

The documentation for GINØIØ is as follows:

Purpose

To perform physical I/Ø on the 1108.

Calling Sequence

CALL GINØIØ($N,ØPCØDE,BUFF), where $N is a statement number to return to if an I/Ø error occurs. In this case, GINØIØ will set the ERRØR word in /GINØX/ as follows ERRØR = 6 - ISTAT, where ISTAT is the NTRAN status word.

ØPCØDE is an integer 1 through 5 where:

1 is rewind file

2 is write one block

3 is read one block

4 is backspace one block

5 is forward space one block

BUFF is the address of the block to be written. The length of the block is given by word NBUFF3 in /GINØX/.

Method

NTRAN operations for Rewind (10), WRITE (1), READ (2), Backspace (6,7), or forward space (6,7) are given. Reads and writes are proceeded by and followed by waits (22). Backspace and forward space are proceeded by waits. The forward space and backward space operations depend on proper identification of the file type (tape or disk). To do this, the TAPE flag (word NTAPE) of /GINØX/ is considered. Disk files are positioned forward or backward, according to the word NØSECT in /GINØX/.

NTRAN documentation must be obtained from UNIVAC.

The GINØ buffer for the 1108 is exactly as described in the Programmer's Manual in Section 3 (GINØ). On the 1108 subroutines READ and WRITE do not call XGINØ and GINØ, but rather contain within themselves this code to improve efficiency.

Most communication within the GINØ routines is accomplished via the common block /GINØX/.

```
COMMON/GINOX/LENGTH,FILEX,EOR,OP,ENTRY,LSTNAM,N,NAME,NTAPE,XYZ(2),UNITAB(75),BUFADD(75),
NBUFF3,ERRØR,NØSECT,DIAG15,IFET,IMST,ISUB,NBUFF,CBP,CLR
```

where:

LENGTH is the length of GINØX

FILEX is the internal file number

EØR is the end-of-record flag

ØP is the operation requested

ENTRY is the entry type to GINØ

LSTNAM is the internal file number of the last GINØ operation

N is the number of words to transmit

NAME is the GINØ file name

NTAPE is the tape flag for this file

XYZ(2) is not used

UNITAB is the unit status table

Bits 1-16 are the largest block number on the file
Bits 16-32 are the number of logical records on the file

BUFADD is the buffer address table

NBUFF3 is the length of a physical block

ERRØR is the GINØIØ error flag

NØSECT is the number of 28 word sectors/record

DIAG15 is the DIAG15 switch status for ØPEN/CLØSE tracer

IFET,IMST,ISUB are not used

NBUFF is the current buffer size from /SYSTEM/

CBP is the current buffer pointer from GINØ

CLR is the current record pointer from GINØ

Entry points QWRITE (in WRITE) and QREAD (in READ) are special entry points for matrix packing/unpacking, and are discussed in Section 5.4.17.

5.4.17 Matrix Packing Routines

5.4.17.1 Introduction

Matrix packing is the most critical area to running times for most NASTRAN operations. The basic operation is quite simple; take a term from the programmer and store it in packed format in a GINØ buffer, or more often, take a term from a GINØ buffer and provide it to the programmer. Functionally, the routines are:

BLDPK - Pack out a matrix one term at a time.

PACK - Pack out a matrix one column at a time.

INTPK - Unpack a matrix one term at a time.

UNPACK - Unpack a matrix one column at a time.

These routines are functionally documented in Section 3 of the Programmer's Manual. The nature of a packed record is conceptually described in Section 3.5.1 of the Programmer's Manual.

Prior to Level 15, data was retrieved via the following flow:

1. The programmer called UNPACK to unpack a column of the matrix.
2. UNPACK called INTPK for each nonzero term in the matrix.
3. INTPK called READ for each 50-word string.
4. READ called XGINØ for each call.
5. XGINØ called GINØ for each call.
6. GINØ called GINØIØ for each block needed.
7. GINØIØ called NTRAN for each block needed.

Thus, the following tree could be drawn:

$$\text{UNPACK} \xrightarrow{\text{term}} \text{INTKP} \xrightarrow{\text{50 terms}} \text{READ} \xrightarrow{\text{50 terms}} \text{XGINØ} \xrightarrow{\text{50 terms}} \text{GINØ} \xrightarrow{\text{block}} \text{GINØIØ} \xrightarrow{\text{block}} \text{NASTRAN}$$

The result was a time to unpack per term that was ten times the time to read two words. Level 14 imbedded XGINØ and GINØ in READ, reducing the time by 20 percent. Level 15 rewrote the matrix packing routines, such that they are allowed direct access into the GINØ buffer. In particular, define a string of matrix terms as a string of consecutive nonzero terms. The 1108 matricies are packed as strings. Thus, our flow diagram now appears as follows:

$$\text{UNPACK} \xrightarrow{\text{string}} \text{INTPK} \xrightarrow{\text{string}} \text{READ} \xrightarrow{\text{block}} \text{GINØIØ} \xrightarrow{\text{block}} \text{NTRAN}$$

This was done all in FØRTRAN (in contrast to IBM and CDC GINØ/PACK routines) for three reasons:

1. The FØRTRAN compiler produces reasonable code.
2. Register-to-register operations are only a factor of two faster than core-to-register (and not at all if the instructions and data are in separate banks, which is usually the case).
3. Development and maintenance costs of FØRTRAN code are less than those for assembly language code.

5.4.17.2 Format of a Packed Column

The format of a packed column on the 1108 is as follows:

Word Number	Contents
1	Type of elements (1-4)
2	String descriptor (NS/RØW)
3	Floating point values
4	.
.	.
.	.
.	.
2+NS*NWØRDS	.
.	String descriptor
.	.
.	

where:

Type of Elements

1	Real Single Precision	NWØRDS = 1
2	Real Double Precision	NWØRDS = 2
3	Complex Single Precision	NWØRDS = 2
4	Complex Double Precision	NWØRDS = 4

String descriptor is two packed half words.

Right 16 bits are the row number of the first element in the string (RØW).

Left bits are the number of elements which follow (NS).

NOTES:

1. No matricies written under pre-Level 15 NASTRAN's can be read by Level 15.

2. All strings are broken at the end of a buffer (i.e., a phoney string descriptor is inserted in the packed column if needed).

3. Null columns are null records (i.e., GINØ records which contain 0 words). Such a record can be generated by CALL WRITE (F1,0,0,1).

4. Note 2 above implies that matricies may not be manipulated by READ and WRITE, except for the trivial case of an exact copy (such as in PØØLing and checkpointing).

5.4.17.3 Programming Methods

Two new common blocks /QREADX/ and /QWRITX/ were established to provide communication between the matrix packing routines.

/QREADX/PTYPE,M,L,IS,ØLØI,MM,IØPT1,N1,NS,IRØW,FILES,EØR1

Name	Set By	Content
PTYPE	INTPK	Type of element.
M	INTPK	Number of words per elements returned.
L	INTPK	Computed goto for element conversion.
IS	INTPK	Number of terms used in the current string.
ØLDI	INTPK	Row number of first term in the string.
MM	INTPK	Number of words per element in the buffer.
IØPT1	INTPK	Multifile version flag.
N1	INTPK	Pointer from /XNSTRN/ to the current element in the buffer.
NS	INTPK/ QREAD	Number of elements in the current string.
IRØW	INTPK/ QREAD	Row number of the first element in the current string.
FILES	QREAD	Internal GINØ file number of this matrix.
EØR1	QREAD	End of record flag for the column.

/QWRITX/XD(6),PTYPE,TYPE,LX,LY,ØLDI,CØUNT,NNZ,LPR,FILES,IØPT1,IRØW,N1,WRITE,LZ,MK,MM

Name	Set By	Content
XD	BLDPK	Term and row number to be packed.
PTYPE	BLDPK	Form of elements after packing.
TYPE	BLDPK	Computed goto for type of element packing.
LX LY	BLDPK	Computed goto's for type of element packing.
ØLDI	BLDPK/ PACK	Row number of previously packed element.
CØUNT	BLDPK/ USER	Total number of elements packed.
NNZ	BLDPK/ QWRIT	Number of nonzero words to date in current string.

Name	Set By	Content
LPR	BLDPK/ QWRIT	Pointer relative to /XNSTRN/ to the last string descriptor
FILES	BLDPK/ QWRIT	Internal GINØ file number for this matrix.
IØPT1	BLDPK	Multiple version flag.
IRØW	BLDPK	Row position of first term in string.
N1	BLDPK/ QWRIT	Pointer relative to /XNSTRN/ to the current buffer position.
NWRITE	BLDPK/ QWRIT/ PACK	Number of words which can be written in the buffer from now on.
LZ	BLDPK	First nonzero term computed goto.
MK	BLDPK	Number of words per term after packing.
MM	BLDPK	Number of words per term before packing.

In addition, four special entry points were provided to the GINØ routines to facilitate matrix work. These are as follows:

Deck

WRITE

Entry Point

QWRITE

Calling Sequence

CALL QWRITE

Method

QWRITE moves the N words stored in XD into the GINØ buffer specified by FILES, where N is set in /GINØX/. It also maintains NNZ, CBP, N1, NWRITE, and LPR.

Deck

ØPNCØR

Entry Point

QWCØR

Calling Sequence

CALL QWCØR(IZ,N)

Method

QWCØR moves the N words stored in XD into the core buffer starting at IZ(1). It also maintains NNZ, N1, and LPR.

Deck

READ

Entry Point

QREAD

Calling Sequence

CALL QREAD

Method

QREAD returns the row position and number of elements in a string on file FILES. It also maintains N1, NS, IRØW, and EØR1 in common block /QREADX/.

Deck

ØPNCØR

Entry Point

QRCØR

Calling Sequence

CALL QRCØR(IZ)

Method

QRCØR returns the row position and number of elements in a string from the core file starting at IZ(1). It also maintains N1, NS, IRØW, and EØR1 in /QREADX/.

Each of the four major functional routines (BLDPK, INTPK, PACK, and UNPACK) uses a slightly different strategy in utilizing the information available in /GINØX/, /QREAD/, /QWRITX/, and the new entry points into GINØ.

PACK

PACK provides a special option (in addition to successive calls to BLDPK) where the type of the terms in core are the same as the type to be passed to GINØ. In this case, the first term in each string is passed via BLDPK, but subsequent terms are stored directly in the GINØ buffer.

BLDPK

BLDPK provides for two options: 1) If conversion of types must take place, each term is converted and QWRITE is called; 2) if no conversion of types takes place, terms are stored directly into the GINØ buffer until the buffer is full, when QWRITE is called.

UNPACK

UNPACK provides two special options (in addition to successive calls to ZNTPK) when the type of the terms in core is the same as the type to be passed to the user. 1) if INCUR = 1, a tight (3 instruction loop) passes each string to the user core. 2) If INCUR $\neq$ 1, a special loop passes each string to the user core. In both cases, the first and last terms in each string are obtained via a call to ZNTPK.

INTPK

INTPK calls QREAD for each string. All subsequent requests for terms within the string use direct pointers into the GINØ buffer.

5.4.18 1108 Time Estimation

In estimating running times for various operations in NASTRAN, several machine dependent factors are critical. These include:

1. Buffer size (SYSBUF) = 871.
2. Basic double precision multiple and add tight loop time = 14.0×10^{-6} sec.
3. Double precision multiply and add not tight loop time = 35
4. Pack or unpack 1 D.P. term = 25×10^{-6} sec.
5. INTPK or BLDPK 1 D.P. term = 50×10^{-6} sec.
6. Read or write 1 word = 6×10^{-6} sec.
7. Open core available -- DIAG 13 on small problem.
8. Stiffness matrix formulation (QUADPlate) = .7 sec

5.4.19 Single Precision Routines

For the convenience of 1108 users, single precision versions of some critical routines have been included on the 1108 tapes and placed properly in the overlay structure. It is not the

intent to support a precision choice in Level 15 or to support single precision on the 1108, but many problems can be successfully solved on smaller cores and faster by making use of these single precision decks.

Single precision versions of the following decks are available on the 1108 object tape:

Function	S.P. Name	D.P. Name
Real symmetric decomposition	RSPSDC	SDCØMP
Complex symmetric decomposition	CSPSDC	SCDCMP
Real inverse power FBS (symmetric)	INVFSP	FBSINV

The calling sequence to each single precision routine is identical to the call to the double precision counterpart. Thus, the single precision version can be activated by adding an EQU card to each link in which it is used and recollecting the executables.

5.4.20 UNIVAC Overlay Diagrams

Figures 2 through 15 on the following fold-out pages represent the NASTRAN overlay structure for the UNIVAC 1108.

NOTES:

The following comments are included to aid the user in reading the overlay diagram.

1. Segments having 0000000 as the first routine are most likely not accurately represented. This type of segment should follow the longest of several segments enumerated in a SEG statement. Instead it can follow any one of these enumerated segments which is not necessarily the longest. For such 0000000 flagged segments, the map processor input should be referenced.

2. In order to meet restrictions imposed by printing overlay structures, some routine names are omitted from the main segments of each of the fourteen links. The following fourteen lists are of those routines omitted from each main segment.

LINK 1

RWUNLD	STAPID	TWØ	GINØ	READ
XEØT	TIME	NAMES	XGINØ	PPDUMP
SKPFIL	XLINK	ØUTPUT	GINØIØ	MAPFNS
EØF	SEM	XVPS	FNAME	MESAGE
PAGE	QREADX	XPFIST	PEXIT	QWRITX
CØRSZ	TYPE	XXFIAT	SSWTCH	FWDREC
DESCRP	XMDMSK	XFIST	UTIL	WRITE
XCEITB	ØCLNT	XFIAT	ØPEN	REWIND
STIME	GINØX	MSGX	CLØSE	BCKREC
				SYSTEM

LINK 2

QWRITX	STIME	TYPE	ØUTPUT	MSGX
ØPNCØR	STAPID	XMDMSK	XVPS	XDPL
ZNTPKX	TIME	ØCLNT	XPFIST	ØSCENT
CØRSZ	XLINK	GINØX	XXFIAT	XNSTRN
DESCRP	SEM	TWØ	XFIST	SYSTEM
XCEITB	QREADX	NAMES	XFIAT	

LINK 3

QREADX	ØUTPUT	GINØ	ØPEN	FWDREC
TYPE	XVPS	XGINØ	CLØSE	WRITE
XMDMSK	XPFIST	GINØIØ	READ	REWIND
ØCLNT	XXFIAT	FNAME	PPDUMP	BCKREC
GINØX	XFIST	PEXIT	MAPFNS	XDPL
TWØ	XFIAT	SSWTCH	MESAGE	ØSCENT
NAMES	MSGX	UTIL	QWRITX	XNSTRN
				SYSTEM

LINK 4

CØRSZ	TYPE	XXFIAT	SSWTCH	FWDREC
DESCRP	XMDMSK	XFIST	UTIL	WRITE
XCEITB	ØCLNT	XFIAT	ØPEN	XDPL
STIME	GINØX	MSGX	CLØSE	ØSCENT
STAPID	TWØ	GINØ	READ	XNSTRN
TIME	NAMES	XGINØ	PPDUMP	REWIND
XLINK	ØUTPUT	GINØIØ	MAPFNS	BCKREC
SEM	XVPS	FNAME	MESAGE	SYSTEM
QREADX	XPFIST	PEXIT	QWRITX	

LINK 5

CØRSZ	TYPE	XXFIAT	SSWTCH	FWDREC
DESCRP	XMDMSK	XFIST	UTIL	WRITE
XCEITB	ØCLNT	XFIAT	ØPEN	REQIND
STIME	GINØX	MSGX	CLØSE	BCKREC
STAPID	TWØ	GINØ	READ	XDPL
TIME	NAMES	XGINØ	PPDUMP	ØSCENT
XLINK	ØUTPUT	GINØIØ	MAPFNS	XNSTRN
SEM	XVPS	FNAME	MESAGE	SYSTEM
QREADX	XPFIST	PEXIT	QWRITX	

LINK 6

CØRSZ	TYPE	XXFIAT	SSWTCH	FWDREC
DESCRP	XMDMSK	XFIST	UTIL	WRITE
XCEITB	ØCLNT	XFIAT	ØPEN	REWIND
STIME	GINØX	MSGX	CLØSE	BCKREC
STAPID	TWØ	GINØ	READ	XDPL
TIME	NAMES	XGINØ	PPDUMP	ØSCENT
XLINK	ØUTPUT	GINØIØ	MAPFNS	XNSTRN
SEM	XVPS	FNAME	MESAGE	SYSTEM
QREADX	XPFIST	PEXIT	QWRITX	

LINK 7

CØRSZ	TYPE	XXFIAT	SSWTCH	FWDREC
DESCRP	XMDMSK	XFIST	UTIL	WRITE
XCEITB	ØCLNT	XFIAT	ØPEN	REWIND
STIME	GINØX	MSGX	CLØSE	BCKREC
STAPID	TWØ	GINØ	READ	PATX
TIME	NAMES	XGINØ	PPDUMP	PARMEG
XLINK	ØUTPUT	GINØIØ	MAPFNS	XDPL
SEM	XVPS	FNAME	MESAGE	ØSCENT
QREADX	XPFIST	PEXIT	QWRITX	XNSTRN
				SYSTEM

LINK 8

QREADX	ØUTPUT	GINØ	ØPEN	FWDREC
TYPE	XVPS	XGINØ	CLØSE	WRITE
SMDMSK	XPFIST	GINØIØ	READ	BCKREC
ØCLNT	XXFIAT	FNAME	PPDUMP	XDPL
GINØX	XFIST	PEXIT	MAPFNS	ØSCENT
TWØ	XFIAT	SSWTCH	MESAGE	XNSTRN
NAMES	MSGX	UTIL	QWRITX	SYSTEM

LINK 9

GINØ	PEXIT	CLØSE	MAPFNS	ØSCENT
XGINØ	SSWTCH	READ	MESAGE	XNSTRN
GINØIØ	UTIL	PPDUMP	XDPL	SYSTEM
FNAME	ØPEN			

LINK 10

SKPFIL	UNPAKX	TYPE	MSGX	MAPFNS
PACK	ZNTPKX	XMDMSK	GINØ	MESAGE
UNPACK	ZBLPKX	ØCLNT	XGINØ	QWRITX
PRELØC	CØRSZ	GINØX	GINØIØ	FWDREC
INTPK	DESCRP	TWØ	FNAME	WRITE
BLDPK	XCEITB	NAMES	PEXIT	REWIND
WRTTRL	STIME	ØUTPUT	SSWTCH	BCKREC
CDCMPX	STAPID	XVPS	UTIL	XDPL
DCØMPX	TIME	XPFIST	ØPEN	ØSCENT
TMTØGØ	XLINK	XXFIAT	CLØSE	XNSTRN
BITPØS	SEM	XFIST	READ	SYSTEM
PACKX	QREADX	XFIAT	PPDUMP	

LINK 11

BLDPK	UNPAKX	XMDMSK	GINO	MESAGE
PRELOC	PACKX	OCLNT	XGINO	QWRITX
INTPK	CORSZ	GINOX	GINOIO	FWDREC
PACK	DESCRP	TWO	FNAME	WRITE
UNPACK	XCEITB	NAMES	PEXIT	REWIND
WRTTRL	STIME	OUTPUT	SSWTCH	BCKREC
BITPOS	STAPID	XVPS	UTIL	XDPL
TMTOGO	TIME	XPFIST	OPEN	OSCENT
CINVPX	XLINK	XXFIAT	CLOSE	XNSTRN
ZBLPKX	SEM	XFIST	READ	SYSTEM
ZNTPKX	QREADX	XFIAT	PPDUMP	
TRDXX	TYPE	MSGX	MAPFNS	

LINK 12

SEMDBD	STIME	TWO	XGINO	MAPFNS
XSEM12	STAPID	NAMES	GINOIO	MESAGE
MAIN12	TIME	OUTPUT	FNAME	QWRITX
NTAB$	XLINK	XVPS	PEXIT	FWDREC
NTRAN$	SEM	XPFIST	SSWTCH	WRITE
PATX	QREADX	XXFIAT	UTIL	BCKREC
PARMEG	TYPE	XFIST	OPEN	XDPL
CORSZ	XMDMSK	XFIAT	CLOSE	OSCENT
DESCRP	OCLNT	MSGX	READ	XNSTRN
XCEITB	GINOX	GINO	PPDUMP	SYSTEM

LINK 13

BLDPK	STIME	NAMES	GINOIO	MESAGE
INTPK	STAPID	OUTPUT	FNAME	QWRITX
UNPACK	TIME	XVPS	PEXIT	FWDREC
WRTTRL	XLINK	XPFIST	SSWTCH	WRITE
ZBLPKX	SEM	XXFIAT	UTIL	REWIND
SORT	QREADX	XFIST	OPEN	BCKREC
ZNTPKX	TYPE	XFIAT	CLOSE	XDPL
UNPAKX	XMDMSK	MSGX	READ	OSCENT
CORSZ	OCLNT	OPNCOR	PPDUMP	XNSTRN
DESCRP	GINOX	GINO	MAPFNS	SYSTEM
XCEITB	TWO	XGINO		

LINK 14

XXFIAT	XGINO	UTIL	MAPFNS	REWIND
XFIST	GINOIO	OPEN	MESAGE	XDPL
XFIAT	FNAME	CLOSE	QWRITX	OSCENT
MSGX	PEXIT	READ	FWDREC	XNSTRN
GINO	SSWTCH	PPDUMP	WRITE	SYSTEM

3. Note that on the 1108, contrary to any other NASTRAN computer, there are really two similarly shaped overlay pictures, one for the I bank (instructions), and another for the D bank (data).

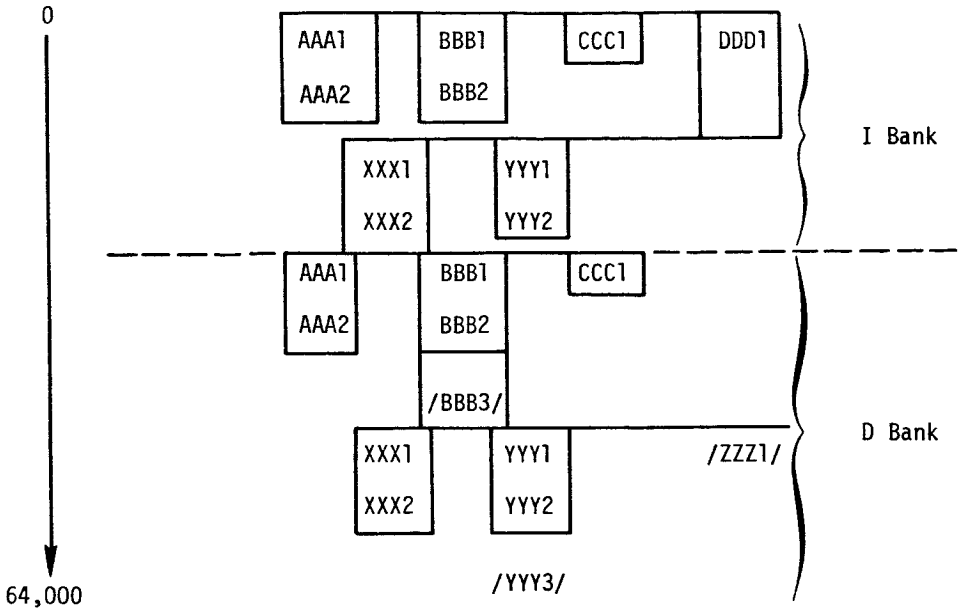


Figure 1. Overlay Sample

Several important points result from this figure. First, all modules are penalized by long instruction banks in other modules. Second, a reasonable overlay tree derived from total routine lengths may not be reasonable for the 1108. Thus, the 1108 overlay tends to be more complex than the overlay for the other NASTRAN computers. Critical statistics are the length of the I-bank, the length of the D-bank, the total length of each link, and the smallest open core address possible (End of D-bank of the root segment).

The following table summarizes these statistics for each link:

Link	I_{10}	D_{10}	$TØT_8$	$ØC_8$
1	19051	13638	101505	62724
2	20280	10941	76274	65426
3	22172	10963	102322	71300
4	16423	11032	67427	56721
5	19799	11264	75777	65301
6	18056	10908	72233	61525
7	16779	11056	67457	56751
8	15107	10367	64176	53575
9	13604	10165	63664	53030
10	16643	11012	67403	56704
11	20910	11170	77641	67107
12	15939	10523	65432	54724
13	21192	11547	101432	70076
14	14067	15068	75333	53655

4. Note that the same module may appear in more than one link. The following table (Figure 17) shows which link each module occurs in on the 1108.

5. Each link may have unresolved references. They are as follows:

   LINK1 -- LINK, SEMTRN, LD45, LD46, LD47, LD48, LD50, LD51, NCLØS$

   LINK2 -- NCLØS$, LINK, TA1D, TA1E

   LINK3 -- NCLØS$, LINK, KBEAM, MBEAM

   LINK4 -- NCLØS$, LINK

   LINK5 -- NCLØS$, LINK

   LINK6 -- NCLØS$,RSTTVV, LINK

   LINK7 -- NCLØS$, LINK

   LINK8 -- NCLØS$, LINK

   LINK9 -- NCLØS$, LINK

```
LINK10 -- NCLØS$, LINK
LINK11 -- NCLØS$, LINK
LINK12 -- NCLØS$, LINK
LINK13 -- NCLØS$, LINK, SBEAM1, SBEAM2
LINK14 -- NCLØS$, LINK
```

MSGWRT
USRMSG

BTSTRP
ENDSYS
SEARCH
ENDSSS

RPDABD
XCEI
XCHK
XPURGE
XPOLCK
XSFRI

OSCENT
ESFR

02

GNFIAT
TTLPGE
XCSA
XRGDFM
XSPGET

XCSABF

LOOI

L002

L003

L004

L005

L006

L007

L008

YTRACE
SEMDBD
XSEM1
MAIN1
NTAB
BITPOS
XNSTRN
XDPL
XSORBD
XSRTBD
SETUP

XRCARD

TAPBIT
GOPEN

LD09 | LD10 | LD11 | LD12 | LD13 | Q6

SORT | Q7

IFP1
IFP1B
IFP1C
IFP1D
IFP1E
IFP1F
IFP1G
GWSRT
IFPABD
IFP1XY
FNDPLT
IFP1A

IFP1X | Q8

IFP4B
IFP4C
IFP4E
IFP4F
IFP4G
BISRCH

IFP4
IFP4A

IFP4ZZ | Q10

IFP5
IFP5A

IFP5ZZ | Q11 | Q9

XSORT
ESORT

LINK 1

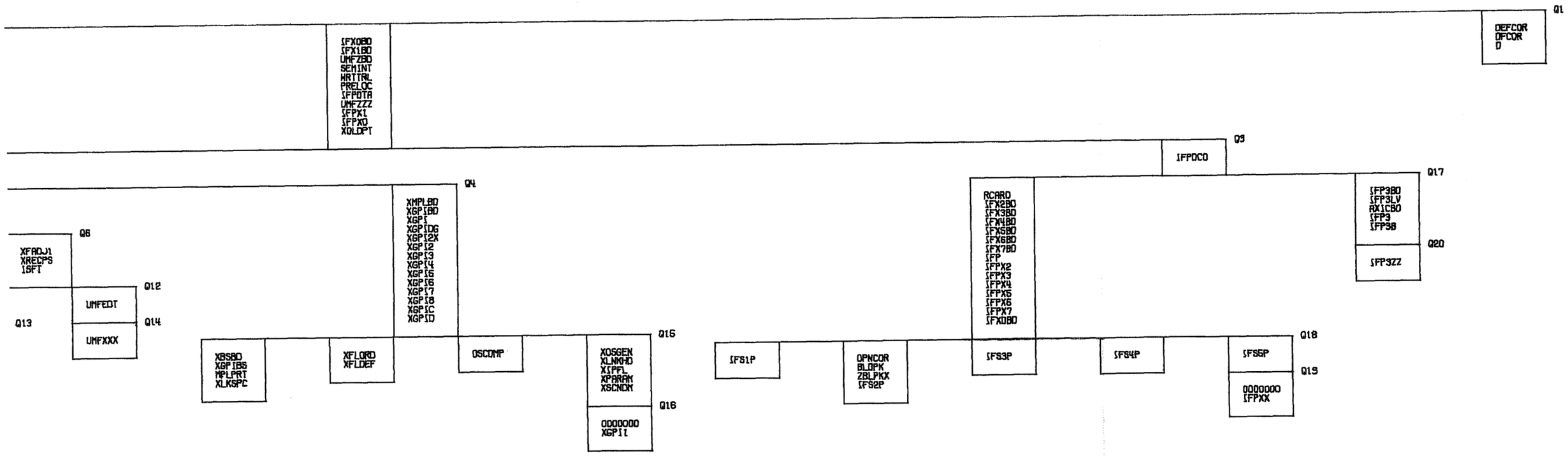
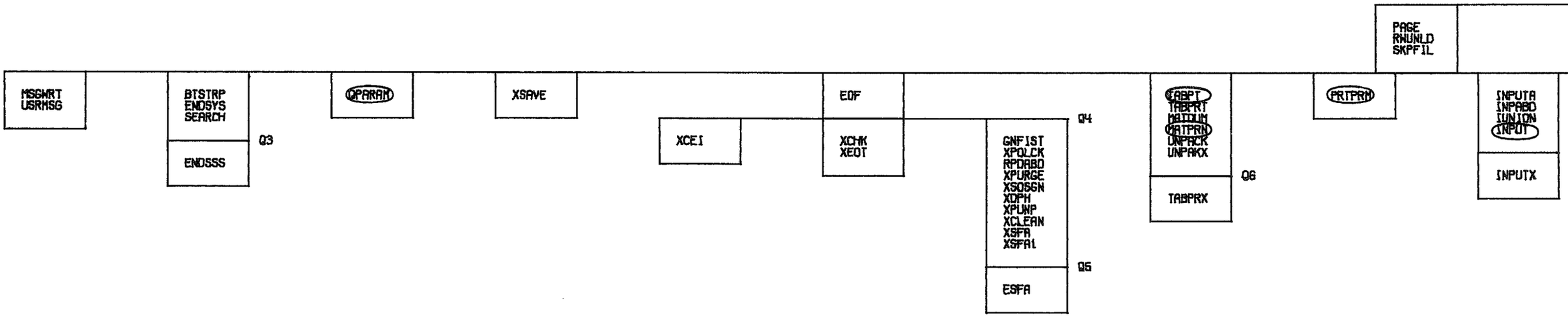
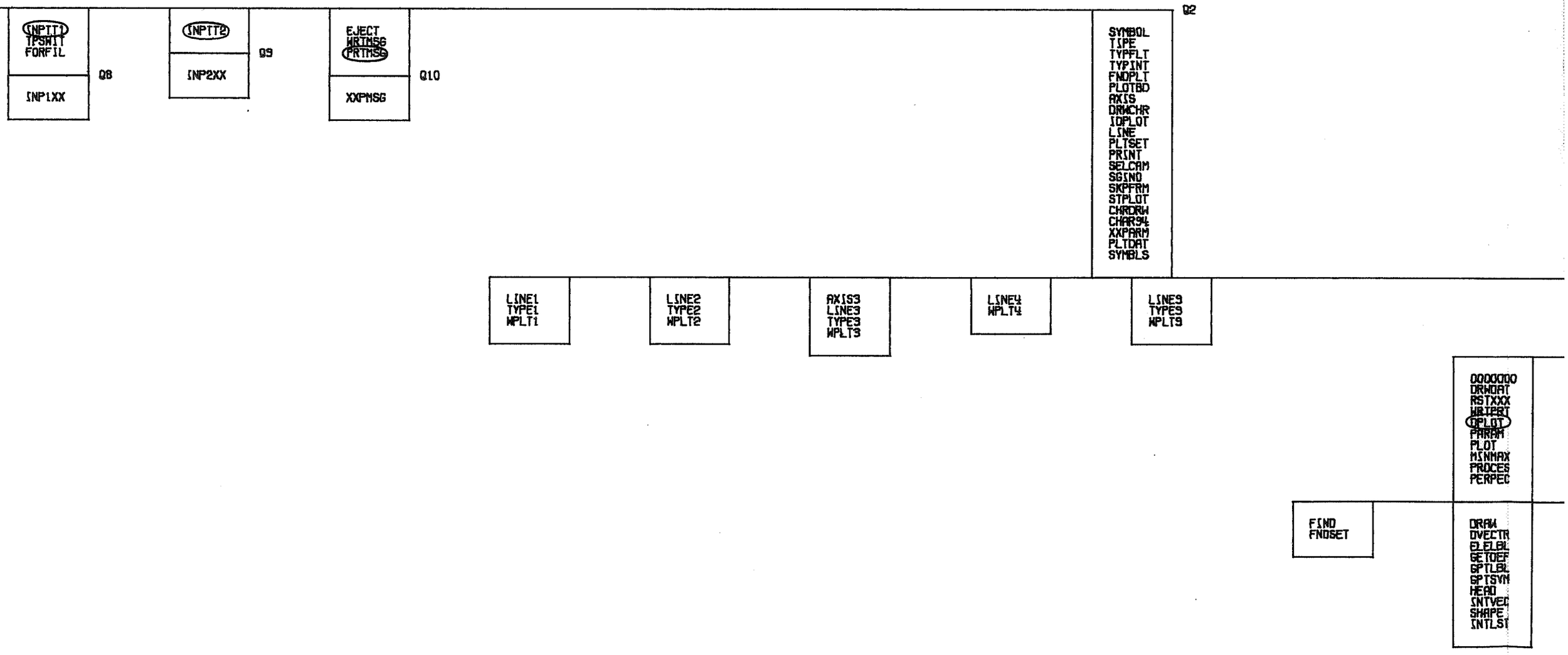


Figure 2. Overlay Structure for Link 1 on the UNIVAC 1108.


MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
XCEI
EOF
XCHK
XEOT
Q4
GNFIST
XPOLCK
RPDABD
XPURGE
XSOSGN
XDPH
XPUNP
XCLEAN
XSFA
XSFAL
ESFA
Q5
QABPT
TABPRT
MAIDUM
MATPRN
UNPACK
UNPAKX
TABPRX
Q6
PRTPRM
PAGE
RWUNLD
SKPFIL
INPUTA
INPABD
JUNION
INPUT
INPUTX
Q7


INPTT1
TPSWTT
FORFIL
INP1XX
Q8
INPTT2
INP2XX
Q9
EJECT
WRTMSG
PRTMSG
XXPMSG
Q10
Q2
SYMBOL
TYPE
TYPFLT
TYPINT
FNDPLT
PLOTBD
AXIS
DRWCHR
IDPLOT
LINE
PLTSET
PRINT
SELCAM
SGINO
SKPFRM
STPLOT
CHRDRW
CHAR94
XXPARM
PLTDAT
SYMBLS
LINE1
TYPE1
WPLT1
LINE2
TYPE2
WPLT2
AXIS3
LINE3
TYPE3
WPLT3
LINE4
WPLT4
LINE9
TYPE9
WPLT9
QQQQQQQ
DRWDAT
RSTXXX
WBIBRT
QPLOT
PARAM
PLOT
MINMAX
PROCES
PERPEC
FIND
FNDSET
DRAW
DVECTR
ELELBL
GETDEF
GPTLBL
GPTSYM
HEAD
INTVEC
SHAPE
INTLST

YTRACE
SEMOBO
XSEM2
MAIN2
NTAB
TAPBIT
CLSTAB
CLOSE
FREAD
WRITE
GOPEN
OPEN
READ
BCKREC
MESAGE
FNAME
FWDREC
REWIND
X6INO
INTPK
GINOIO
MAPFNS
RDMODX
WRTTRL
PEXIT
PPDUMP
SSWTCH
UTIL
GINO

SETVAL

SORT

GP1
GPA1
Q19

GP2
GPA2
Q20

GP3COM
GP3D
BISRCH
GP3
GP3A
GP3B
GP3BD
GP3C
GP3COR
Q21

TA1A
TAA1
Q23

TA1B
TAA2
Q24

AXIS1D
LINE1D
TYPE1D
WPLT1D
Q11

SEEMAP
MAPSET
SEENTX
Q15

XYPLOT
XYPLIN
XYPLXX
Q16
Q12

PLTOPR
Q13

OOOOOOO
XXPLOT
Q14

LINK 2

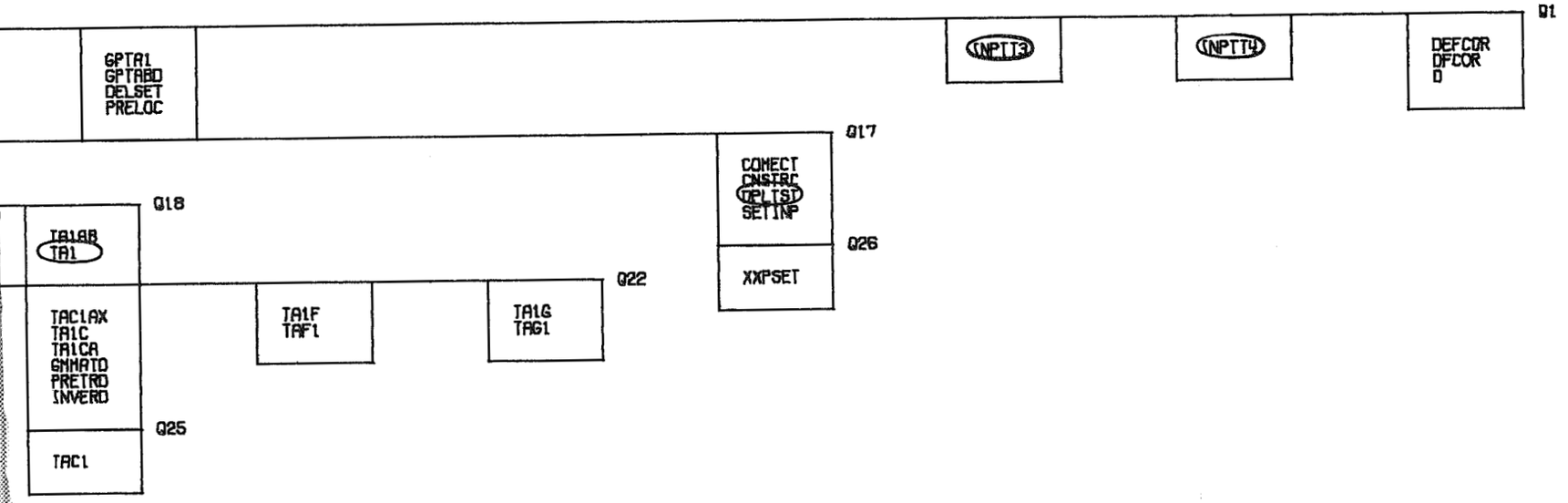
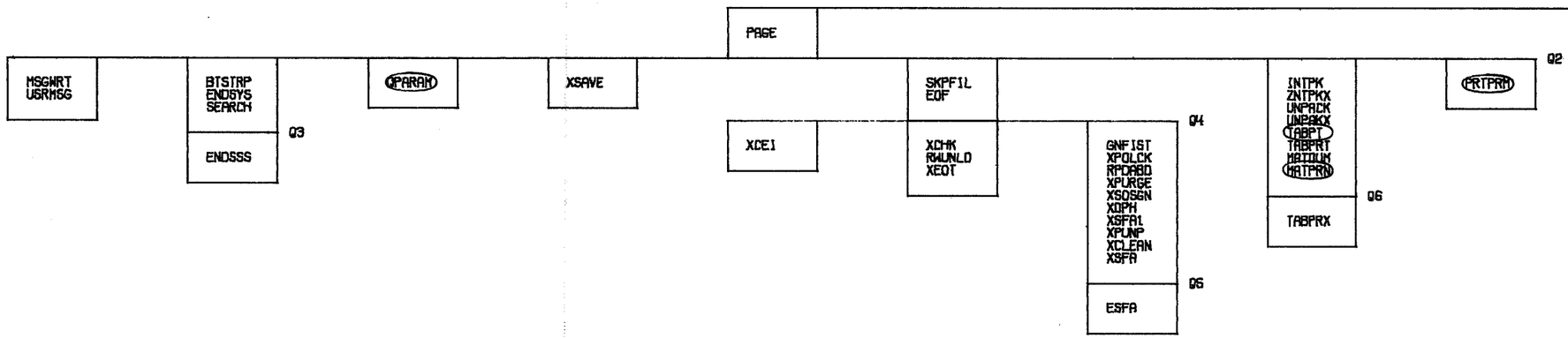
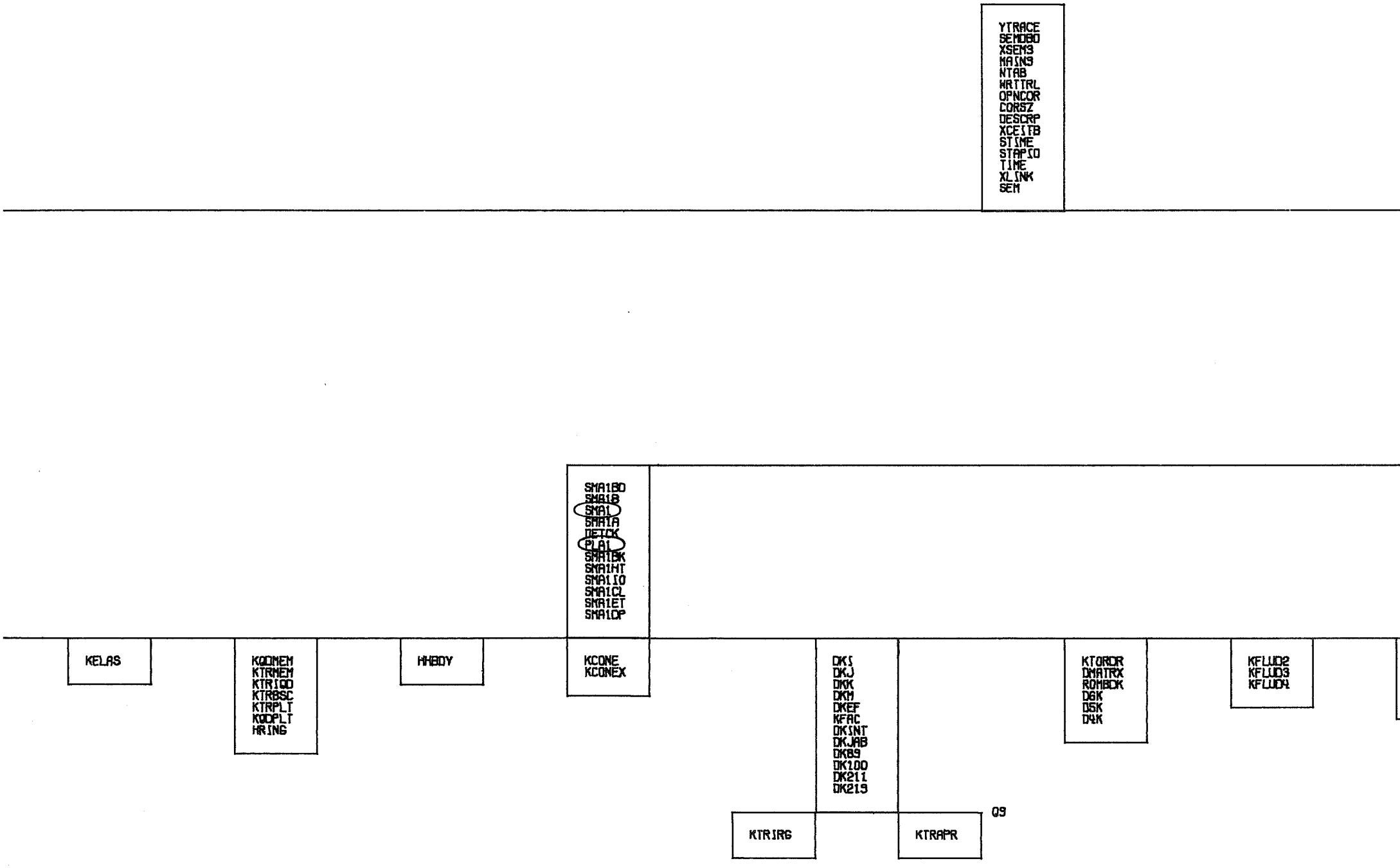


Figure 3. Overlay Structure for Link 2 on the UNIVAC 1108.


MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
PAGE
XCEI
SKPF1L
EOF
XCHK
RWUNLD
XEQT
Q4
GNFIST
XPOLCK
RPDABD
XPURGE
XSOSGN
XDPH
XSFA1
XPUNP
XCLEAN
XSFA
ESFA
Q5
Q6
INTPK
ZNTPKX
UNPACK
UNPAKX
TABPT
TABPRT
MATDUM
MATPRN
TABPRX
PRTPRM
Q2
KROD
KTUBE
KBAR
KPANEL


YTRACE
SEMOBO
XSEM3
MAIN3
NTAB
WRTTRL
OPNCOR
CORSZ
DESCRP
XCEITB
STIME
STAPID
TIME
XLINK
SEM
SMA1BD
SMA1B
SMAL
SMA1A
DEICK
PLAL
SMA1BK
SMA1HT
SMA1IO
SMA1CL
SMA1ET
SMA1DP
KELAS
KQDMEM
KTRMEM
KTRIQD
KTRBSC
KTRPLT
KQDPLT
HRING
HHBDY
KCONE
KCONEX
DKI
DKJ
DKK
DKM
DKEF
KFAC
DKINT
DKJAB
DK89
DK100
DK211
DK215
KTRIRG
KTRAPR
09
KTORDR
DMATRX
ROMBDK
D6K
D5K
D4K
KFLUID2
KFLUID3
KFLUID4

GPTABD
DELSET
GMMATD
PRETRD
INVERD
GMMATS
PREMAT
HMAT
BISRCH
SAXB
SADDTB
DAXB
DADDTB
PRELOC
BLOPK
HMATDD
ZBLPKX
GPTAL
HMTOUT

Q7

SMA2
SMA2BD
SMA2A
SMA2B
SMA2BK
SMA2IO
SMA2ET
SMA2CL
SMA2DP

MASSD
BVISC
MCONMX

MCONE

MFLUD2
MFLUD3
MFLUD4
MFREE

MTRIRG
MTRAPR
MTORDR
DMI
DMJ
DMK
DMM
DMEF
DMINT
MFAC
DMJAB
DM89
DM100
DM211
DM219

Q8

KTETRA
KSOLID
KPLTST
KSLOT

KDUM1
KDUM2
KDUM3
KDUM4
KDUM5
KDUM6
KDUM7
KDUM8
KDUM9

Q10

0000000
SMA1X

MROD
MBAR
MTUBE

MCROD

MCBAR

Q12

MTRBSC
MQDPLT
MTRPLT
MTRIQD
MASSTQ

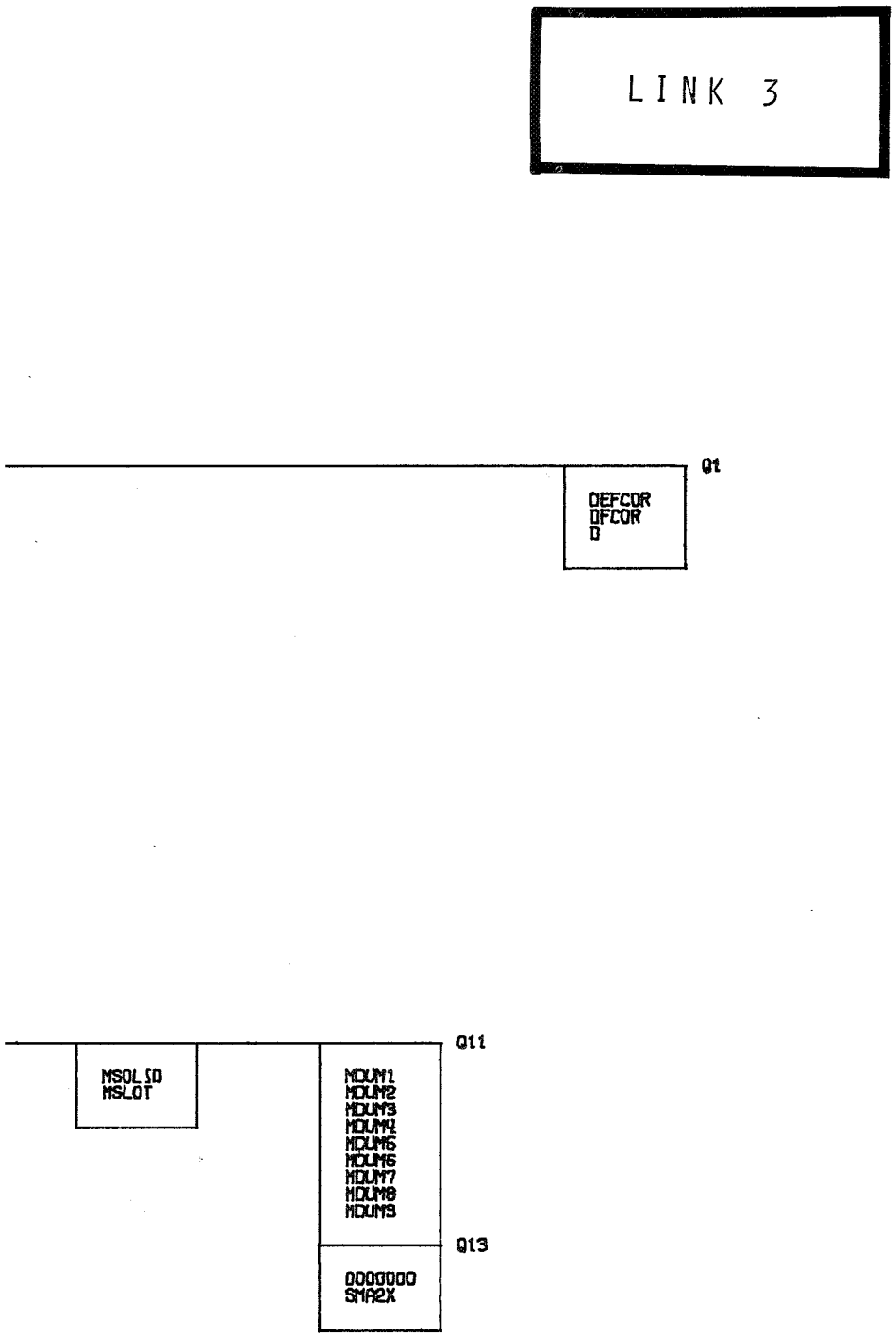
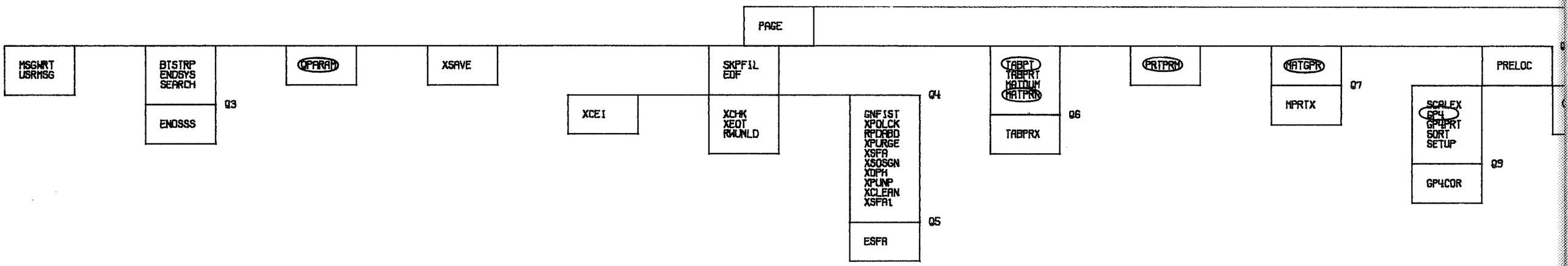
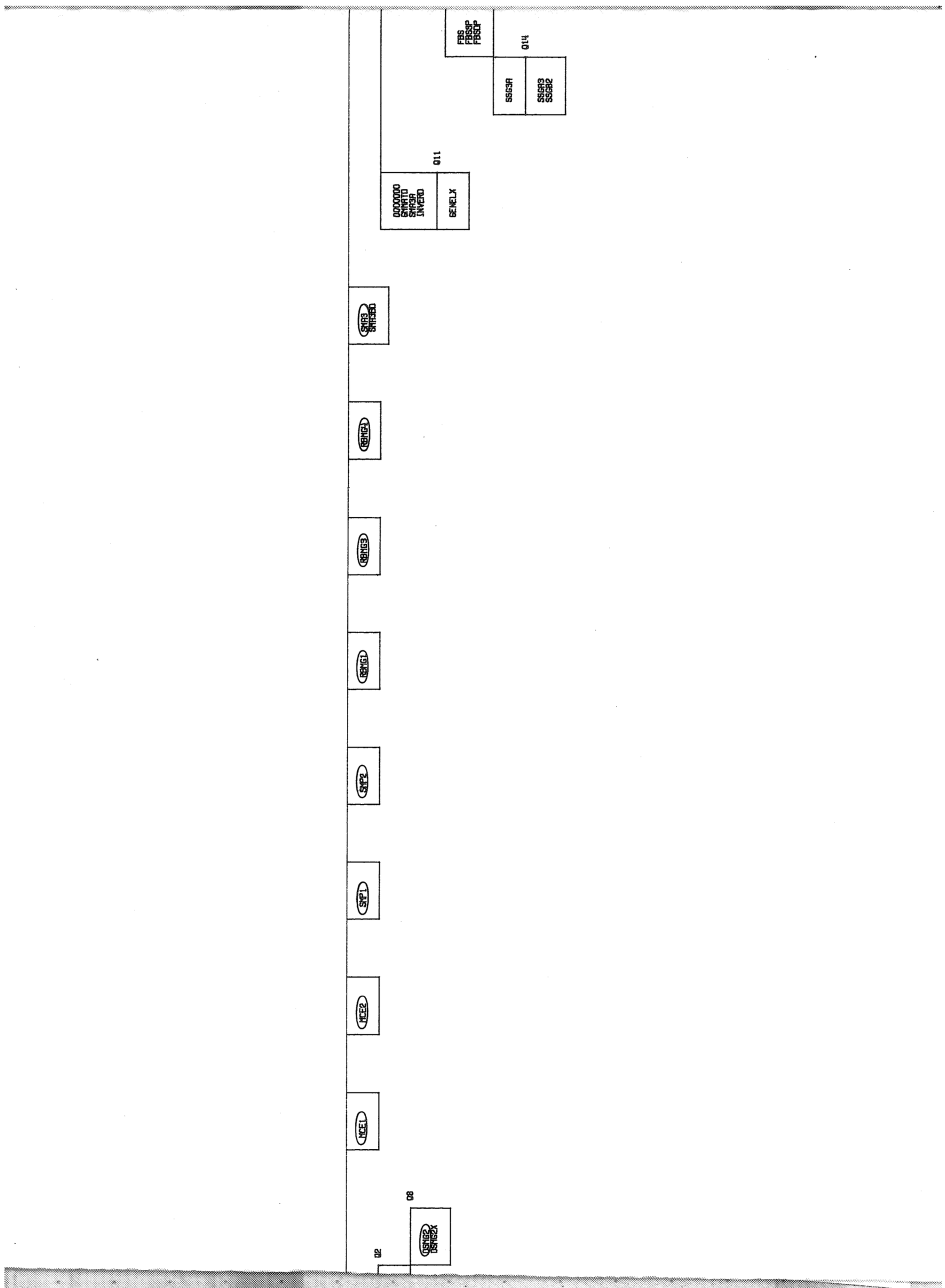
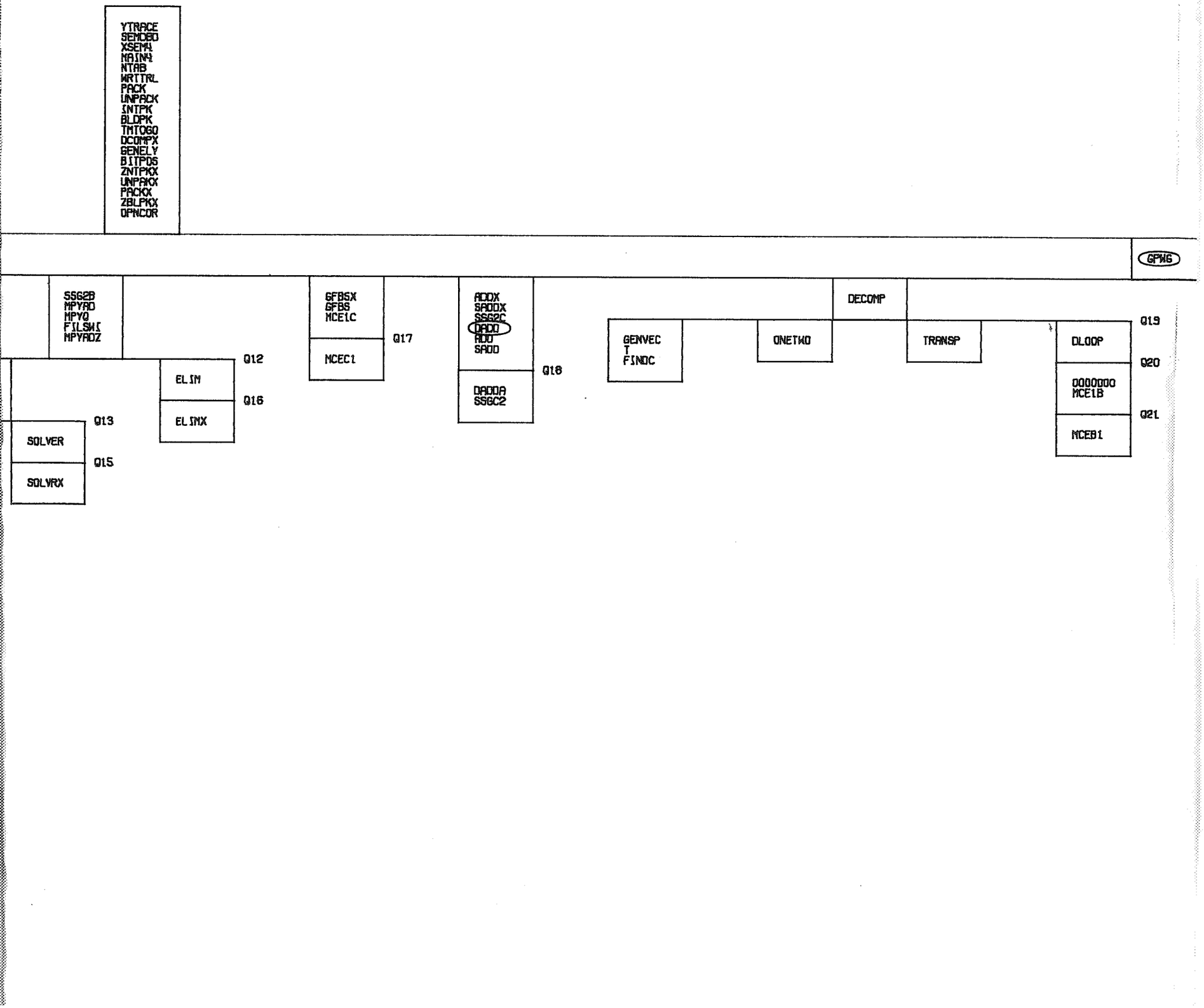


Figure 4. Overlay Structure for Link 3 on the UNIVAC 1108.


PAGE
MSGWRT
UBRMSG
BTSTRP
ENDSYS
SEARCH
Q3
ENDSSS
QPARAM
XSAVE
XCEI
SKPFIL
EOF
XCHK
XEOT
RWUNLD
Q4
GNFIST
XPOLCK
RPDABD
XPURGE
XSFA
XSOSGN
XDPH
XPUNP
XCLEAN
XSFA1
Q5
ESFA
TABPT
TABPRT
MATDUM
MATPRN
Q6
TABPRX
PRTPRM
MATGPR
Q7
MPRTX
PRELOC
SCALEX
GP4
GP4PRT
SORT
SETUP
Q9
GP4COR


D2
D8
XSHSI
DSNG2
MCE1
MCE2
SNP1
SNP2
RBNG1
RBNG3
SNP3
SNP3D
D11
BENELX
0000000
GNMATD
SNP3R
INVERD
D11
SSG3R
SSGB3
SSGB2
D11
FBS
FBSSP
FBSDP


YTRACE
SEMDBD
XSEM4
MAIN4
NTAB
WRTTRL
PACK
UNPACK
INTPK
BLDPK
TMTOGO
DCOMPX
GENELV
BITPOS
ZNTPKX
UNPAKX
PACKX
ZBLPKX
OPNCOR
GPWG
SSG2B
MPYAD
MPYQ
FILSHI
MPYADZ
Q12
ELIM
ELIMX
Q16
Q13
SOLVER
SOLVRX
Q15
GFBSX
GFBS
MCE1C
MCEC1
Q17
ADDX
SADDX
SSG2C
DADD
ADD
SADD
DADDA
SSGC2
Q18
DECOMP
GENVEC
T
FINDC
ONETWO
TRANSP
DLOOP
Q19
Q20
0000000
MCE1B
Q21
MCEB1

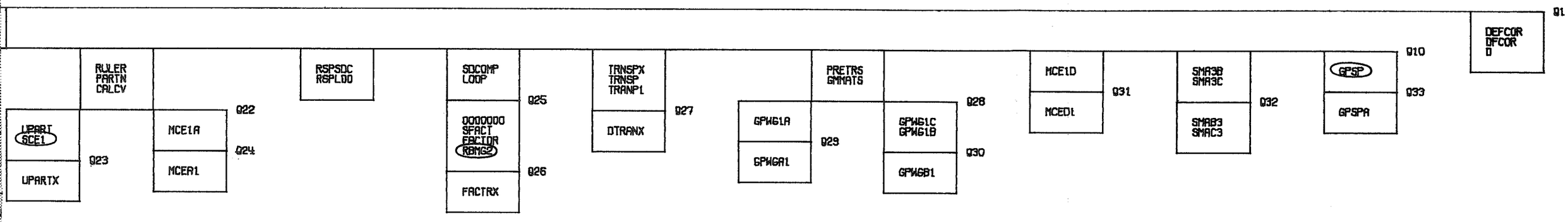
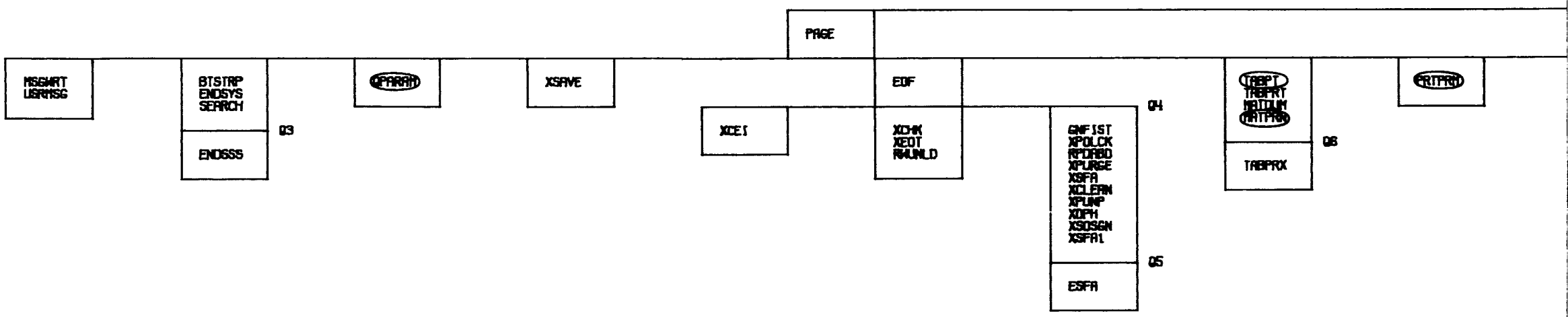
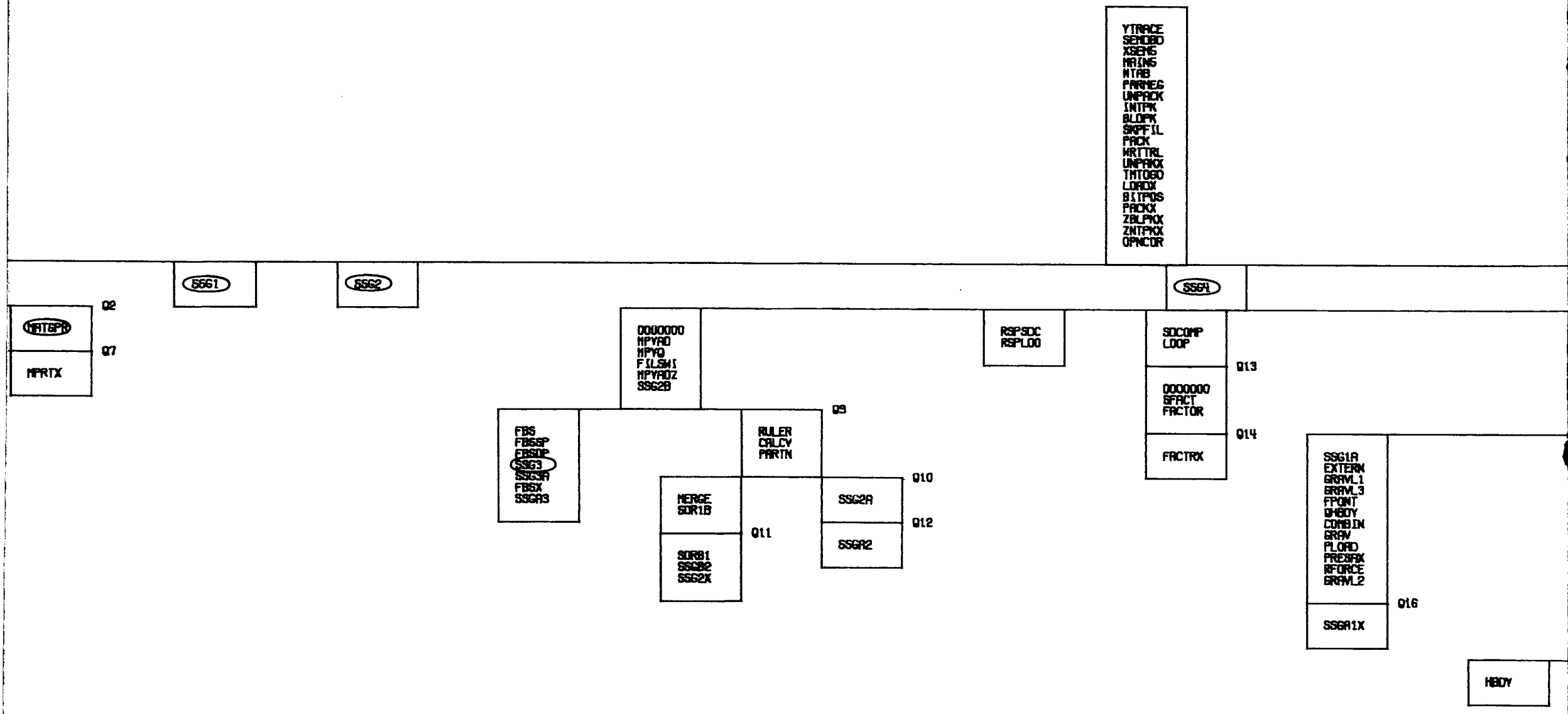


Figure 5. Overlay Structure for Link 4 on the UNIVAC 1108.


PAGE
MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
XCEI
EOF
XCHK
XEOT
RAUNLD
Q4
GNFIST
XPOLCK
RPDRBD
XPURGE
XSFA
XCLEAN
XPUMP
XDPH
XSOSGN
XSFA1
Q5
ESFA
TRBPT
TRBPRT
MBTDUM
MBTPRN
TABPRX
Q6
ERTPRO


YTRACE
SEMOBD
XSEMS
MRINS
MTAB
PARMEG
UNPACK
INTPK
BLOPK
SKPFIL
PACK
MRTTRL
UNPACK
TMTOGO
LOADX
BITPOS
PACKX
ZBLPKX
ZNTPKX
OPNCOR
SSG1
SSG2
SSG4
Q2
MATGPB
Q7
MPRTX
OOOOOOO
MPYAD
MPYQ
FILSMI
MPYADZ
SSG2B
Q8
RSPSDC
RSPLOO
SDCOMP
LOOP
Q13
OOOOOOO
SFACT
FACTOR
Q14
FACTRX
FBS
FBSSP
FBSDP
SSG3
SSG3A
FBSX
SSGA3
RULER
CALCV
PARTN
Q10
MERGE
SOR1B
Q11
SSG2A
Q12
SSGA2
SOR1
SSGB2
SSG2X
SSG1A
EXTERN
GRAVL1
GRAVL3
FPONT
QHBDY
COMBIN
GRAV
PLOAD
PRESPX
RFORCE
GRAVL2
Q16
SSGA1X
HBDY

LINK 5

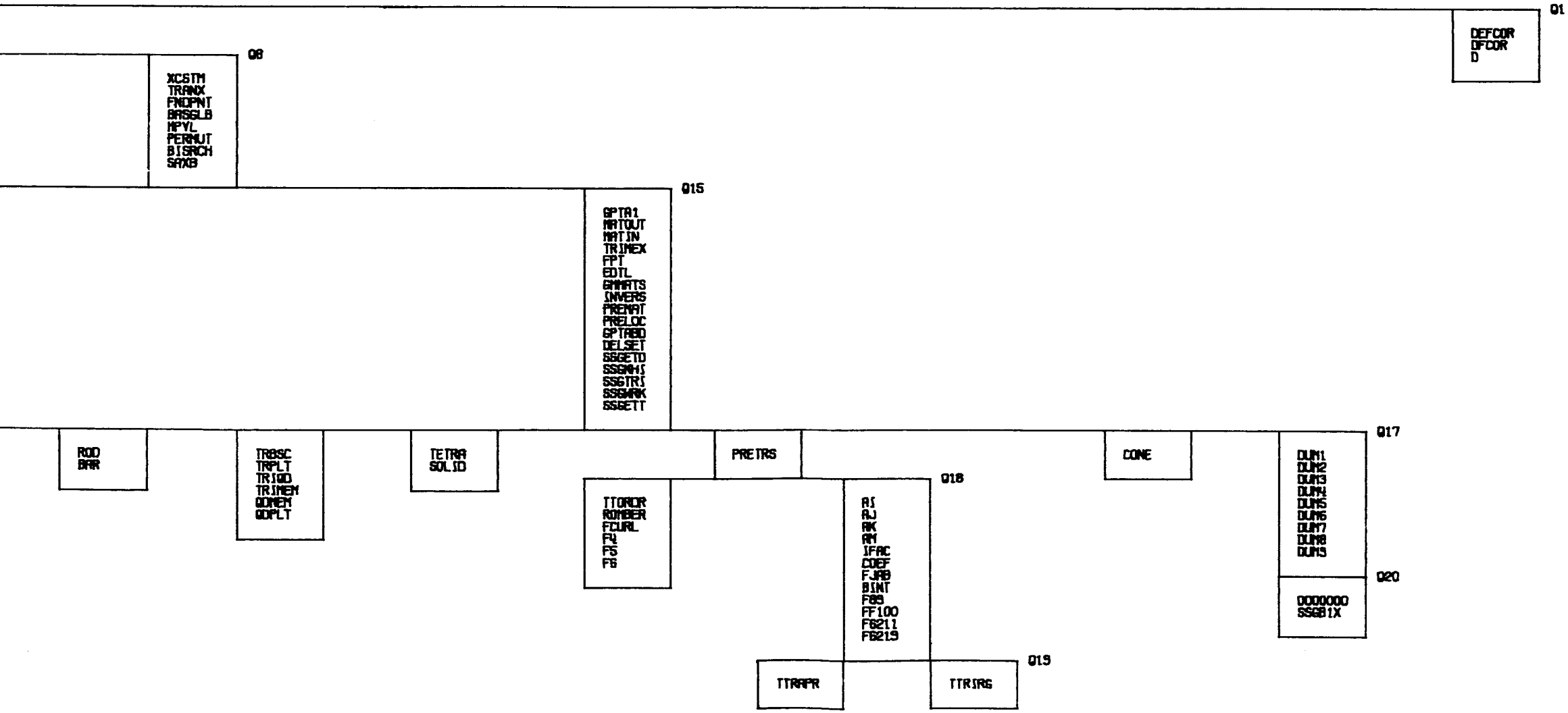
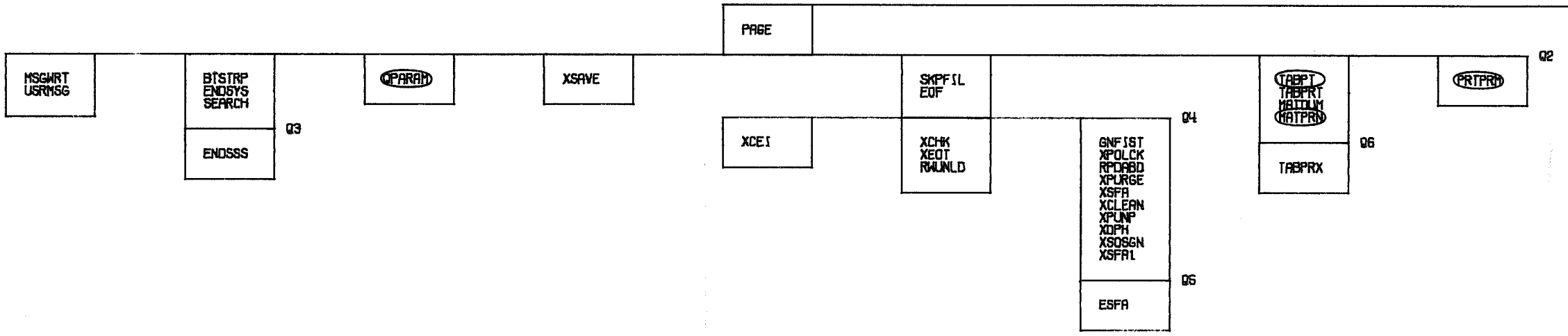


Figure 6. Overlay Structure for Link 5 on the UNIVAC 1108.


MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
PAGE
XCEI
SKPFIL
EOF
XCHK
XEOT
RWUNLD
Q4
GNFIST
XPOLCK
RPOABD
XPURGE
XSFA
XCLEAN
XPUNP
XDPH
XSOSGN
XSFAL
Q5
ESFA
TABPT
TABPRT
MATTOM
MATPRN
TABPRX
Q6
PRTPRM
Q2

YTRACE
SEMDBG
XSEMG
MAING
NTAB
SFACT
ADDX
SADDX
WRTTRL
INTPK
UNPACK
ZNTPKX
BITPOS
UNPAKX
OPNCOR

BLOPK
PACK
REIGKR
GIVN
GOPEN
INVPWX
REGERN
ZBLPKX
PACKX
REIG
READBD
PRELOC
TMTOGO

SETUP
DPDCOM
SQRT
DPDCBD
DPD
DPDAA
DPD1
DPD2
DPD3
DPD4
DPD5

DPDCOR

Q8

SSG2B
MPYAD
MPYQ
FILSWI
RULER
CALCV
MERGE
MPYADX
MPYADZ

READ1
SDR1B

READ1A
SDRB1

Q10

READ2
READ3
READ4
ORTCK

READ2A
SSGB2
INVP4X

Q9

Q11

GENVEC
T
FINDC

DECOMP

ONETWO

TRANSP

DLOOP

Q14

ADD
SADD

RSPSDC
RSPLOO

INVPXX
INVPWR

Q12

INFBSX
NORM1
SUB
INVP3
XTRNSY
MTINSU
INVFBS
FBSINV
INVFSP
INVP3X

EMPCOR
ROTAX
SICOX
FILCOR
WILVEC
QRITER
TRIDI
SMLEIG
VALVEC
XXVLVC

Q13

SDCOMP
LOOP

Q15

0000000
FACTOR
FACTRX

Q16

0000000
DETMX
DETM
DETDET
EADD
SQRTM

INVP2V
INVP1
INVP2
INVPX
INVP1X
INVP2X

Q19

0000000
REIGA

Q17

DETM1
DETM3
ARRM
SUMM

DETM4
DETM5
FDVECT
DETFBS

Q18

0000000
DETDX

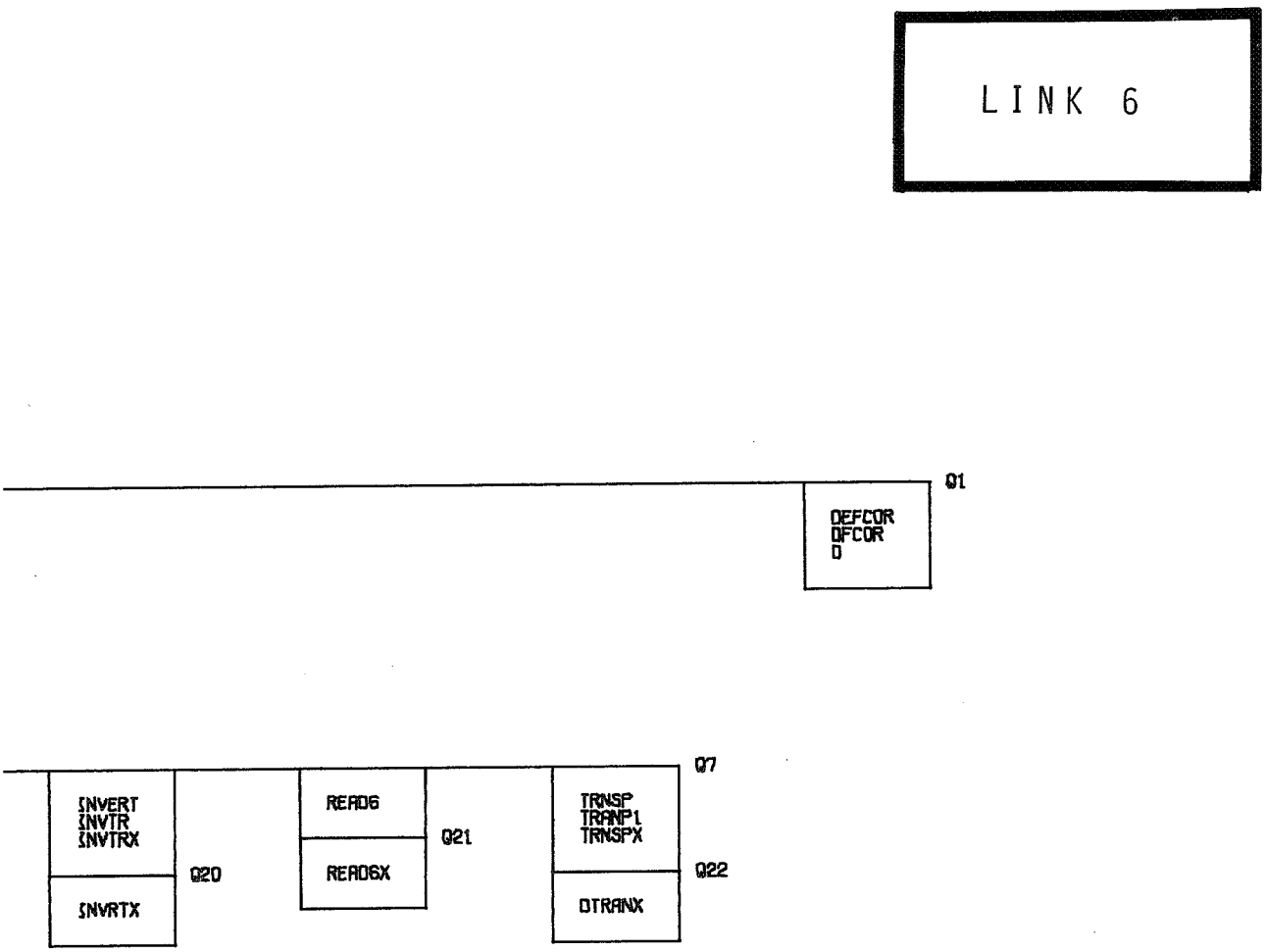
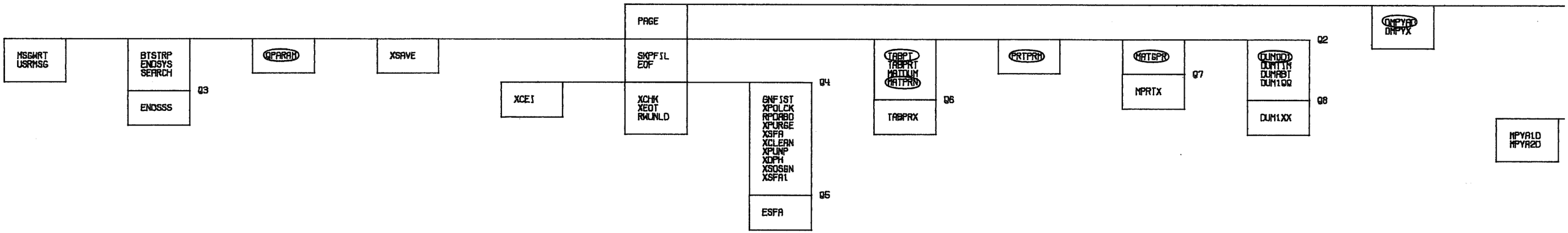


Figure 7. Overlay Structure for Link 6 on the UNIVAC 1108.


PAGE
MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
Q3
ENDSSS
QPARAM
XSAVE
XCEI
SKPFIL
EOF
XCHK
XEOT
RWUNLD
Q4
GNFIST
XPOLCK
RPORBD
XPURGE
XSFA
XCLEAN
XPUNP
XDPH
XSOSGN
XSFA1
Q5
ESFA
TABPT
TABPRT
MAIDUM
MATPRM
Q6
TABPRX
PRTPRM
MATGPR
Q7
MPRTX
DUM1CD
DUM11M
DUMABT
DUM1QQ
Q8
DUM1XX
Q2
DMPYAD
DMPYX
MPYA1D
MPYA2D

YTRACE
SEMOBO
XSEM7
MAIN7
NTAB
UNPACK
SNTPK
BLOPK
PACK
WRTTRL
BITPOS
ADDX
MPYADX
FBSX
DCOMPX
CDCMPX
SFACT
TMTOGO
GFBSX
ZBLPKX
ZNTPKX
UNPAKX
PACKX
OPNCOR

0000000
DMPY
MPYAD
MPYQ
FILSW1
MPYADZ

Q10

FBS
FBSSP
FBSDP

SOLV2X
DFBS1X

Q11

SADDX
ADD
DADD
SADD
DADDS

MPYA3D
DADDA

Q13

RSPSDC
RSPLOO

SDCOMP
LOOP

0000000
SOLV1X
DECP1X

Q19

DUM002

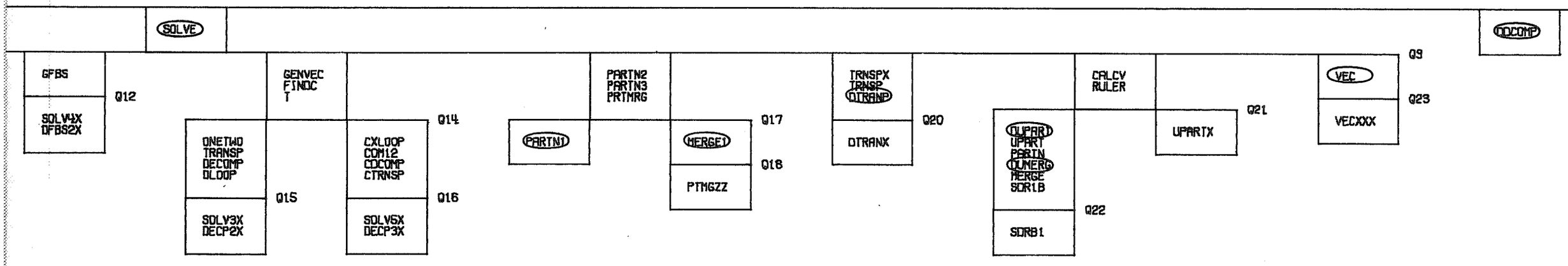
DUM003

DUM004

MODA

MODB

MODC


SOLVE
GFBS
SOLV4X
DFBS2X
Q12
ONETWO
TRANSP
DECOMP
DLOOP
SOLV3X
DECP2X
Q15
GENVEC
FINDC
T
CXLOOP
COM12
CDCOMP
CTRNSP
SOLV5X
DECP3X
Q14
Q16
PARTN1
PARTN2
PARTN3
PRTMRG
MERGE1
PTMGZZ
Q17
Q18
TRNSPX
TRNSP
DTRANP
DTRANX
Q20
DUPART
UPART
PBRIN
DUMERG
MERGE
SDR1B
SDRB1
Q22
CALCV
RULER
UPARTX
Q21
VEC
VECXXX
Q23
Q9
DDCOMP

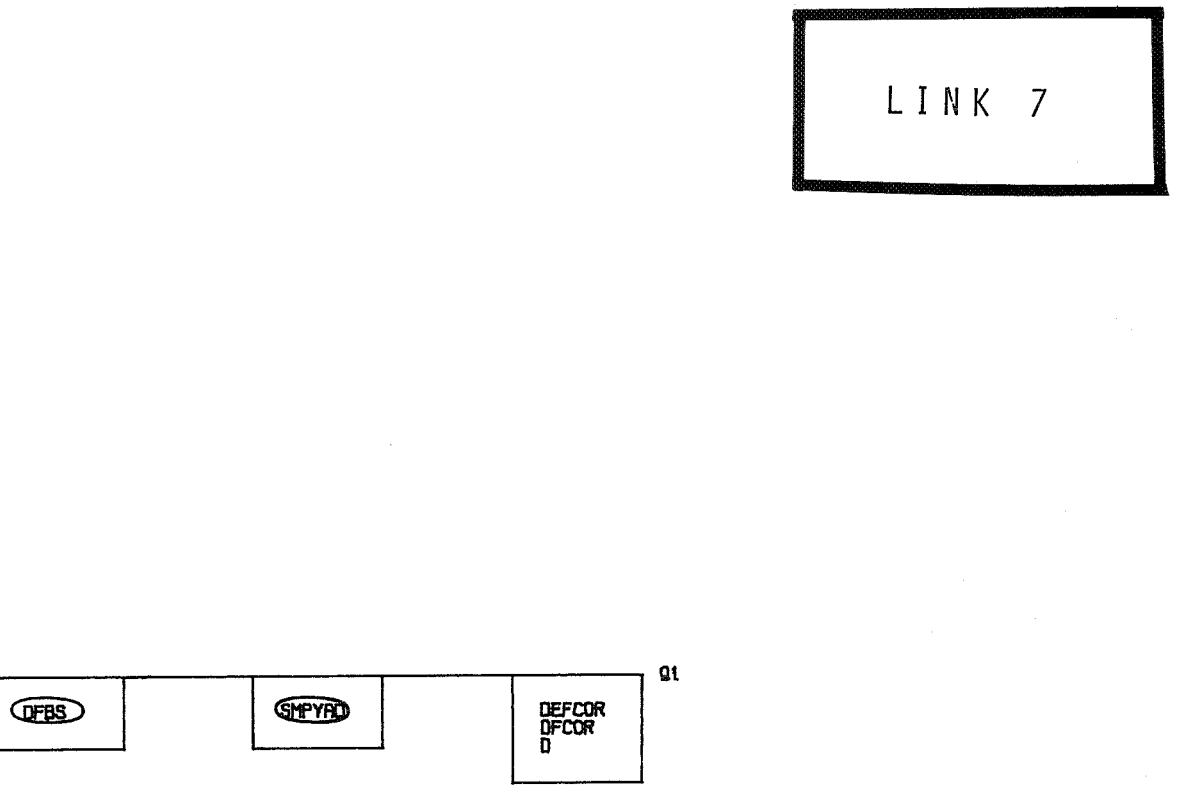


Figure 8. Overlay Structure for Link 7 on the UNIVAC 1108.

MSGWRT
USRMSG

BTSTRP
ENDSYS
SEARCH

ENDSSS

Q2

QPARAM

XSAVE

XCEI

REWIND
SKPFIL
EOF

XCHK
RWUNLD
XEOT

Q3

YTRACE
SEMOBD
XSEMB
MAINB
NTAB
OPNCOR
INTPK
ZNTPKX
UNPACK
PAGE
WRTTRL
UNPAKX
CORSZ
DESCRP
XCEITB
STIME
STAPID
TIME
XLINK
SEM

XSFA1
XSFA
GNFIST
RPORBD
XPOLCK
XOPN
XSOSGN
XCLEAN
XPUNP
XPURGE

ESFA

Q4

TABPT
TABEPT
MATPRN
MATOUM

TABPRX

Q5

PRTPRM

TABFMT
TABFTX

TABFTZ

Q6

XXMPRT
GOPEN
FORMAT
VECPRT
MATPRT
INTPRT
PRTIND
EJECT

XXPRTI

Q7

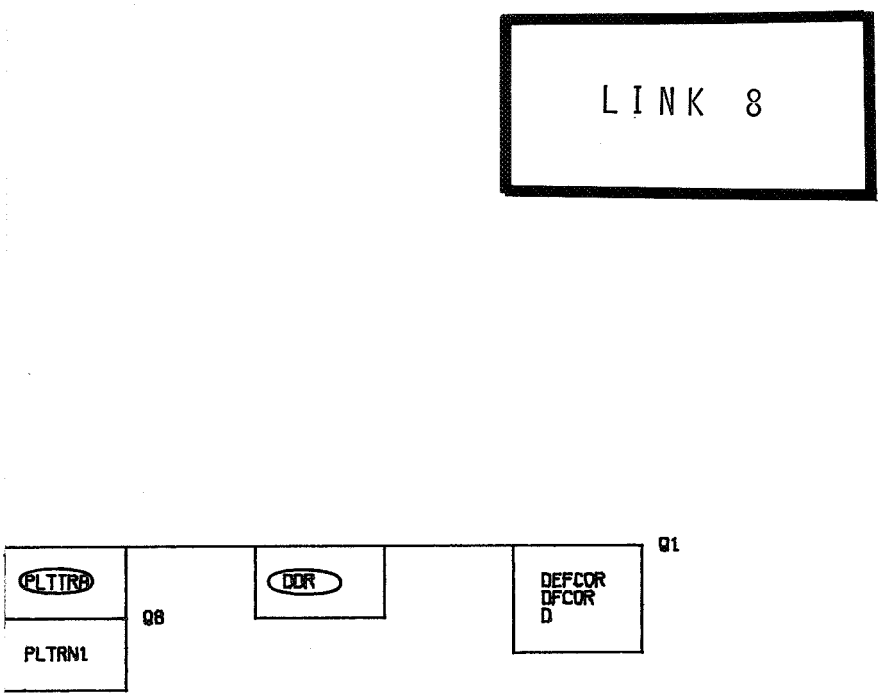


Figure 9. Overlay Structure for Link 8 on the UNIVAC 1108.

YTRACE
SEMOBD
XSEM9
MAIN9
NTAB
BITPOS
CORSZ
DESCRP
XCEITB
STIME
STAPID
TIME
XLINK
SEM
QREADX
TYPE
XMOMSK
QCLNT
GINOX
TWO
NAMES
OUTPUT
XVPS
XPFIST
XXFIAT
XFIST
XFIAT
MSGX

QWRITX
WRITE
BCKREC
FWDREC
PAGE

MSGWRT
USRMSG

BITSTRP
ENDSYS
SEARCH

Q3

ENDSSS

OPARAM

XSAVE

XCEI

REWIND
SKPFIL
EOF

XCHK
XEOT
RWUNLD

Q4

GNFIST
XPOLCK
RPDRBD
XPURGE
XSFA
XCLEAN
XPUNP
XOPN
XSOSGN
NEXP1
ESFA

OPNCOR
INTPK
ZNTPKX
UNPACK
WRTTRL
UNEBKX
TABPT
TABPRT
MRTDUM
MRTPRN

Q5

TABPRX

PRTPRN

SUBVEC

Q2

SVECZZ

Q6

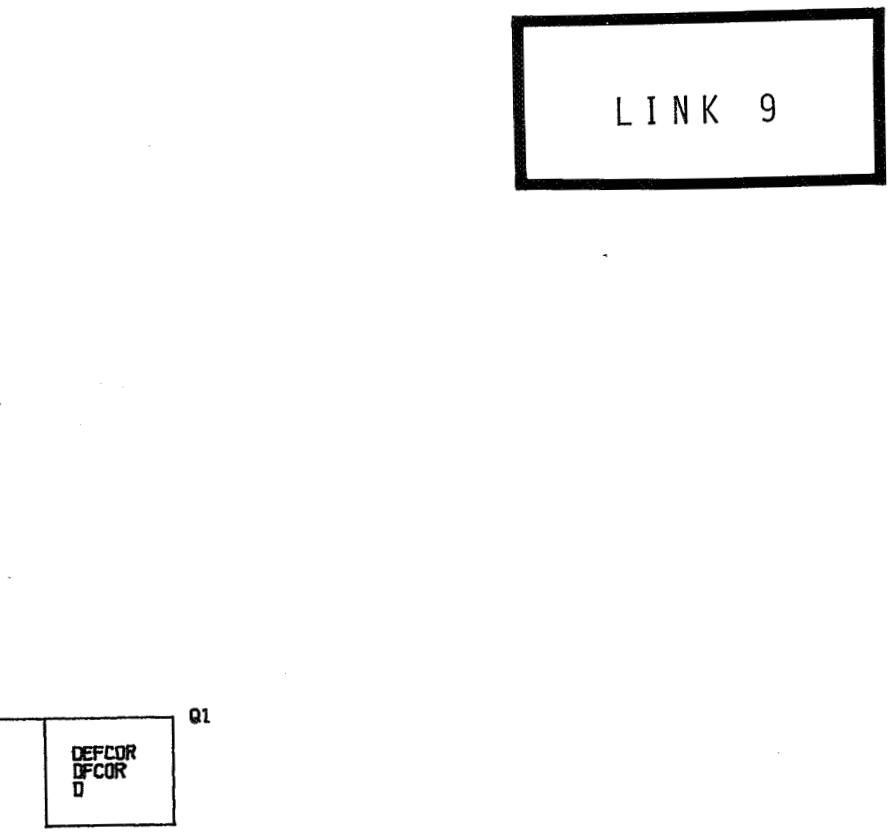
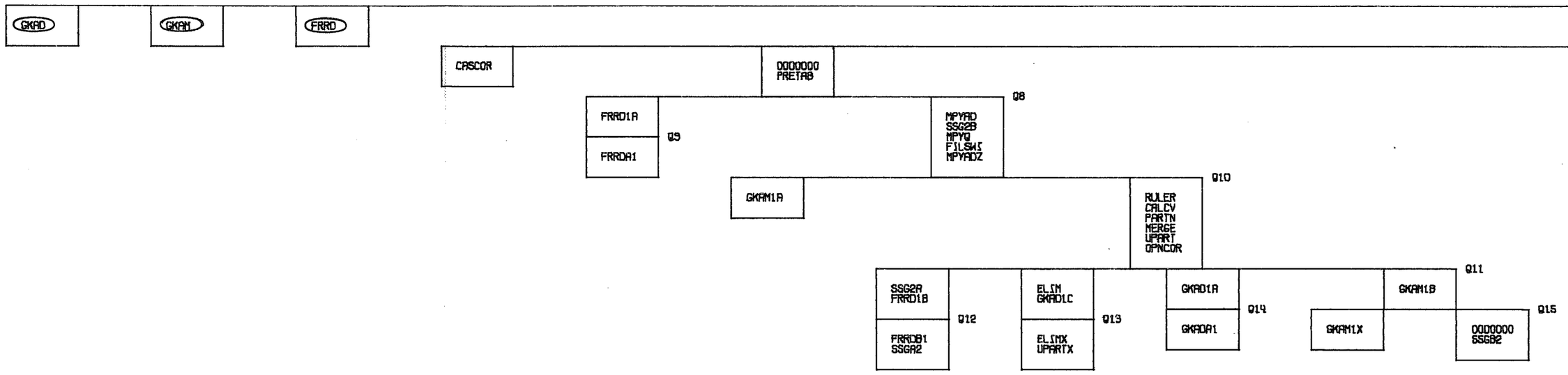
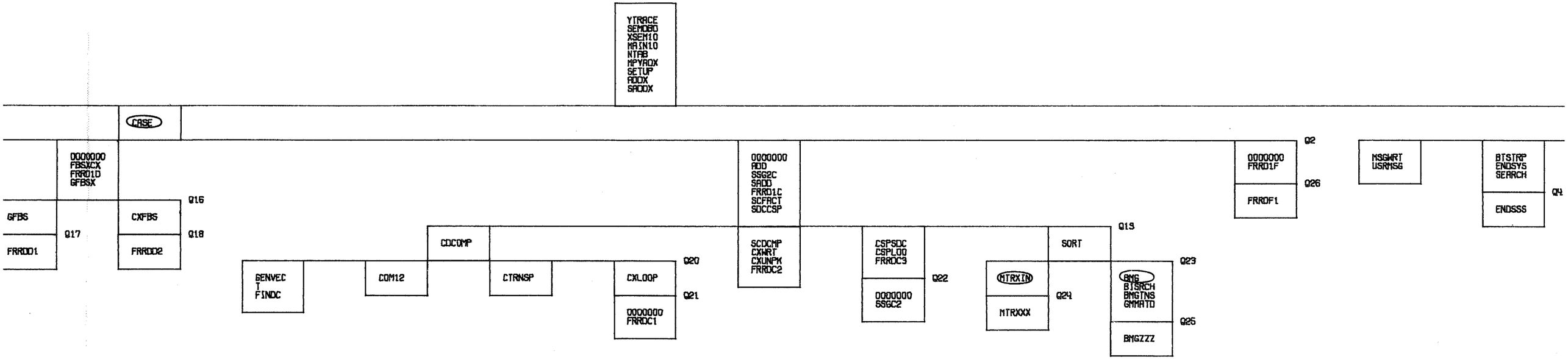


Figure 10. Overlay Structure for Link 9 on the UNIVAC 1108.


GKAD
GKAM
FRRD
CASCOR
0000000
PRETAB
FRRD1A
FRRDA1
Q9
MPYAD
SSG2B
MPYQ
FJLSWI
MPYADZ
Q8
GKAM1A
Q10
RULER
CALCV
PARTN
MERGE
UPART
OPNCOR
SSG2A
FRRD1B
FRRDB1
SSGA2
Q12
ELIM
GKADLC
ELIMX
UPARTX
Q13
GKAD1A
GKADA1
Q14
GKAM1X
GKAM1B
Q11
0000000
SSGB2
Q15


YTRACE
SEMOBO
XSEM10
MAIN10
NTAB
MPYADX
SETUP
ADDX
SADDX
CASE
0000000
FBSXCX
FRRD1D
GFBSX
GFBS
FRRDD1
Q17
CXFBS
FRRDD2
Q16
Q18
CDCOMP
GENVEC
T
FINDC
COM12
CTRNSP
CXLOOP
0000000
FRRDC1
Q20
Q21
0000000
ADD
SSG2C
SADD
FRRD1C
SCFACT
SDCCSP
SCDCMP
CXWRT
CXUNPK
FRRDC2
CSPSDC
CSPLOO
FRRDC3
0000000
SSGC2
Q22
Q13
SORT
MTRXIN
MTRXXX
Q24
BMG
BTSRCH
BMGTNS
GMMATD
BMGZZZ
Q23
Q25
0000000
FRRD1F
FRRDF1
Q2
Q26
MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q4

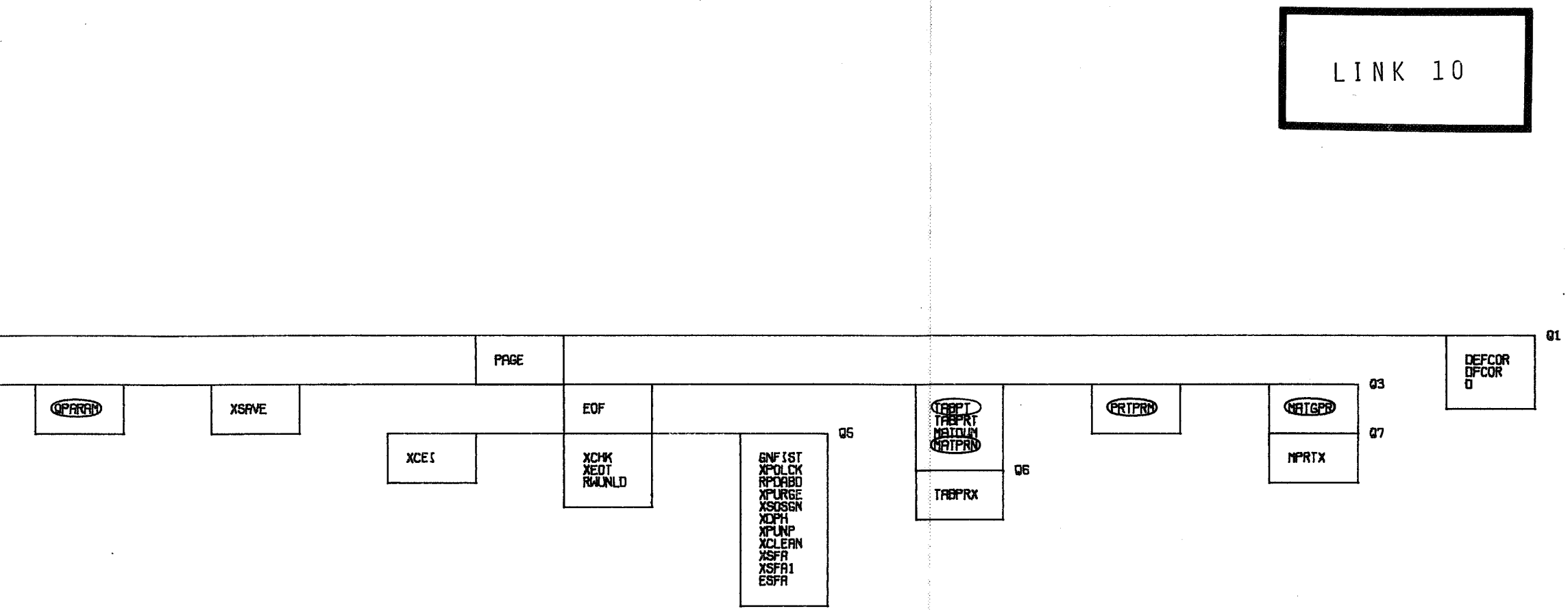
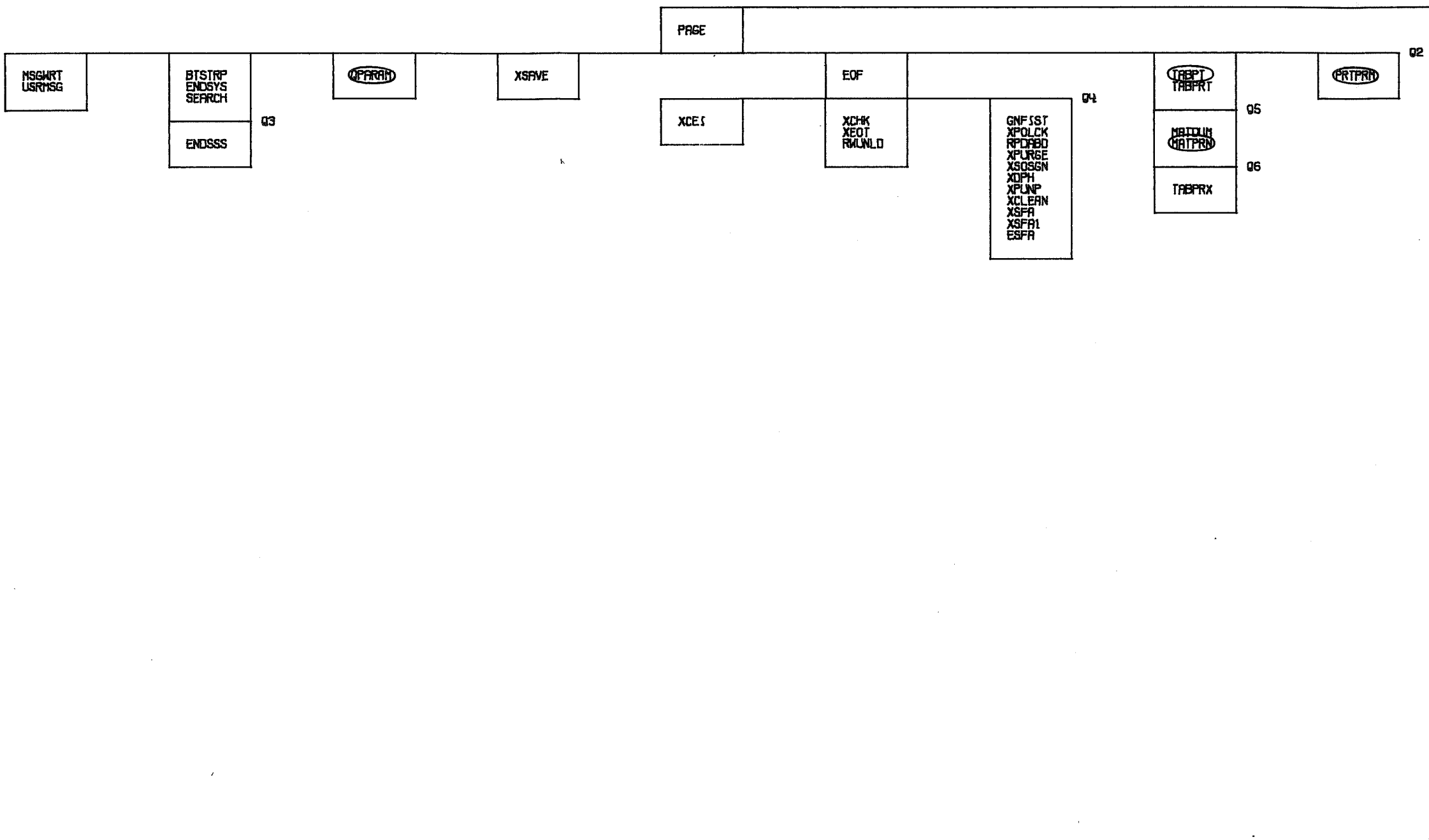
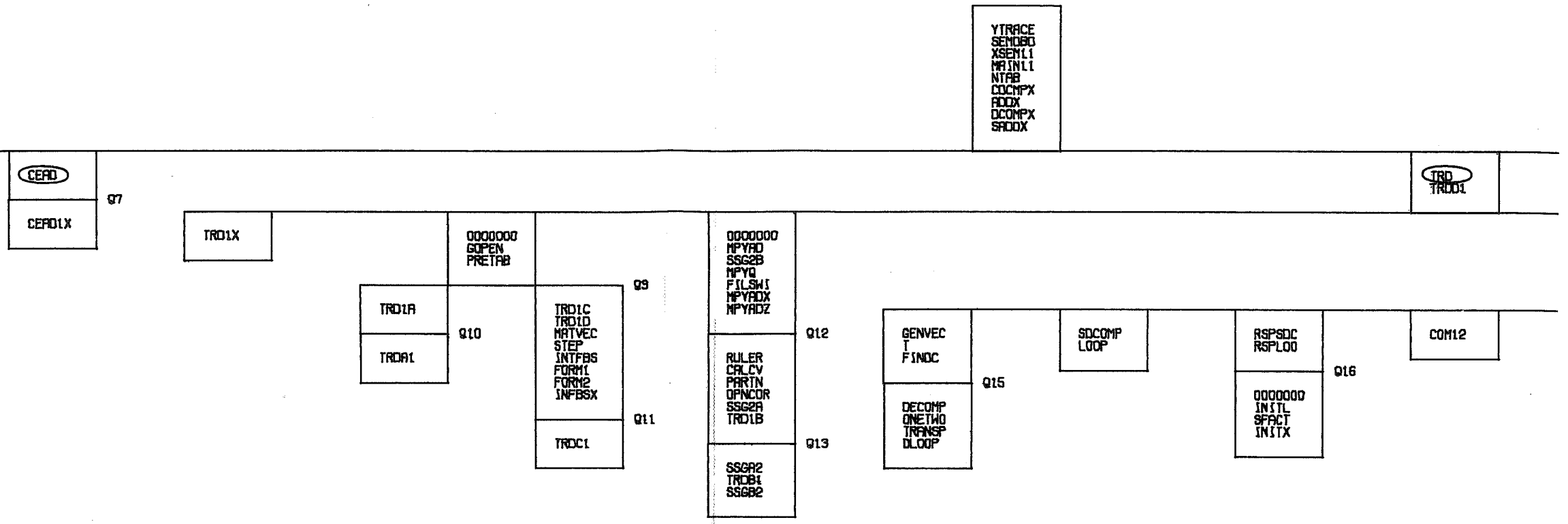


Figure 11. Overlay Structure for Link 10 on the UNIVAC 1108.


MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
PAGE
XCES
EOF
XCHK
XEOT
RWUNLD
Q4
GNFIST
XPOLCK
RPDABD
XPURGE
XSOSGN
XDPH
XPUNP
XCLEAN
XSFA
XSFA1
ESFA
TABPT
TABPRT
MBIOUN
MATPRN
TABPRX
Q5
Q6
PRTPRN
Q2


YTRACE
SEMOBO
XSEM11
MAIN11
NTAB
COCMPX
ADDX
DCOMPX
SADDX
CEAD
CEAD1X
Q7
TRD1X
0000000
GOPEN
PRETAB
Q9
TRD1A
TRDA1
Q10
TRD1C
TRD1D
MATVEC
STEP
INTFBS
FORM1
FORM2
INFBSX
Q11
TRDC1
0000000
MPYAD
SSG2B
MPYQ
FILSWI
MPYADX
MPYADZ
Q12
RULER
CALCV
PARTN
OPNCOR
SSG2A
TRD1B
Q13
SSGA2
TRDB1
SSGB2
GENVEC
T
FINDC
Q15
DECOMP
ONETWO
TRANSP
DLOOP
SDCOMP
LOOP
RSPSDC
RSPLOO
Q16
0000000
INITL
SFACT
INITX
COM12
TRD
TRDD1

LINK 11

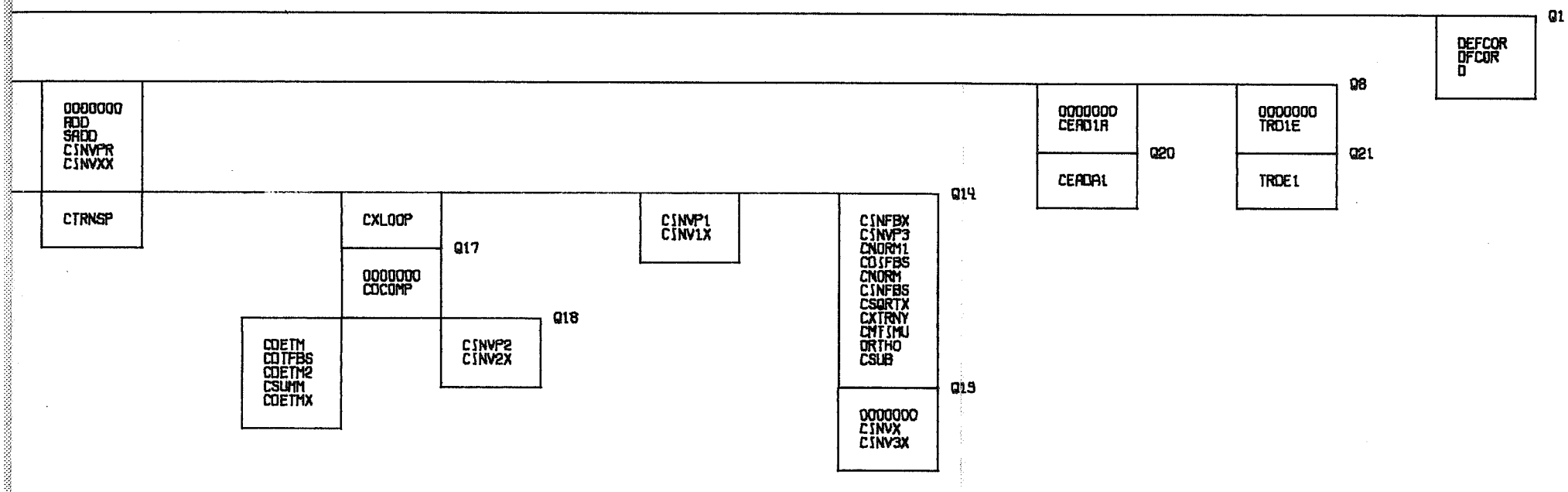
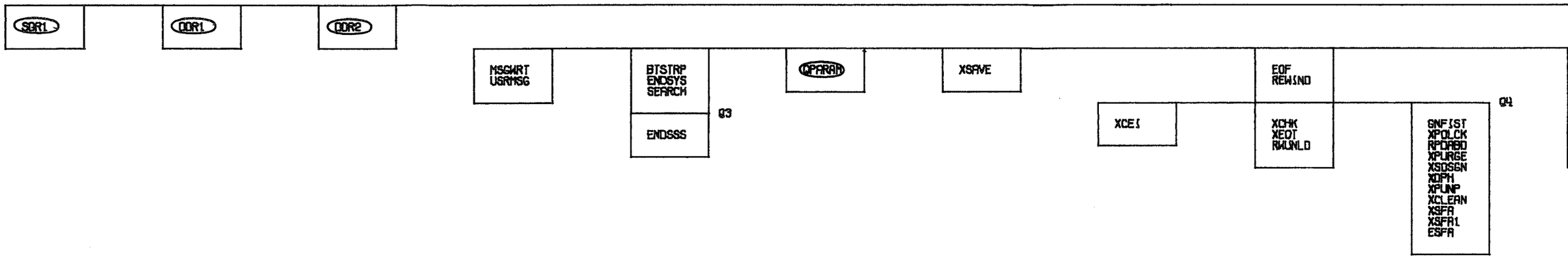


Figure 12. Overlay Structure for Link 11 on the UNIVAC 1108.


SDR1
DDR1
DDR2
MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
03
QPARAM
XSAVE
XCES
EOF
REWIND
XCHK
XEOT
RWUNLD
04
GNFIST
XPOLCK
RPDRBD
XPURGE
XSDSGN
XDPM
XPUNP
XCLEAN
XSFA
XSFA1
ESFA

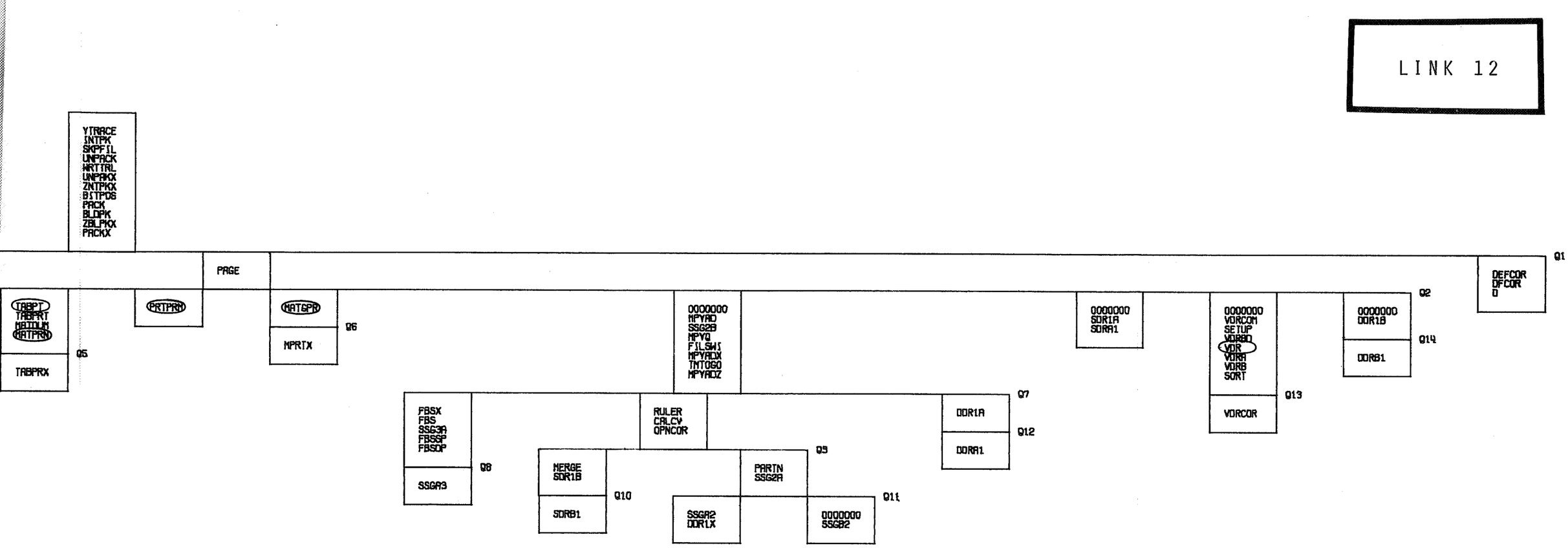
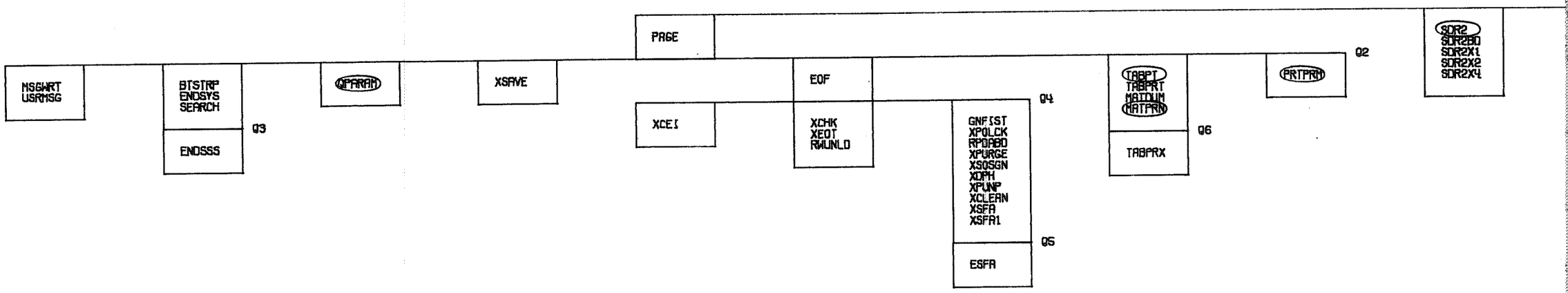


Figure 13. Overlay Structure for Link 12 on the UNIVAC 1108.


MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
Q3
ENDSSS
QPARAM
XSAVE
PAGE
XCEI
EOF
XCHK
XEQT
RWUNLD
Q4
GNFIST
XPQLCK
RPQABD
XPURGE
XSQSGN
XQPH
XPUNP
XCLEAN
XSFA
XSFR1
Q5
ESFA
TABPT
TABPRT
MAIDUM
MATPRN
Q6
TABPRX
PRTPRM
Q2
SDR2
SDR2BD
SDR2X1
SDR2X2
SDR2X4

DSMG1

PLA3

0000000
SDR2A
SDR2AA

SDR2B
SDR2X6
SDR2X5

SCONE1

SROD1
STUBE1
SPANL1
SELAS1
SBAR1

STRQD1
STRPL1
SQDPL1
STRBS1
SQDME1
STRME1

SSOLD1
SAXIF1
SSLOT1

STRIR1
STRAP1
AI
BINT
AK
AN
AJ
COEF
F89
FF100
IFAC
FJAB
F6219
F6211

STORD1
ROMBER
F4
F5
F6
AMATRX
SCRLM
SOLVE1

SDUM11
SDUM21
SDUM31
SDUM41
SDUM51
SDUM61
SDUM71
SDUM81
SDUM91

Q11

Q12

0000000
SDRA2

DBAR
DROD
DSHEAR

YTRACE
SEMDBD
XSEM13
MAIN13
NTAB
PLAGP

PLAY

PRETRS
GMMATS
SAXB
SADOTB

PREMAT
INVERS
PLAMAT

GNMATD
PRETRD
INVERD

Q10

PLA3UV
PLA3ES
SOUT
PLA32C
PLA32E
PLA32S
PLA32

Q20

PSRQD
PSBAR

Q21

0000000
PLA32X

PSTRB1
PSQPL1
PSTPL1
PSQDM1
PSTRQ2
PSTRM1
PSTQ2
PSTQ1
PSQAD1
PSQAD2
PSTRI2
PSQDM
PSTRM
PSTRI1

DS1A
DS1B
DS1ABD
DS1ADP
DS1AAA
DS1AET

Q13

PLA42
PLA4BD
PLA4B
PLA42S
PLA42D
PLA42E
PLA42C
PLA4UV
PLA4ES

DQDMEM
DTRMEM
DTRSA
DQUAD
DTRBSC

DCONE

Q14

DDUMY

Q15

0000000
DS1AXX

PKRDD

PKBAR

Q16

PKTRMS
PKQDMS
PKQDM1
PKTRM1

Q17

PKTRM
PKQDM
PKTRQ2

Q19

0000000
PLA42X

PKTQ1
PKTQ2
PKTRQD
PKTRBS
PKQDPL
PKTRPL

Q18

PKQAD1

PKTRI1

PKQAD2

PKTRI2

LINK 13

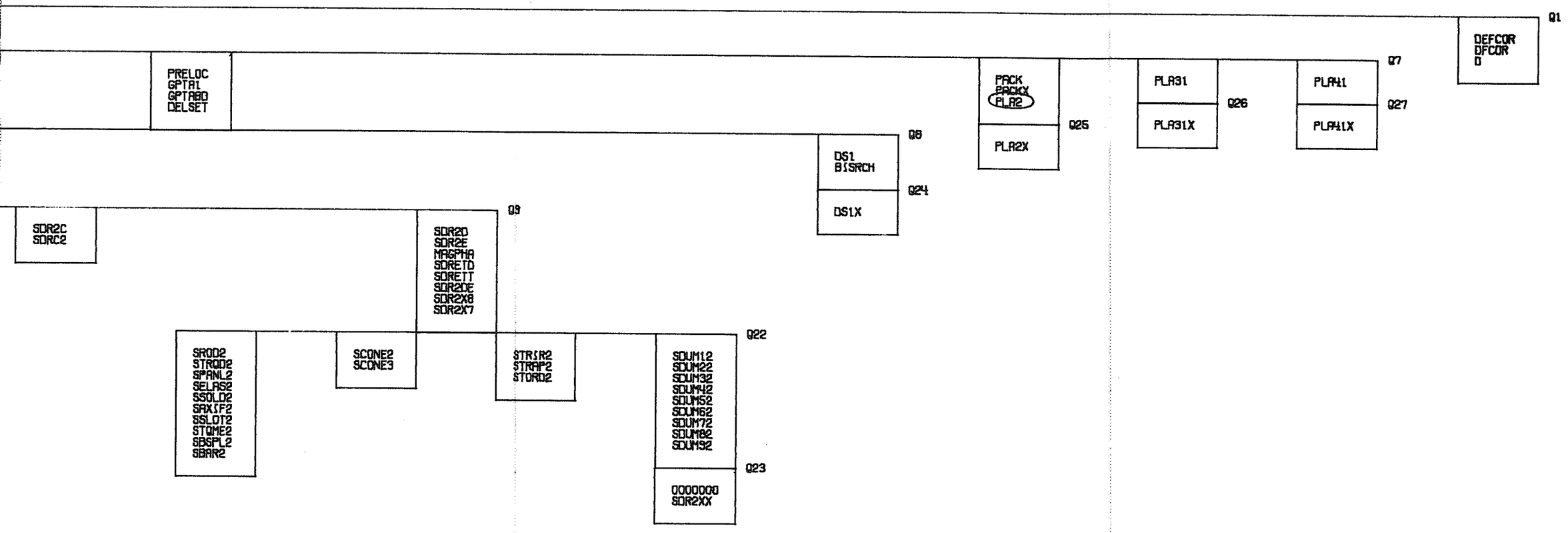


Figure 14. Overlay Structure for Link 13 on the UNIVAC 1108.

MSGWRT
USRMSG
BTSTRP
ENDSYS
SEARCH
ENDSSS
Q3
QPARAM
XSAVE
XCEI
SKPFIL
EOF
XCHK
XEOT
RWUNLD
GNFIST
XPOLCK
RPDABD
XPURGE
XSOSGN
XDPH
XPUNP
XCLEAN
XSFA
XSFA1
ESFA
Q4
Q5
OPNCOR
MAIDUM
MAIPRM
INTPK
UNPACK
ZNTPKX
UNPKX
PRTPRM
TABPT
TABPRT
OFPRS1
OFPB1
OF1PBD
OFPC51
OFPB2
OF2PBD

YTRACE
SEMDBD
XSEM14
MAIN14
NTAB
WRTTRL
CORSZ
DESCRP
XCEITB
STIME
STAPID
TIME
XLINK
SEM
QREADX
TYPE
XMDMSK
DCLNT
GINOX
TWO
NAMES
OUTPUT
XVPS
XPFIST

PAGE
BCKREC

SDR3

SDR3A
Q6
SDR3ZZ
Q10

XYTRAN
SORT
SETUP
XYWORK

XYPRPL
XYCHAR
XYGRAF
XYPPPP

Q11
XYDUMP
XYFIND
XYOUT
XYTICS
XYLOG
Q12
0000000
XYTRZZ

TAPBIT
TPSWIT
FOREIL
OUTPT1
Q13
OUT1XX

OUTPT2
Q14
OUT2XX

OFPBD1
OFPBD5
OFP
OFPPUN
OFP1
OFP1A
OFP1BD
OFP6BD
OFPCOM
Q7

OFPRS2
OFPB3
OF3PBD

OFPCS2
OFPB4
OF4PBD

OFPRF1
OFPB5
OF5PBD

OFPCF1
OFPB6
OF6PBD

OFPRF2
OFPB7
OF7PBD

OFPCF2
OFPB8
OF8PBD

OFPMIS
OFPB9
OF9PBD
Q8

0000000
OFPXXX
TABPRX
Q9

LINK 14

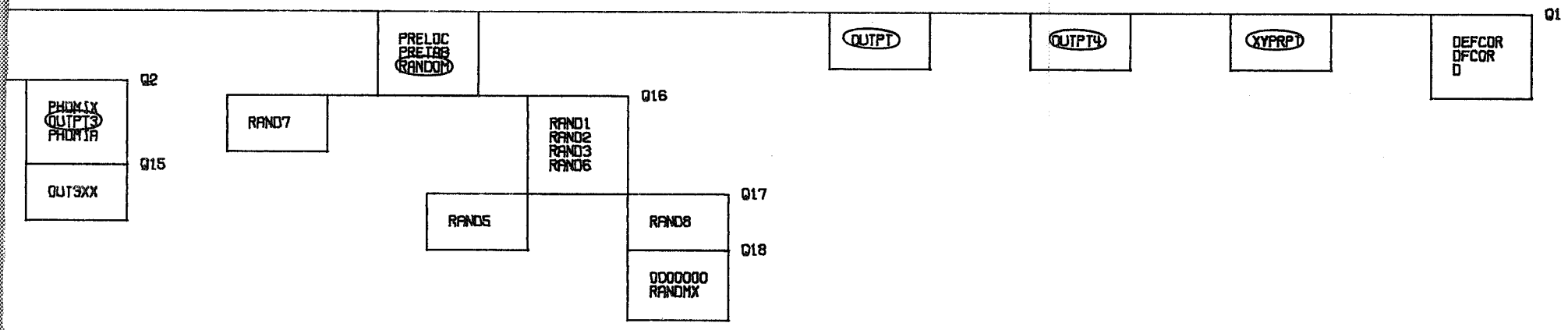


Figure 15. Overlay Structure for Link 14 on the UNIVAC 1108.

MODULE INDEX	DMAP NAME OF MODULE	MODULE ENTRY POINT NAME	LINKS MODULE RESIDES IN OR IS USED BY													
3	CHKPNT	XCHK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
5	REPT	XCEI	1	2	3	4	5	6	7	8	9	10	11	12	13	14
6	JUMP	XCEI	1	2	3	4	5	6	7	8	9	10	11	12	13	14
7	COND	XCEI	1	2	3	4	5	6	7	8	9	10	11	12	13	14
8	SAVE	XSAVE		2	3	4	5	6	7	8	9	10	11	12	13	14
9	PURGE	XPURGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	EQUIV	XEQUIV	1	2	3	4	5	6	7	8	9	10	11	12	13	14
11	END	XCEI	1	2	3	4	5	6	7	8	9	10	11	12	13	14
12	EXIT	XCEI	1	2	3	4	5	6	7	8	9	10	11	12	13	14
13	ADD	DADD				4			7							
14	ADD5	DADD5							7							
15	BMG	BMG										10				
16	CASE	CASE										10				
17	CEAD	CEAD											11			
18	DDR	DDR								8						
19	DDR1	DDR1												12		
20	DDR2	DDR2												12		
21	DECOMP	DDCOMP							7							
22	DPD	DPD						6								
23	DSMG1	DSMG1													13	
24	DSMG2	DSMG2				4										
25	DUMMOD1	DUMOD1							7							
26	DUMMOD2	DUMOD2							7							
27	DUMMOD3	DUMOD3							7							
28	DUMMOD4	DUMOD4							7							
29	FBS	DFBS							7							
30	FRRD	FRRD										10				
31	GKAD	GKAD										10				
32	GKAM	GKAM										10				
33	GP1	GP1		2												
34	GP2	GP2		2												
35	GP3	GP3		2												
36	GP4	GP4				4										
37	GPSP	GPSP				4										
38	GPWG	GPWG				4										
39	INPUT	INPUT		2												
40	INPUTT1	INPTT1		2												
41	INPUTT2	INPTT2		2												
42	INPUTT3	INPTT3		2												
43	INPUTT4	INPTT4		2												
44	MATGPR	MATGPR				4	5		7			10		12		
45	MATPRN	MATPRN		2	3	4	5	6	7	8	9	10	11	12	13	14
46	MATPRT	PRTINT								8						
47	MCE1	MCE1				4										
48	MCE2	MCE2				4										

Figure 16. Link Specification Table.

MODULE INDEX	DMAP NAME OF MODULE	MODULE ENTRY POINT NAME	LINKS MODULE RESIDES IN ON 1108
49	MERGE	MERGE1	7
50	MODA	MODA	7
51	MODB	MODB	7
52	MODC	MODC	7
53	MPYAD	DMPYAD	7
54	MTRXIN	MTRXIN	10
55	OFP	OFP	14
56	OUTPUT	OUTPT	14
57	OUTPUT1	OUTPT1	14
58	OUTPUT2	OUTPT2	14
59	OUTPUT3	OUTPT3	14
60	OUTPUT4	OUTPT4	14
61	PARAM	OPARAM	2 3 4 5 6 7 9 9 10 11 12 13 14
62	PARTN	PARTN1	7
63	PARTVEC	SUBVEC	9
64	PLA1	PLA1	3
65	PLA2	PLA2	13
66	PLA3	PLA3	13
67	PLA4	PLA4	13
68	PLOT	DPLOT	2
69	PLTSET	DPLTST	2
70	PLTTRAN	PLTTRA	8
71	PRTMSG	PRTMSG	2
72	PRTPARM	PRTPRM	2 3 4 5 6 7 8 9 10 11 12 13 14
73	RANDOM	RANDOM	14
74	RBMG1	RBMG1	4
75	RBMG2	RBMG2	4
76	RBMG3	RBMG3	4
77	RBMG4	RBMG4	4
78	READ	RFIG	6
79	SCE1	SCE1	4
80	SDR1	SDR1	12
81	SDR2	SDR2	13
82	SDR3	SDR3	14
83	SEEMAT	SEEMAT	2
84	SETVAL	SETVAL	2
85	SMA1	SMA1	3
86	SMA2	SMA2	3
87	SMA3	SMA3	4
88	SMP1	SMP1	4
89	SMP2	SMP2	4
90	SMPYAD	SMPYAD	7
91	SOLVE	SOLVE	7
92	SSG1	SSG1	5
93	SSG2	SSG2	5

Figure 16. Link Specification Table (Continued)

MODULE INDEX	DMAP NAME OF MODULE	MODULE ENTRY POINT NAME	LINKS MODULE RESIDES IN ON 1108												
94	SSG3	SSG3				5									
95	SSG4	SSG4				5									
96	TA1	TA1	2												
97	TABPRT	TABFMT							8						
98	TABPT	TABPT	2	3	4	5	6	7	8	9	10	11	12	13	14
99	TRD	TRD										11			
100	TRNSP	DTRANP						7							
101	UMERGE	DUMERG						7							
102	UPARTN	DUPART						7							
103	VDR	VDR											12		
104	VEC	VEC						7							
105	XYPLOT	XYPLOT	2												
106	XYPRNPLT	XYPRPT													14
107	XYTRAN	XYTRAN													14

Figure 16. Link Specification Table (Continued)

5.5 NASTRAN ON THE CDC 6400/6600 (SCOPE 3)

5.5.1 Introduction

NASTRAN operates as a single job step on the CDC 6400/6600 computers under the SCOPE 3 Operating System. NASTRAN is created by the Linkage Editor (see Section 5.6), a special program developed for the CDC 6400/6600 computers to provide compatibility with the other computing systems for which NASTRAN has been developed.

The overlay structure for NASTRAN on the CDC 6400/6600 is somewhat different from the other computing systems in that one link, Link 0, remains in core at all times during program execution. This link contains subroutines and Executive tables common to all links (e.g., GINØ, RDTRL, FNAME, /XXFIAT/, /XFIAT/, /SYSTEM/). Consequently, the primary functions of ENDSYS and BGNSYS (see Section 3.3.5), which save and restore Executive tables, are not required. Link switching is accomplished in a manner similar to the IBM 360 through a CALL LINK. LINK is an entry point in the segment loader, which was developed in conjunction with the linkage editor.

The NASTRAN executable program normally exists as a sequential file on tape, although it may exist as an indexed file on disk. The first few records of the file contain an initial load program produced by the linkage editor. This program is written as a CDC main level overlay (0,0) and set to reside on absolute overlay file PPPPP. The remainder of the file is comprised of the NASTRAN links (one directory record per link plus one logical record per segment). To initiate the NASTRAN program, a control statement such as NASTRAN, is executed. This causes the CDC overlay loader to load the initial program load portion of the NASTRAN file and transfer control to XBØØT (see Section 5.6.1.1). The XBØØT program reads the remainder of the file, writes it on the disk in indexed form, reads Link 0 into central memory and transfers control to Link 0. Link 0 is entered through a small main program called NASTRAN which in turn calls Link 1 (the Preface Link). Execution continues until the program terminates through a call to PEXIT which in turn calls EXIT.

For Level 15 most of the matrix operations, other than the various matrix assemblers, have been converted to single precision (60 bits) arithmetic. Since the packing routines in NASTRAN will accept either single-precision or double-precision input and prepare either single-precision or double-precision output on request, it is possible to change the arithmetic precision in the matrix operations on a selective basis. The following routines are used in Level 15 to provide single-precision matrix operations on the CDC 6000 series:

1. RSPSDC - Matrix decomposition for real, symmetric matrices.
2. RSPLØØ - Inner loop for RSPSDC.
3. FBSSP - Inner loop for FBS.
4. MPYQ - Inner loop for real and complex multiply-add (MPYAD) operations.
5. CSPSDC - Matrix decomposition for complex, symmetric matrices.
6. CSPLØØ - Inner loop for CSPSDC.
7. INVFSP - Equation solution for inverse power method of eigenvalue extraction.

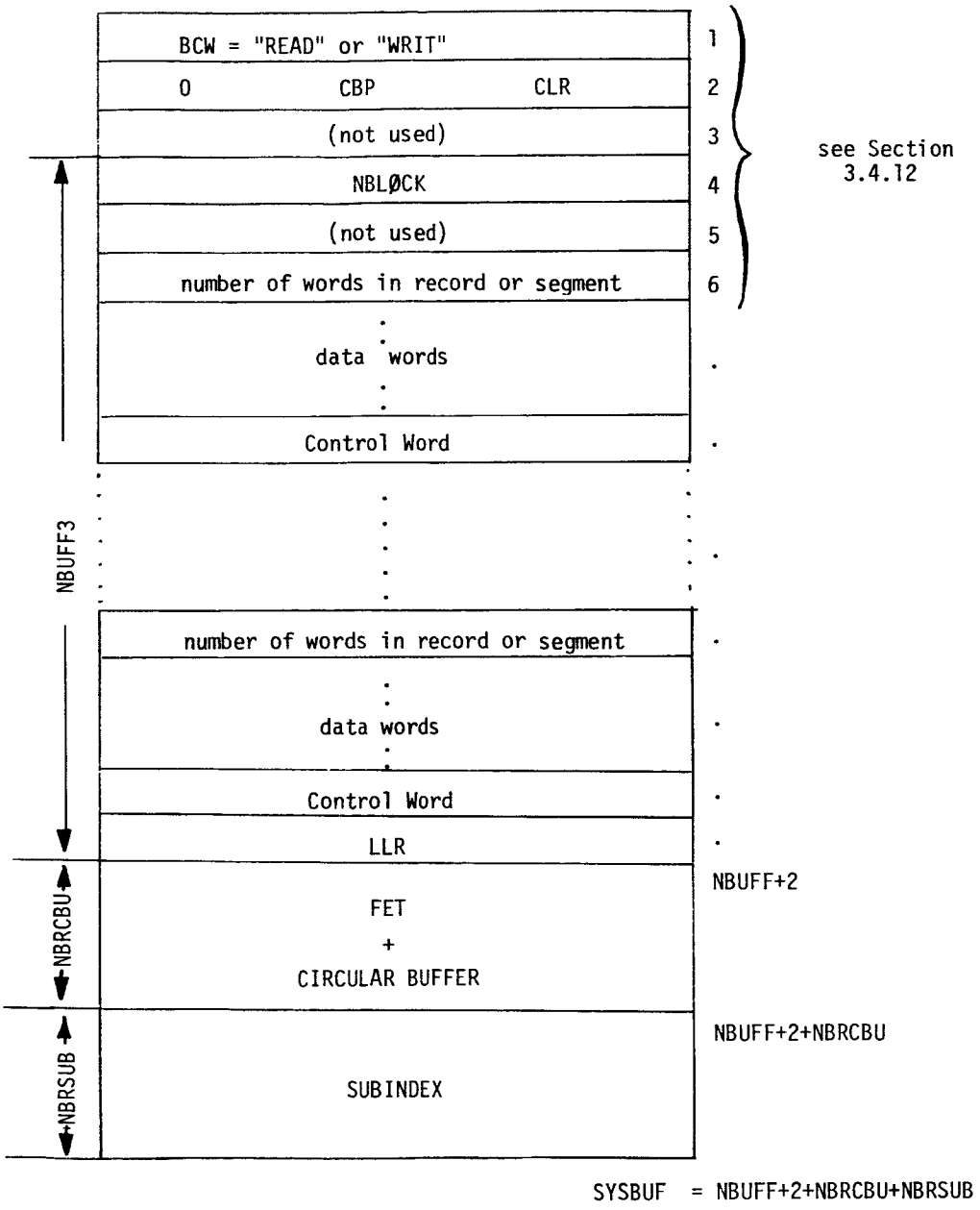
5.5.2 Input/Output

NASTRAN input/output is performed in three ways: (1) card input, printed output, and punched output is accomplished through standard FØRTRAN formatted input and output statements; (2) all other input/output except plots is accomplished through the GINØ routines which in turn call IØ6600 (see Section 5.5.6.13) to perform reads and writes; and (3) plot output is accomplished through SGINØ (see Section 3.4.51).

The number of files available to GINØ is a function of the MAXFILES parameter in the SYSTEM common block (see section 2.4.1.8). All NASTRAN files which have not been assigned to tape are treated as indexed files on the disk. A master index for each file is permanently maintained in central memory near the end of the field length (see Figure 2). The master index contains a disk pointer for each subindex record. The subindex records contain disk pointers for each of the blocked NASTRAN records. IØ6600 maintains the position of each file in the common block GINØ66. Subindex records are read or written at open and close time and during reading or writing when a subindex boundary is passed. Actual input/output is accomplished through XIØRTNS (see Section 5.5.6.7), which is a COMPASS subprogram. XIØRTNS communicates with the SCØPE Operating System through calls to CPC.

SGINØ on the CDC 6400/6600 functions independently of other I/Ø. Its point of commonality with other I/Ø routines is XIØRTNS, which is used to perform the physical writing of data.

Figure 1 depicts a complete buffer as used by GINØ, IØ6600 and XIØRTNS.



NBUFF3 = NBUFF-2

NBUFF = SYSBUF-2-NBRCBU-NRBSUB

SYSBUF, NBRCBU, and NSRSUB are defined in the SYSTEM common block (see Section 2.4.1.8)

Figure 1. GINØ buffer on the CDC 6400/6600.

5.5.3 Layout of Core Storage

Figure 2 illustrates the layout of core storage on the CDC 6400/6600.

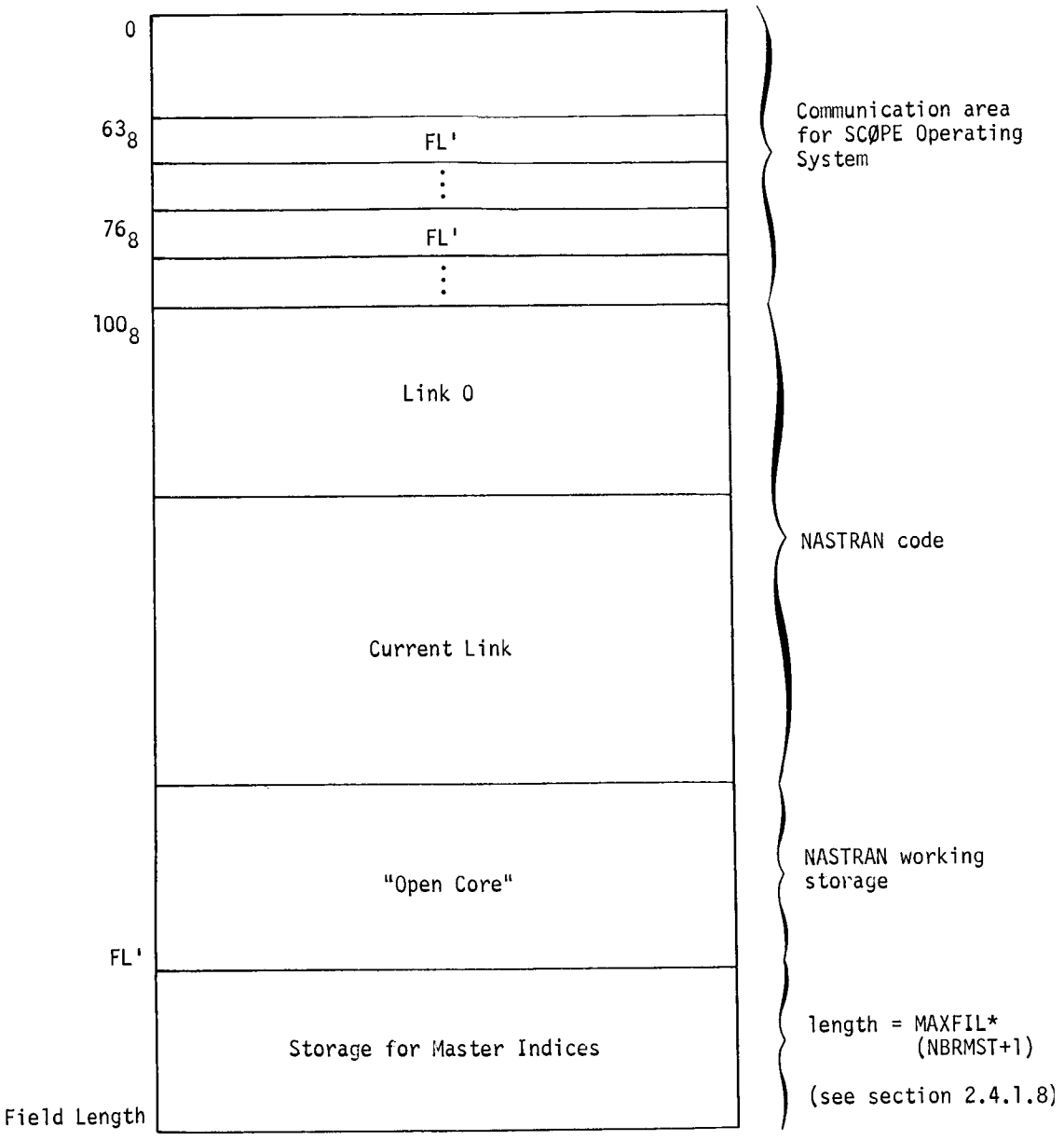


Figure 2. Layout of core storage on the CDC 6400/6600.

The primary function of GNFIAT (see section 3.3.4), which operates in Link 1, is to initialize the XFIAT and FIAT Executive tables. As a secondary function, GNFIAT reserves an area at the end of core storage for storage of the master index pointers for each file. The length of this reserved area is subtracted from the field length for the problem, and the available memory, FL', is stored in words 63_8 and 76_8. The length of open core is returned to a calling program by the CØRSZ function. CØRSZ subtracts the address passed to it from the contents of word 76_8. All NASTRAN modules may then utilize maximum core storage provided to the job.

The discussion in section 5.3.4 regarding overlay considerations on the IBM 360 applies equally to the CDC 6400/6600.

5.5.4 Execution Deck Setup

The following examples illustrate the control statements necessary to execute the NASTRAN program once the generation procedure (see section 5.5.5) is complete. The numbers in parentheses to the left of some of the control statements refer to notes, which follow the examples.

Problem Conditions					
Example	NASTRAN	Bulk Data Input Medium	Checkpoint	Restart	DD80 Plot
A	tape	cards	no	no	no
B	tape	UMF	no	no	no
C	disk(common)	cards	yes	no	yes
D	disk(common)	UMF	yes	no	no
E	tape	ØPTP	no	yes	no
F	tape	ØPTP	yes	yes	yes

Example A

(1) JØB.

```
MAP(ØFF)
REQUEST NASTRAN,HI. reel#,RØL
NASTRAN.
RETURN(NASTRAN)
7
8
9
    {NASTRAN Data Deck}
6
7
8
9
```

Example B

```
JØB.
MAP(ØFF)
```

```
     REQUEST NSTRN,HI. reel#,RØL
     REQUEST UMF,HI. reel#,RØL
(2)  NSTRN.CREATE(NASTRAN)
     RETURN(NSTRN)
     RETURN(UMF)
     7
     8
     9
        {NASTRAN Data Deck}
     6
     7
     8
     9
```

Example C

```
     JØB.
     MAP(ØFF)
     REQUEST NPTP,HI. SAVTP,RIL
     REQUEST PLT2,HI. SAVTP,RIL
(3)  CØMMØN(NASTRAN)
     NASTRAN.ATTACH
     RETURN(NPTP)
     RETURN(PLT2)
     7
     8
     9
        {NASTRAN Data Deck}
     6
     7
     8
     9
```

Example D

```
     JØB.
     MAP(ØFF)
     REQUEST UMF,HI. reel#,RØL
     REQUEST NPTP,HI. SAVTP,RIL
     CØMMØN(NASTRAN)
     NASTRAN.ATTACH
```

RETURN(UMF)

RETURN(NPTP)

7_{8_9}

{NASTRAN Data Deck}

$6_{7_{8_9}}$

Example E

JØB.

MAP(ØFF)

REQUEST ØPTP,HI. reel#,RØL

REQUEST NASTRAN,HI. reel#,RØL

(4) NASTRAN.CATLØG(NASTDA)

RETURN(NASTRAN)

NASTDA.ATTACH

RETURN(ØPTP)

NASTDA.ATTACH

7_{8_9}

{NASTRAN Data Deck (including RESTART packet in the Executive Control Deck)}

7_{8_9}

{2nd NASTRAN Data Deck}

$6_{7_{8_9}}$

Example F

JØB.

MAP(ØFF)

REQUEST NASTRAN,HI. reel#,RØL

REQUEST NPTP,HI. SAVTP,RIL

REQUEST ØPTP,HI. reel#,RØL

REQUEST PLT2,HI. SAVTP,RIL

(5) NASTRAN(,,X)

RETURN(NASTRAN)

RETURN(NPTP)

RETURN(ØPTP)

RETURN(PLT2)

$^{7}_{8}_{9}$

{NASTRAN Data Deck (including RESTART packet in the Executive Control Deck)}

$^{6}_{7}_{8}_{9}$

Notes

(1) The installation dependent JØB card should specify sufficient resources to run the job.

(2) In addition to executing the NASTRAN program, this control statement will cause the NASTRAN file to be declared a common file.

(3) This control statement attaches the common file to the job. If NASTRAN is executed as a common file, running time will be approximately 5-8 minutes faster in elapsed time and 20 seconds faster in CPU time.

(4) This control statement copies the sequential file NASTRAN to the direct access file NASTDA which can then be executed repeatedly.

(5) Any of the NASTRAN program files (INPUT, ØUTPUT, PUNCH) may be substituted for such as X replaces PUNCH in this example.

5.5.5 Physical Deliverables and Generation of Executable System

The CDC 6400/6600 version of NASTRAN is delivered on four (4) multifile tapes recorded at a density of 800 bpi in a binary (odd parity) format. These tapes are:

TAPE1 - EXECUTABLE

This tape contains the executable versions of three programs plus the NASTRAN overlay load map output from the linkage editor

File 1 - NASTRAN executable

File 2 - Linkage Editor executable

File 3 - Langley Run Compiler executable

File 4 - NASTRAN load map

TAPE2 - SØURCE

This tape contains source code for all 6000 NASTRAN decks, the 6000 linkage editor, and control cards for the overlay structure all in sequential ØLDPL format for UPDATE Version 1.2.

File 1 - NASTRAN ØLDPL

Machine-independent decks appear first in alphabetical order followed by machine-dependent decks in alphabetical order.

File 2 - Linkage Editor ØLDPL

Source for linkage editor routines is followed by source for LINKERR, XLØADER, XBØØT, and XEØF. On the CØMPILE file these four routines are separated from the main body of linkage editor routines by a CWEØR after the MAPFNS deck.

File 3 - Overlay Control Cards ØLDPL

Several decks defining the NASTRAN overlay structure are followed by a CWEØR and a single deck defining a linkage editor overlay structure.

TAPE3 - ØBJECT

This tape contains object deck code on three files.

File 1 - NASTRAN object decks in alphabetical order (940 records)

File 2 - Linkage Editor object decks (26 records)

File 3 - LINKLIB object decks (105 records)

Object library from which the linkage editor satisfies external references.

TAPE4 - DEMØNSTRATIØN ITEMS

File 1 - User Master File

File 2 - Demonstration Problem Driver Decks

(fifty records, one record per deck)

File 3-52 - Demonstration Problem execution output print files

File 53 - Data deck for generating the User Master File

The source may be compiled using the Langley RUN compiler which must reside on absolute overlay file LRC. The compilation must be handled in parts since there are too many Block Data

programs for a single run. The following setup will compile the NASTRAN system in two parts.

```
JØB,P1,T1000,CM140000.
REQUEST,TAPE1,HY.                          NASTRAN executable
CØPYBF(TAPE1,X,2)
CØPYBF(TAPE1,LRC)
RETURN(TAPE1)
REQUEST,ØLDPL,HY.                          TAPE2 - Source
UPDATE(Q,L=1,C=ØNE)
UPDATE(Q,L=1,C=TWØ)
RETURN(ØLDPL)
LRC(S,,,ØNE,,,,ASA,XREF)
LRC(S,,,TWØ,,,,ASA,XREF)
EXIT.
UNLØAD(TAPE1)
UNLØAD(ØLDPL)
7
8
9
*CØMPILE,ADD.ØUTPT4
7
8
9
*CØMPILE,PAGE.XCØRSZ
6
7
8
9
```

Once a relocatable object file is created, it can be used with the linkage editor and SUBSYS deck to generate an executable system as follows:

```
JØB,P1,T200,CM120000.
REQUEST,TAPE2,HY.                          Source
CØPYBF(TAPE2,SCRATCH,2)
CØPYBF(TAPE2,ØLDPL)                        SUBSYS Source
RETURN(TAPE2)
REQUEST,TAPE3,HY.                          Object
CØPYBF(TAPE3,NASTØBJ)
```

```
CØPYBF(TAPE3,LINKEDT)
CØPYBF(TAPE3,LINKLIB)
RETURN(TAPE3)
UPDATE(Q,L=1)
LINKEDT(CØMPILE)
REQUEST,TAPE,HI.                          SAVE TAPE
CØPYBF(NEWX,TAPE)
RETURN(TAPE)
EXIT.
UNLØAD(TAPE2)
UNLØAD(TAPE3)
UNLØAD(TAPE )
7
8
9
*IDENT,ØVERLAY
*DELETE,LINKEDT.2
LINKEDIT LET,ØUTFILE=NEWX(T),
  PARAM(2)=1200   ,  PARAM(6)=14000
LIBRARY NASTØBJ
*CØMPILE,LINKEDT.ENDLINK
6
7
8
9
```

5.5.6 Machine Dependent Routines

The following utility routines necessary to NASTRAN operation must, by their nature, be implemented in a machine dependent manner. Certain of the routines have been written in CØMPASS language, and the remainder are in FØRTRAN language.

5.5.6.1 MAPFNS(CØMPASS)

The MAPFNS deck embodies a set of 25 utility functions and routines. These are as follows:

Logical Functions

ANDF (logical product of two words)

ØRF (logical sum of two words)

XØRF (logical difference of two words)

CØMPLF (complement of a word)

LSHIFT (left shift of a word)

RSHIFT (right shift of a word)

Utility Functions

CØRSZ (returns length of "open core")

CØRWDS (returns difference of two addresses + 1)

LWØRDS (returns difference of two addresses. CDC 6000 only)

LØCF (returns the value of an address. CDC 6000 only)

INSTAL (returns installation name, left justified, blank fill. CDC 6000 only)

Utility Routines (CDC 6600 only)

XSTØRE (stores an array at an absolute position in core)

XFETCH (fetches an array from an absolute position in core)

XJUMP (transfers control to an absolute location in core)

ZAP (stores zeros between specified locations in core)

RECØVRY (initializes PP routine RCV)

LINK2O. (provides a special call to Link 20, the NASTRAN exit link)

XCØMMØN (executes the CØMMØN macro and returns the status of a file)

FIELDLN (returns the field length assigned to the job)

FLUSH (makes a special call to SYSTEM. to empty output buffers)

TDATE (returns month, day,year, time)

KLØCK (returns current value of CPU clock)

DAYTIME (returns current time on wall clock)

DMPXXXX (writes exchange register dump on output)

SET66 (stores installation name at designated location)

5.5.6.2 CØNMSG (FØRTRAN)

The CØNMSG routine enters messages in the DAYFILE denoting the times of the initiation and completion of modules during NASTRAN execution.

5.5.6.3 GNFIAT (FØRTRAN)

GNFIAT initializes the XFIAT and FIAT tables and reserves storage for the master indices (see Section 5.5.2).

5.5.6.4 DUMP and PDUMP (FØRTRAN)

A call to PDUMP produces a trace back listing and, if a DIAG 1 card appeared in the Executive Control Deck, a memory dump is given. PDUMP returns to the calling program. DUMP operates similarly except terminates with a CALL EXIT.

5.5.6.5 PEXIT66 (FØRTRAN)

PEXIT66 is called from PEXIT only. It terminates activity on all NASTRAN files. Tapes are unloaded. Space assigned to disk files is evicted. PEXIT66 terminates with a CALL EXIT.

5.5.6.6 SGINØ (FØRTRAN)

SGINØ is used by the plot routines to write plot tapes. Actual writes are accomplished by SGINØ through calls to XIØRTNS.

5.5.6.7 XIØRTNS (CØMPASS)

The XIØRTNS deck embodies a set of utility routines which communicate with the SCØPE Operating System through CPC to accomplish various file operations. Portions of code in XCLØSE and READX are installation dependent. They are modified after determining the installation name by a call to SET66.

Entry Points

XØPEN (constructs FET and initiates activity for file)

XCLØSE (terminates activity for file)

XEVICT (evicts space assigned to a disk file)

REINDX (resets index pointers in the FET)

XWRITE (writes a portion or a complete logical record)

XREAD (reads a portion or a complete logical record)

XREWIND (repositions file to load point)

XBKREC (repositions file one logical record backwards)

XBKPREC (repositions file one physical record backwards)

XFRDREC (repositions file one logical record forwards)

XREQST (issues REQUEST macro)

READX (reads a complete logical record)

WRITEX (writes a complete logical record)

5.5.6.8 GINØ66 (FØRTRAN)

GINØ66 is a BLØCK DATA subprogram which initializes the GINØ66 common block with names of each of the possible NASTRAN files.

5.5.6.9 NASTRAN (FØRTRAN)

NASTRAN is a small main program in Link 0. It establishes FØRTRAN buffers for the files INPUT, ØUTPUT and PUNCH before calling the Preface in Link 1.

5.5.6.10 MPYQ (CØMPASS)

MPYQ is a compass routine written to increase the speed of MPYAD's inner loops (see Section 3.5.12.5).

5.5.6.11 WALTIM (FØRTRAN)

WALTIM calls DAYTIM for time of day and then calculates the elapsed time in seconds after midnight.

5.5.6.12 XCØRSZ (FØRTRAN)

Calls to CØRSZ are renamed to XCØRSZ on the CDC 6000 and open core length is printed if DIAG 13 is on.

5.5.6.13 IØ6600 (FØRTRAN)

IØ6600 is an interface routine between GINØ and XIØRTNS. It maintains index and subindex information for the block being operated on and issues open and close messages as required by DIAG 15. The calling sequence is:

```
CALL IØ6600 (ØPCØDE,BUFF),RETURNS(RETURN1)
```

IØ6600 formats calls to appropriate entry points in XIØRTNS according to ØPCØDE. The requests and calls are:

ØPCØDE	REQUEST	CALL
1	rewind	XREWIND
2	write	WRITEX
3	read	READX
4	backspace	XBKREC
5	forward space	REINDX/READX
6	open	XØPEN
7	close	XCLØSE

Figure 2. Overlay Structure for Link 0 on the CDC 6000.

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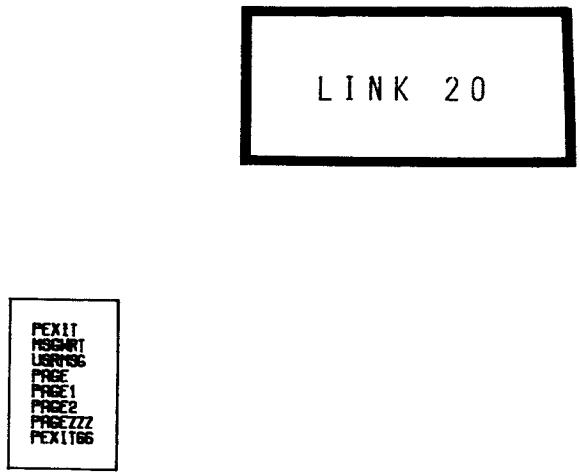
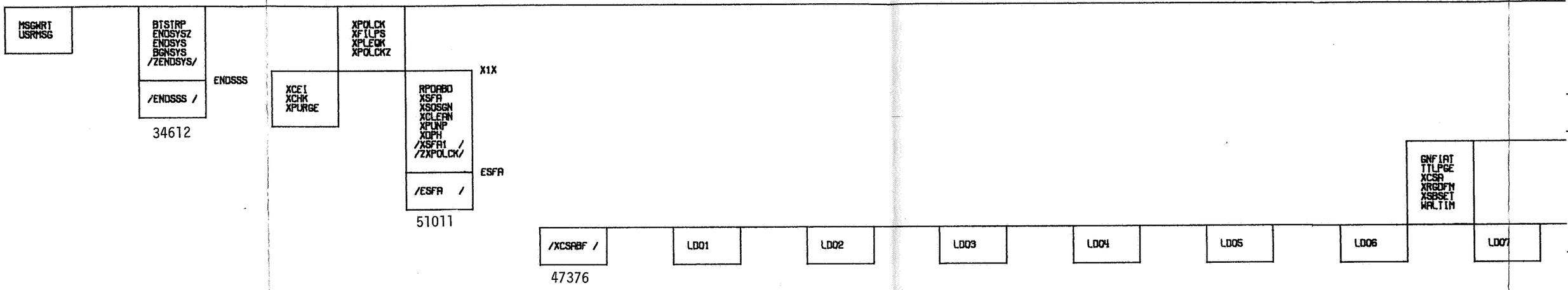
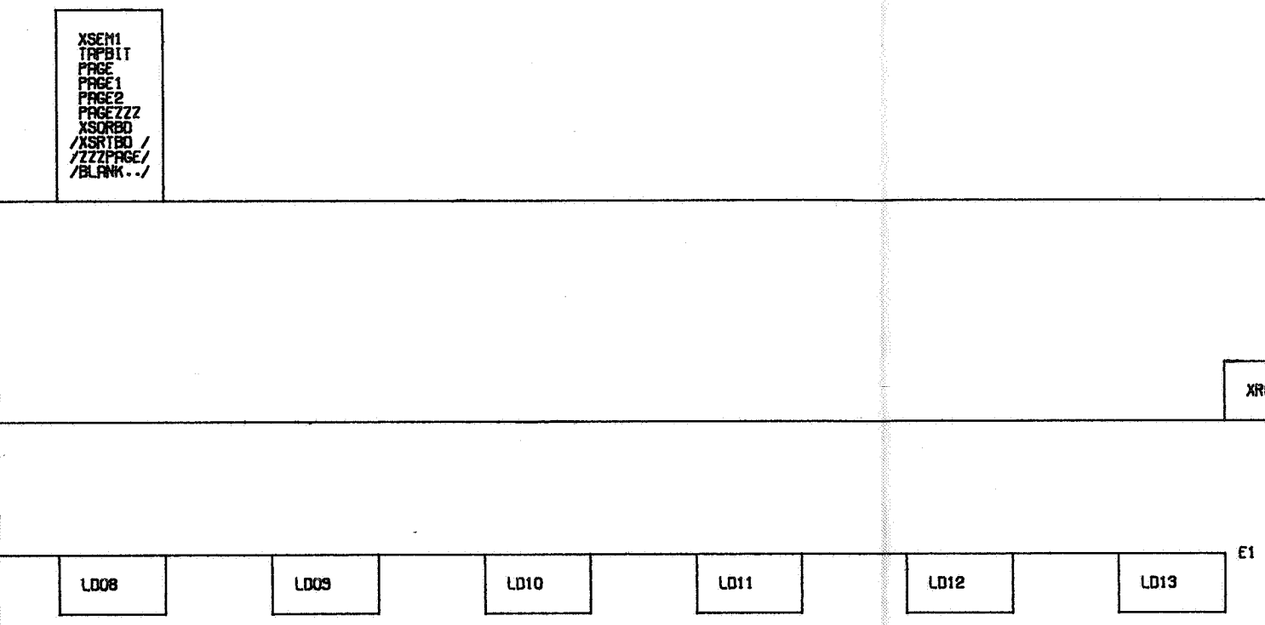
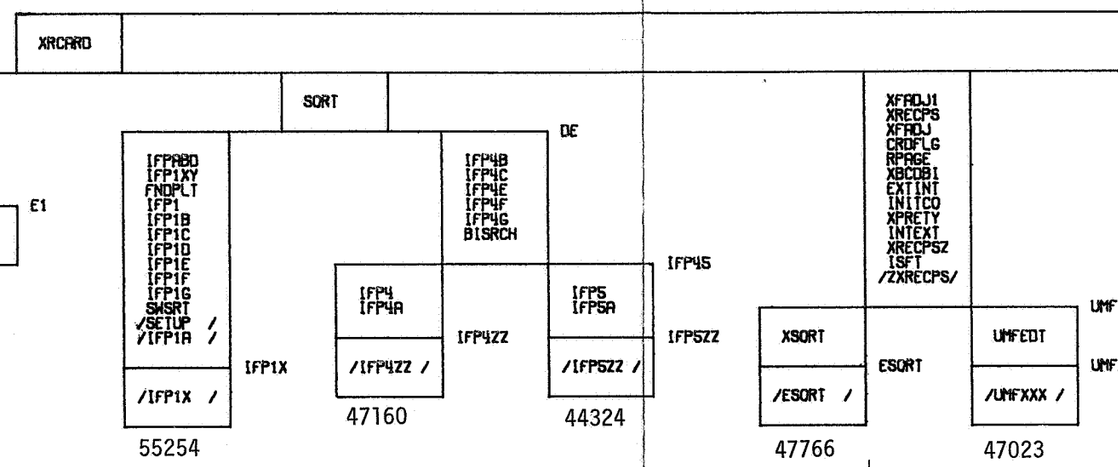
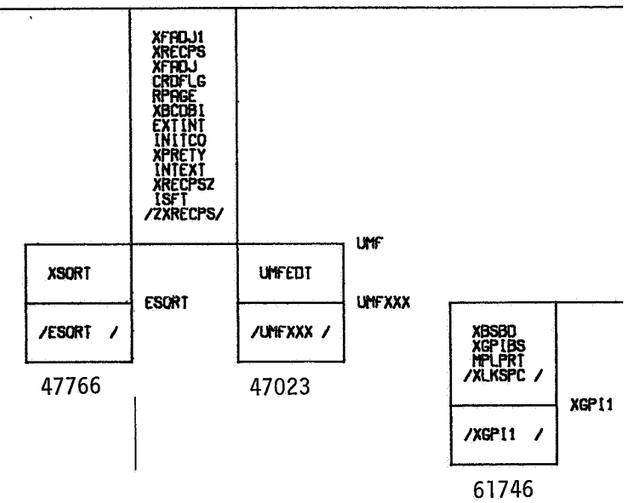


Figure 3. Overlay Structure for Link 20 on the CDC 6000.


MSGWRT
USRMSG
BTSTRP
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
34612
XCEI
XCHK
XPURGE
XPOLCK
XFILPS
XPLEOK
XPOLCKZ
RPOABO
XSFA
XSOSGN
XCLEAN
XPUNP
XDPH
/XSFA1 /
/ZXPOLCK/
X1X
/ESFA /
ESFA
51011
GNFIAT
TTLPGE
XCSA
XRGDFM
XSBSET
WALTIM
/XCSABF /
47376
LD01
LD02
LD03
LD04
LD05
LD06
LD07


XSEM1
TRPBIT
PAGE
PAGE1
PAGE2
PAGEZZZ
XSORBD
/XSRTBD /
/ZZZPAGE/
/BLANK../
LD08
LD09
LD10
LD11
LD12
LD13
E1


XRCARD
SORT
DE
IFPABD
IFP1XY
FNDPLT
IFP1
IFP1B
IFP1C
IFP1D
IFP1E
IFP1F
IFP1G
SWSRT
/SETUP /
/IFP1A /
/IFP1X /
IFP1X
55254
IFP4
IFP4A
/IFP4ZZ /
IFP4ZZ
47160
IFP4B
IFP4C
IFP4E
IFP4F
IFP4G
BISRCH
IFP5
IFP5A
/IFP5ZZ /
IFP5ZZ
IFP4S
44324


XFADJ1
XRECPS
XFADJ
CRDFLG
RPAGE
XBCDBI
EXTINT
INITCO
XPRETY
INTEXT
XRECPSZ
ISFT
/ZXRECPS/
XSORT
/ESORT /
ESORT
47766
UMFEDT
/UMFXXX /
UMFXXX
47023
UMF
XBSBD
XGPIBS
MPLPRT
/XLKSPC /
/XGPI1 /
XGPI1
61746

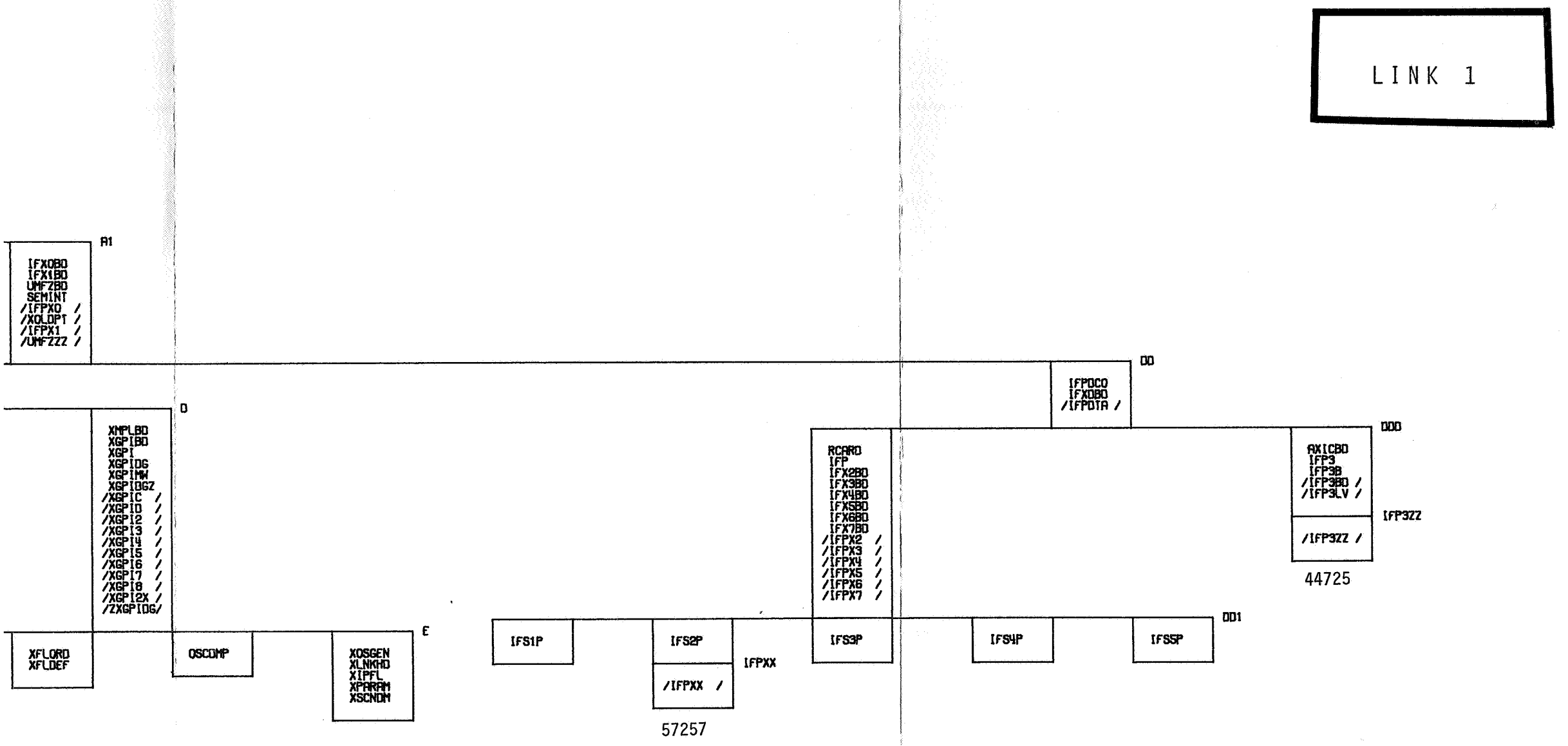
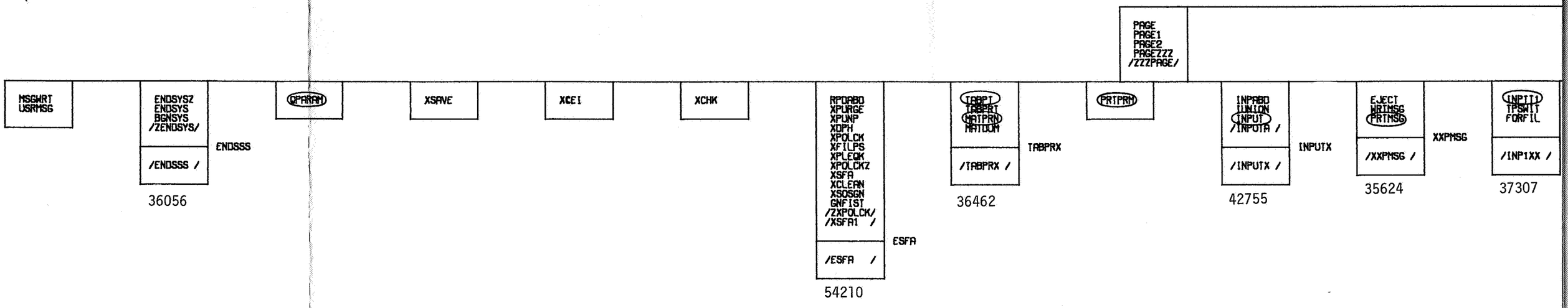


Figure 4. Overlay Structure for Link 1 on the CDC 6000.


MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
36056
QPARAM
XSAVE
XCEI
XCHK
RPDABD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
54210
TABPT
TABPRT
MATPRN
MATDOM
/TABPRX /
TABPRX
36462
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
PRTPRN
INPABD
LUNLOK
INPUT
/INPUTA /
/INPUTX /
INPUTX
42755
EJECT
WRTMSG
PRTMSG
/XXPMSG /
XXPMSG
35624
INPTI
TPSWIT
FORFIL
/INP1XX /
37307

XSEM2
TAPBIT
INTLST
ROMODE
ROMODX
ROMODXZ
ROMODY
ROWORD
/ZROMODX/
/BLANK../

INP1XX

INPIT2
/INP2XX /

INP2XX

37265

A

PLOTBD
AXIS
DRWCHR
IOPLOT
LINE
PLTSET
PRINT
SCLOSE
SELCAM
SEOF
SGINOZZ
SKPFRM
SOPEN
STPLOT
SWRITE
SYMBOL
TIPE
TYPFLT
TYPINT
FNDPLT
/CHAR94 /
/CHRDRW /
/XXPARM /
/PLTDAT /
/SYMBLS /
/ZZSGINO/

DRAW

LINE1
TYPE1
WPLT1

LINE2
TYPE2
WPLT2

AXIS3
LINE3
TYPE3
WPLT3

LINE4
WPLT4

LINE9
TYPE9
WPLT9

AXIS10
LINE10
TYPE10
WPLT10

DPLOT
DRAW
DVECTR
ELELBL
FIND
FNDSET
GETDEF
GPTLBL
GPTSYM
HEAD
INTVEC
MINMAX
PARAM
PERPEC
PLOT
PLTOPR
PROCES
SHAPE
WRTPRT
/DRWDAT /
/RSTXXX /

XXPLOT
/XXPLOT /

70043

SEEMAT
MAPSET
MAP
MAPSETZ
/ZMAPSET/

SEEMTX
/SEEMTX /

56340

LONGST

XYPLOT
/XYPLIN /

XYPLXX
/XYPLXX /

56377

LINK 2

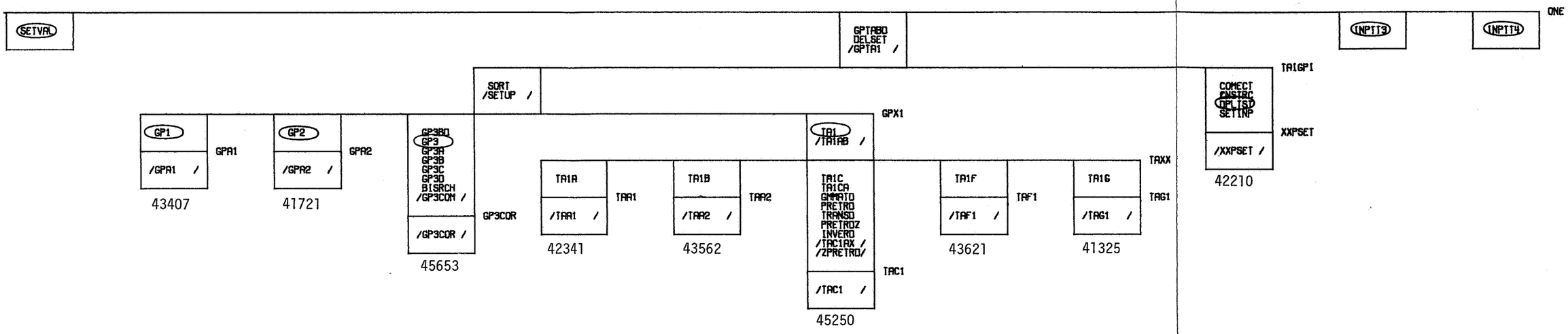
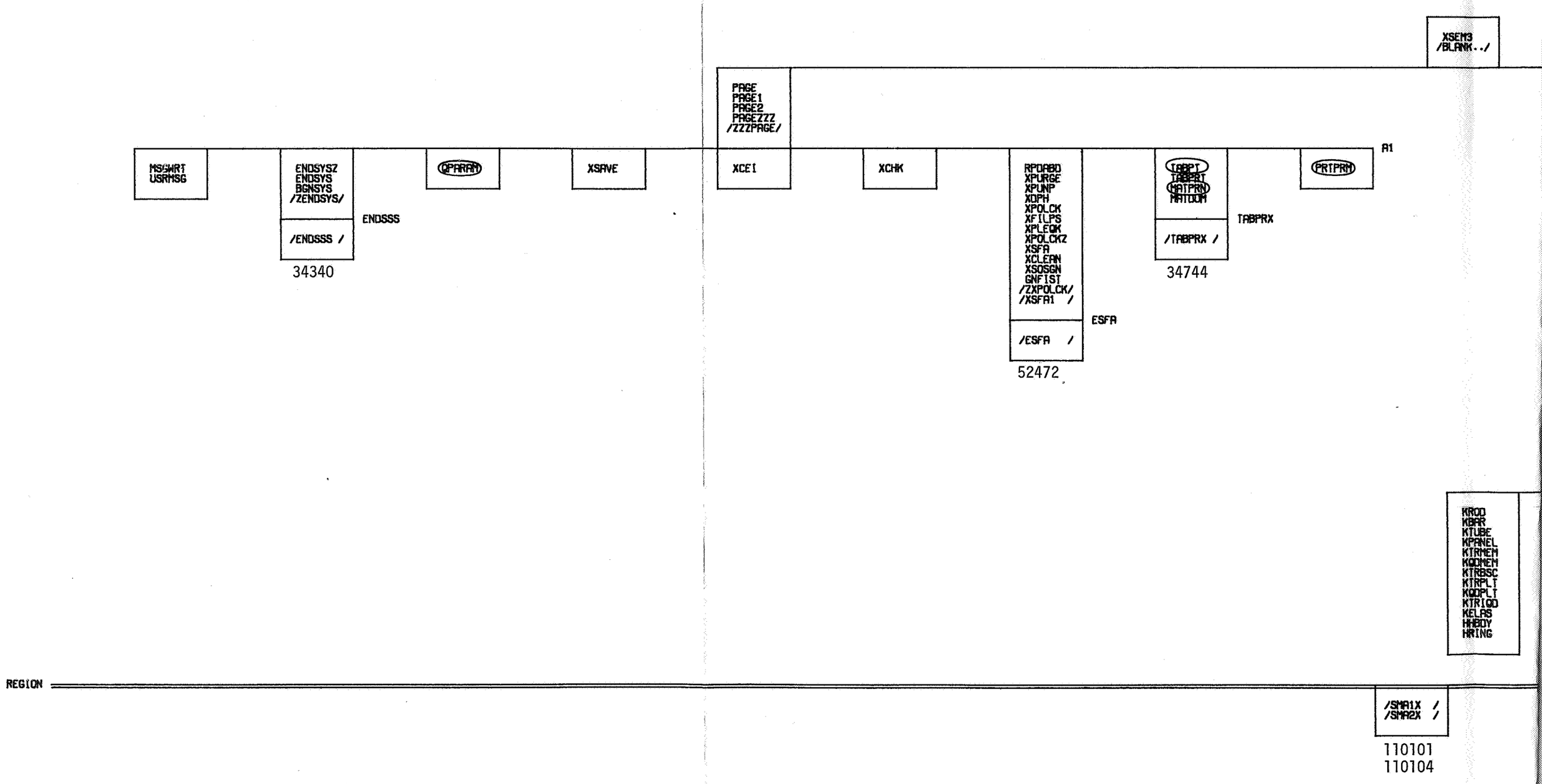


Figure 5. Overlay Structure for Link 2 on the CDC 6000.


MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
34340
QPARAM
XSAVE
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCEI
XCHK
RPDABD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
52472
TABPT
TABPRT
MATPRN
MATDUM
/TABPRX /
TABPRX
34744
PRTPRM
A1
XSEM3
/BLANK../
KROD
KBAR
KTUBE
KPANEL
KTRMEM
KQDMEM
KTRBSC
KTRPLT
KQDPLT
KTRIQD
KELAS
HHBDY
HRING
REGION
/SMA1X /
/SMA2X /
110101
110104

LINK 3

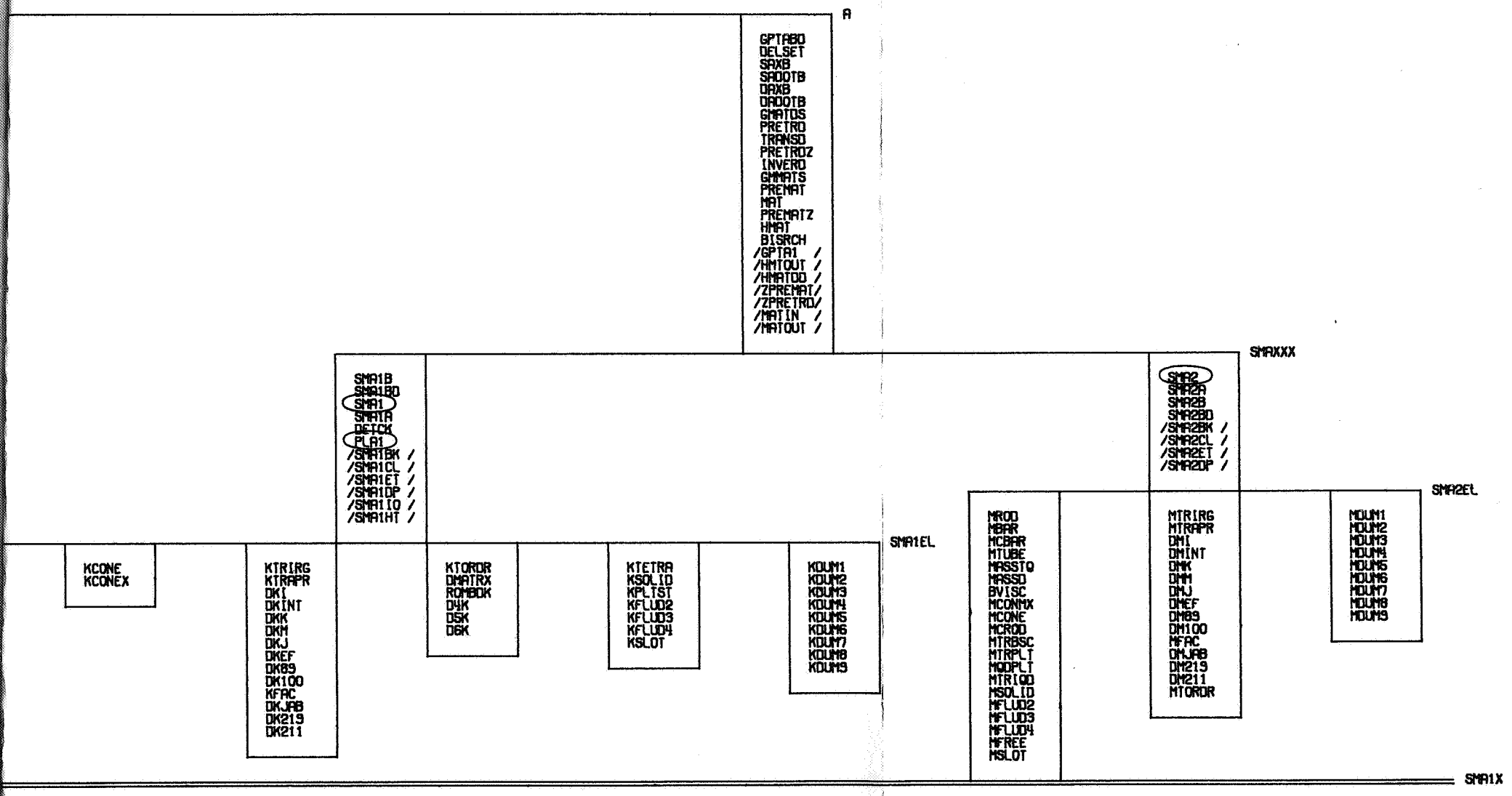


Figure 6. Overlay Structure for Link 3 on the CDC 6000.

REGION

MSGHRT
USRMSG

ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/

/ENDSSS /

ENDSSS

34742

QPARAM

XSAVE

XCEI

PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/

XCHK

RPQABD
XPURGE
XPUNP
XQPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /

/ESFA /

ESFA

53066

TABPT
TABPRT
MATPRM
MATDUM

/TABPRX /

TABPRX

35334

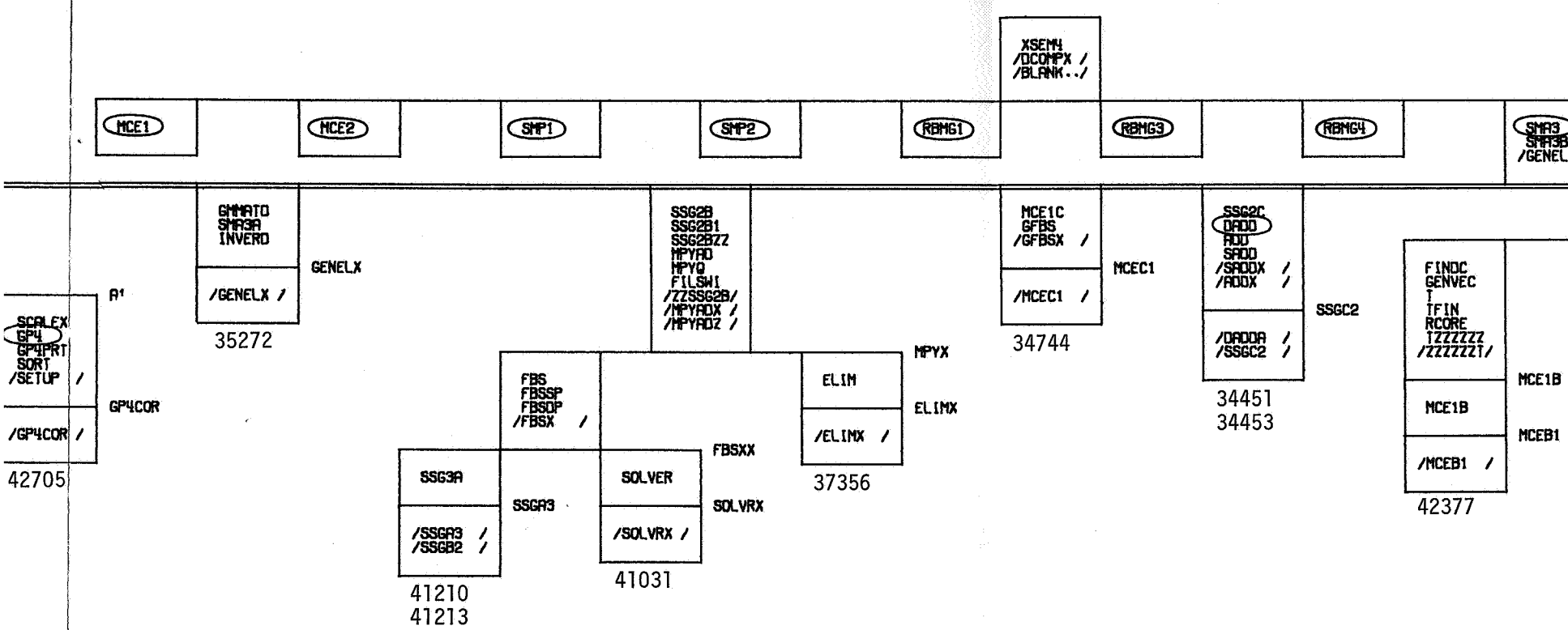
PRTPRM

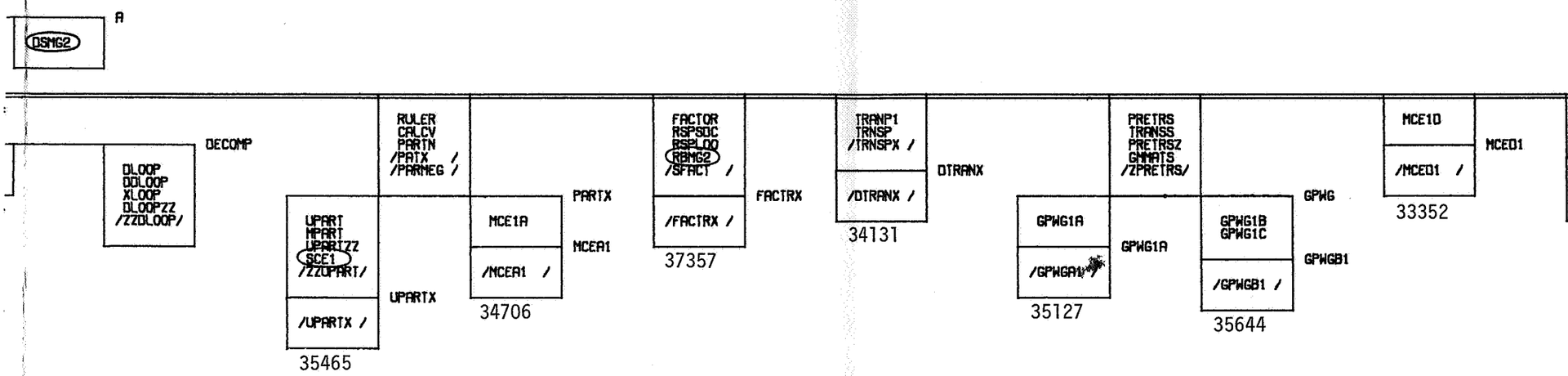
MATGPR

/MPRTX /

MPRTX

34714


MCE1
MCE2
SMP1
SMP2
RBMG1
XSEM4
/DCOMPX /
/BLANK../
RBMG3
RBMG4
SMA3
SMA3BD
/GENELY /
GPWG
DECOMP
TRANSP
GMMATO
SMA3A
INVERD
/GENELX /
GENELX
35272
SSG2B
SSG2B1
SSG2BZZ
MPYAD
MPYQ
FILSWI
/ZZSSG2B/
/MPYADX /
/MPYADZ /
MPYX
MCE1C
GFBS
/GFBSX /
/MCEC1 /
MCEC1
34744
SSG2C
DADD
ADD
SADD
/SADDX /
/ADDX /
/DADDA /
/SSGC2 /
SSGC2
34451
34453
FINDC
GENVEC
T
TFIN
RCORE
TZZZZZZ
/ZZZZZZT/
MCE1B
ONETWO
FINWRT
ONETWOZ
/ZONETWO/
MCE1B
MCE1B
/MCEB1 /
MCEB1
42377
A1
SCALEX
GP4
GP4PRT
SORT
/SETUP /
/GP4COR /
GP4COR
42705
FBS
FBSSP
FBSDP
/FBSX /
FBSXX
ELIM
/ELIMX /
ELIMX
37356
SSG3A
/SSGA3 /
/SSGB2 /
SSGA3
41210
41213
SOLVER
/SOLVRX /
SOLVRX
41031


A
DSMG2
DECOMP
DLOOP
DDLOOP
XLOOP
DLOOPZZ
/ZZDLOOP/
UPART
MPART
UPARTZZ
SCE1
/ZZUPART/
/UPARTX /
UPARTX
35465
RULER
CALCV
PARTN
/PATX /
/PARMEG /
MCE1A
/MCEA1 /
MCEA1
PARTX
34706
FACTOR
RSPSDC
RSPLOO
RBMG2
/SFACT /
/FACTRX /
FACTRX
37357
TRANP1
TRNSP
/TRNSPX /
/DTRANX /
DTRANX
34131
PRETRS
TRANSS
PRETRSZ
GMMATS
/ZPRETRS/
GPWG1A
/GPWGA1/
GPWG1A
35127
GPWG1B
GPWG1C
/GPWGB1 /
GPWGB1
GPWG
35644
MCE1D
/MCED1 /
MCED1
33352

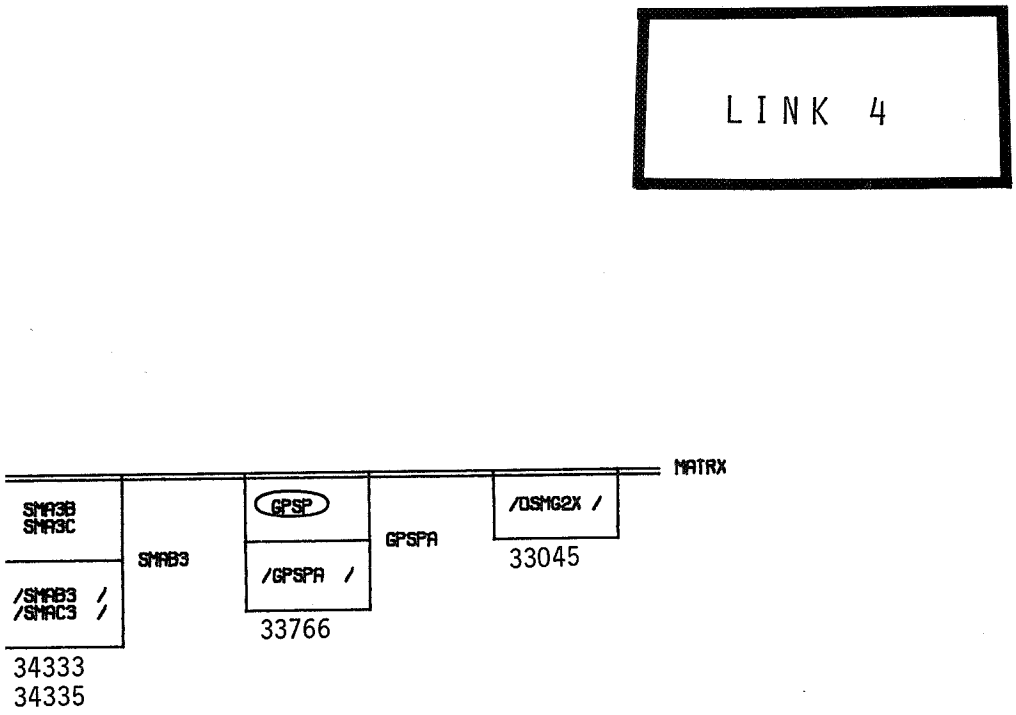
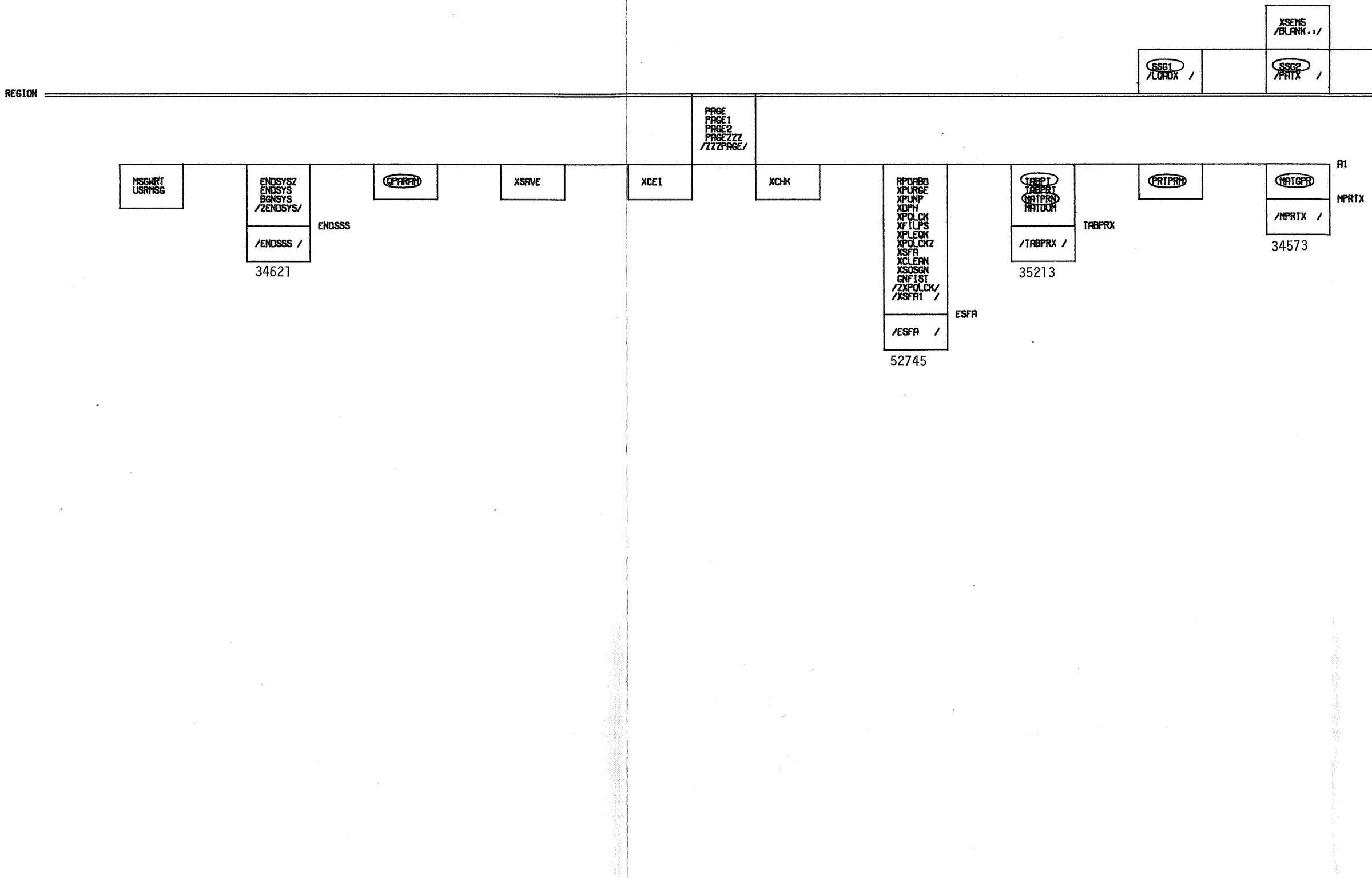


Figure 7. Overlay Structure for Link 4 on the CDC 6000.


REGION
MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
34621
QPARAM
XSAVE
XCEI
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCHK
RPQABD
XPURGE
XPUNP
XQPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
52745
TABPT
TABPRT
MATPRN
MATDUM
/TABPRX /
TABPRX
35213
SSG1
/LOADX /
PRTPRM
XSEMS
/BLANK.*/
SSG2
/PRTX /
MATGPR
/MPRTX /
MPRTX
34573
A1

LINK 5

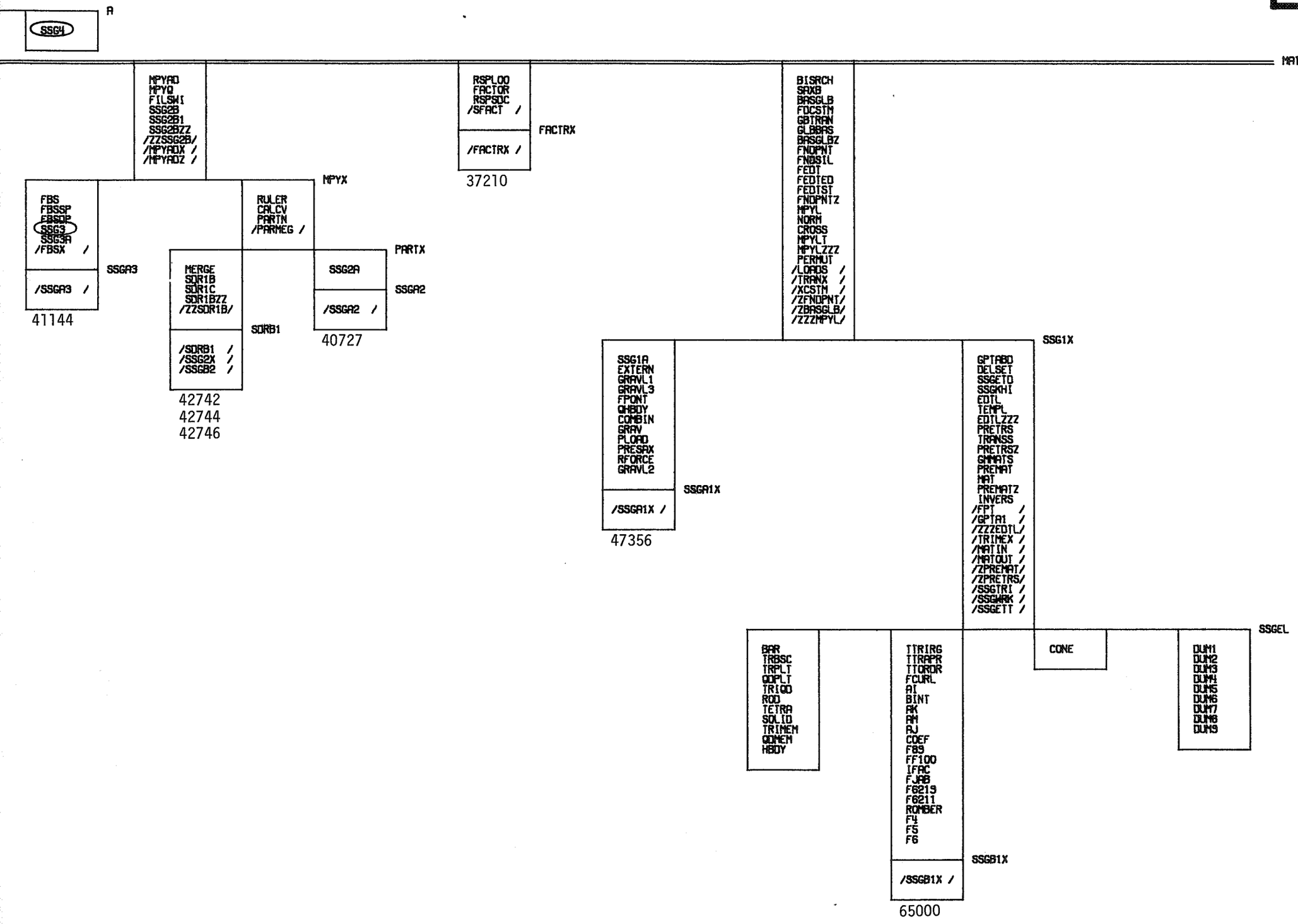
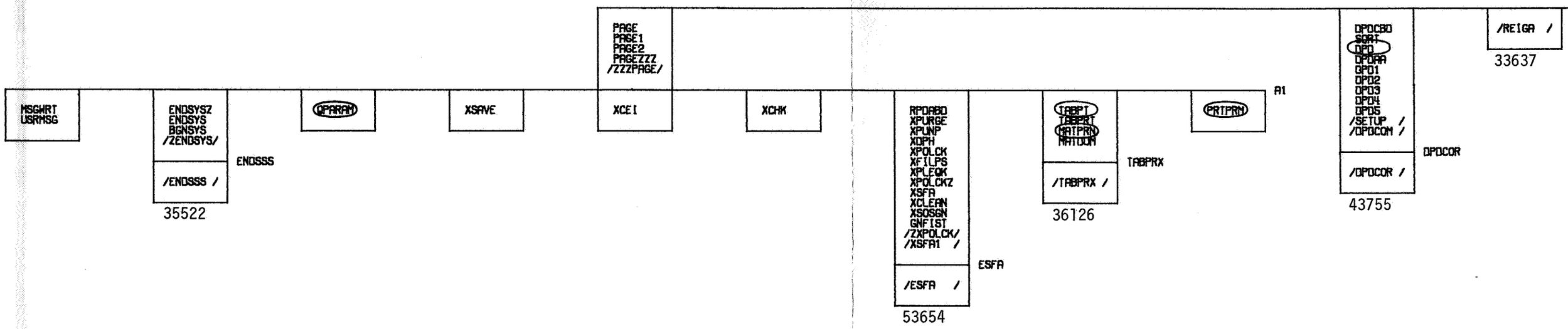


Figure 8. Overlay Structure for Link 5 on the CDC 6000.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USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
35522
QPARAM
XSAVE
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCEI
XCHK
RPDABD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
53654
TABPT
TABPRT
MATPRN
MATDOM
/TABPRX /
TABPRX
36126
PRTPRM
A1
DPDCBD
SQRT
DPD
DPDAA
DPD1
DPD2
DPD3
DPD4
DPD5
/SETUP /
/DPDCOM /
/DPDCOR /
DPDCOR
43755
/REIGA /
33637

LINK 6

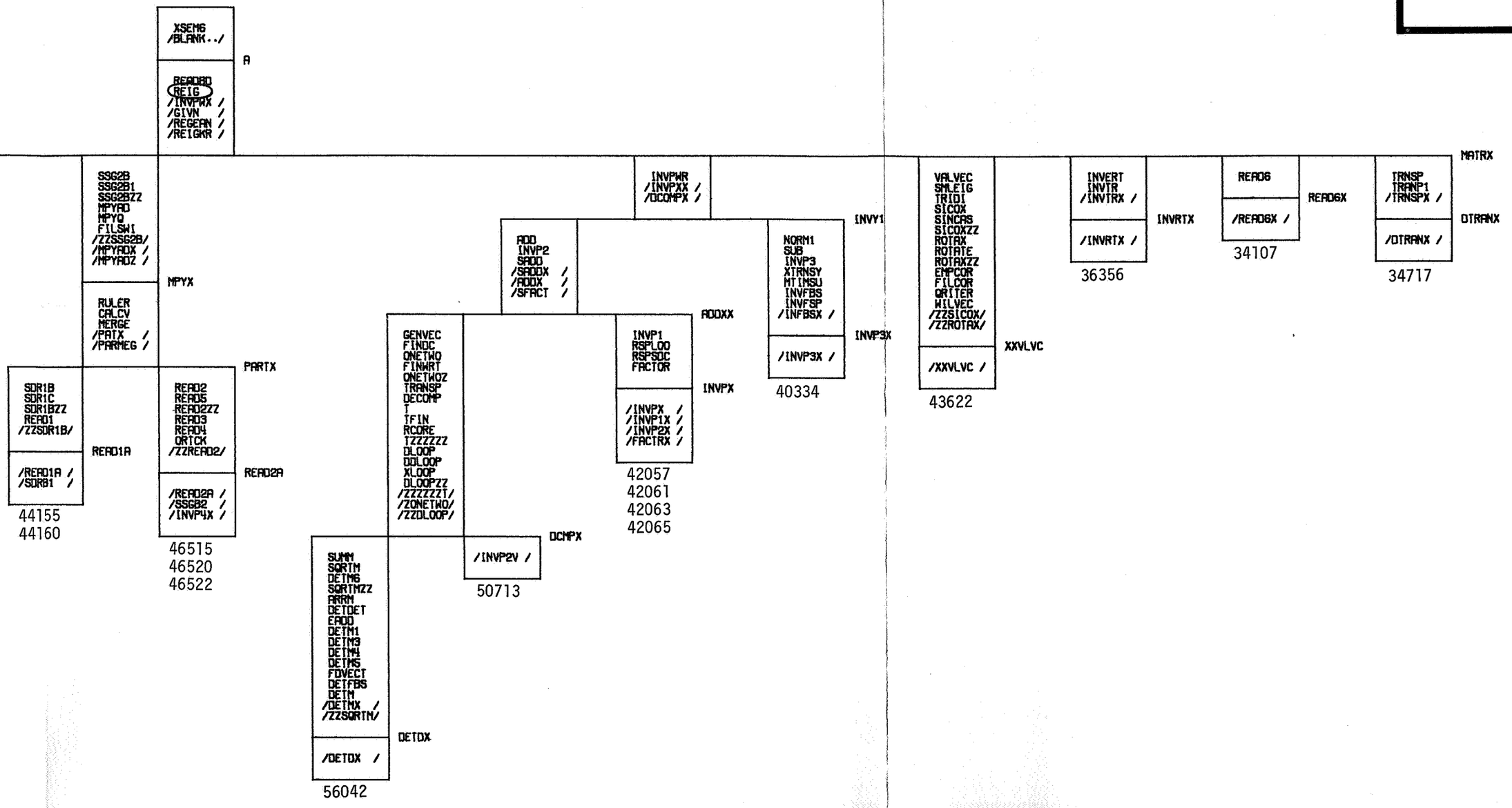


Figure 9. Overlay Structure for Link 6 on the CDC 6000.

REGION

PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/

MSGWRT
USRMSG

ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/

/ENDSSS /

ENDSSS

34661

QPARAM

XSAVE

XCEI

XCHK

RPDABD
XPURGE
XPUNP
XOPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /

/ESFA /

ESFA

53005

TABPT
TABPRT
MATPRM
MATDUM

/TABPRX /

TABPRX

35253

PRTPRM

MATGPR

/MPRTX /

MPRTX

34633

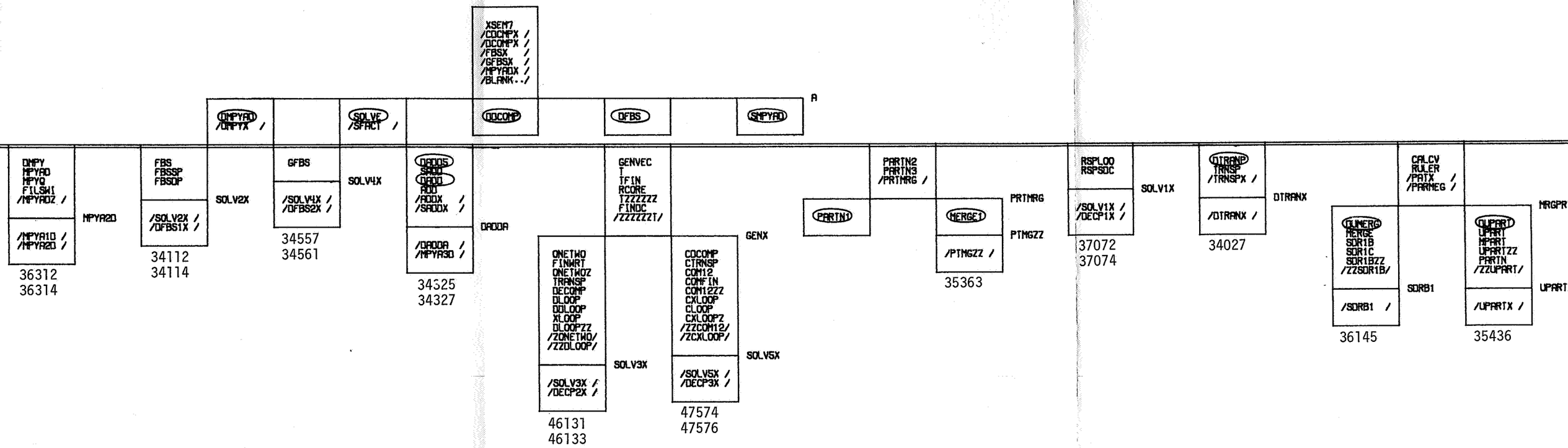
DUM001
DUMTIM
DUMBBT
/DUM1QQ /

/DUM1XX /

DUM1XX

35026

A1


XSEM7
/CDCMPX /
/DCOMPX /
/FBSX /
/GFBSX /
/MPYADX /
/BLANK../
A
DMPYAD
/DMPYX /
SOLVE
/SFACT /
DDCOMP
DFBS
SMPYAD
DMPY
MPYAD
MPYQ
FILSWI
/MPYADZ /
/MPYA1D /
/MPYA2D /
MPYA2D
36312
36314
FBS
FBSSP
FBSDP
/SOLV2X /
/DFBS1X /
SOLV2X
34112
34114
GFBS
/SOLV4X /
/DFBS2X /
SOLV4X
34557
34561
DADD5
SADD
DADD
ADD
/ADDX /
/SADDX /
/DADDA /
/MPYA3D /
DADDA
34325
34327
ONETWO
FINWRT
ONETWOZ
TRANSP
DECOMP
DLOOP
DDLOOP
XLOOP
DLOOPZZ
/ZONETWO/
/ZZDLOOP/
/SOLV3X /
/DECP2X /
SOLV3X
46131
46133
GENVEC
T
TFIN
RCORE
TZZZZZZ
FINDC
/ZZZZZZT/
CDCOMP
CTRNSP
COM12
COMFIN
COM12ZZ
CXLOOP
CLOOP
CXLOOPZ
/ZZCOM12/
/ZCXLOOP/
/SOLV5X /
/DECP3X /
SOLV5X
47574
47576
GENX
PARTN1
PARTN2
PARTN3
/PRTMRG /
MERGE1
/PTMGZZ /
PRTMRG
PTMGZZ
35363
RSPLOO
RSPSOC
/SOLV1X /
/DECP1X /
SOLV1X
37072
37074
DTRANP
TRNSP
/TRNSPX /
/DTRANX /
DTRANX
34027
CALCV
RULER
/PATX /
/PARMEG /
DUMERG
MERGE
SDR1B
SDR1C
SDR1BZZ
/ZZSDR1B/
/SDRB1 /
SDRB1
36145
DUPART
UPART
MPART
UPARTZZ
PARTN
/ZZUPART/
/UPARTX /
UPARTX
MRGPRT
35436

LINK 7

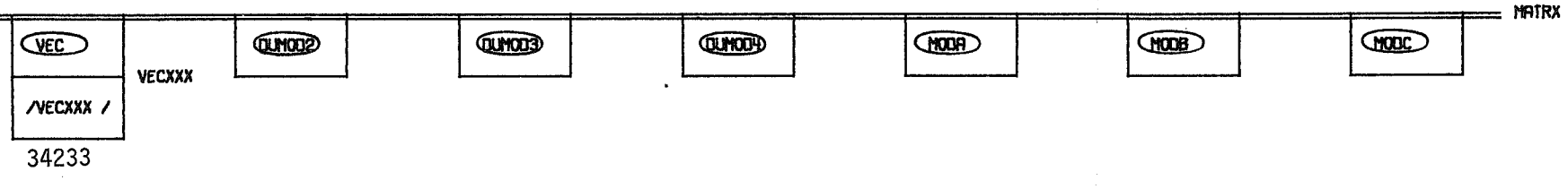
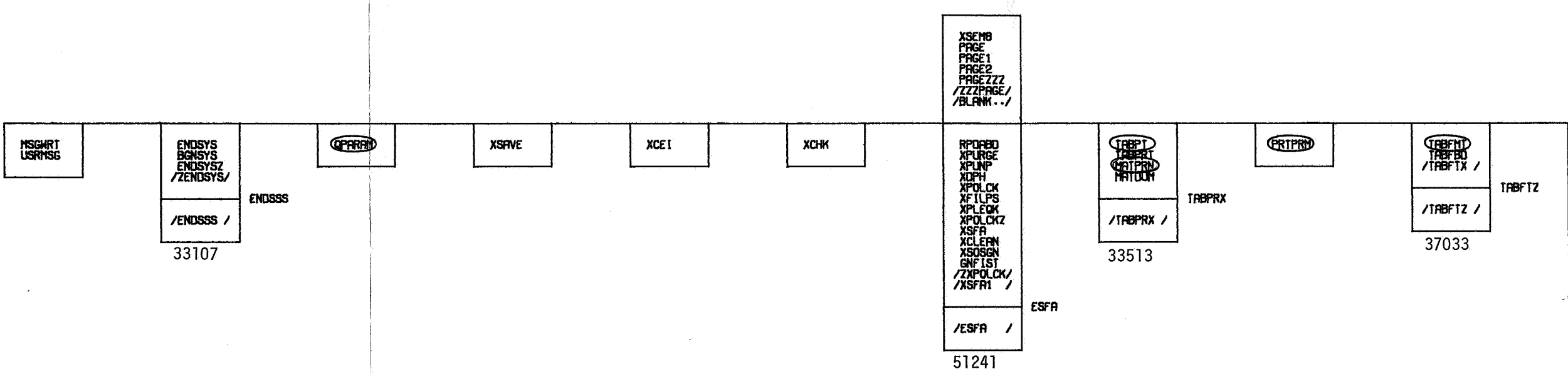


Figure 10. Overlay Structure for Link 7 on the CDC 6000.


MSGWRT
USRMSG
ENDSYS
BGNSYS
ENDSYSZ
/ZENDSYS/
/ENDSSS /
ENDSSS
33107
QPARAM
XSAVE
XCEI
XCHK
XSEMB
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
/BLANK../
RPOABO
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
51241
TABPT
TABERT
HATPRN
HATDUM
/TABPRX /
TABPRX
33513
PRTPRM
TABFNT
TABFBO
/TABFTX /
/TABFTZ /
TABFTZ
37033

LINK 8

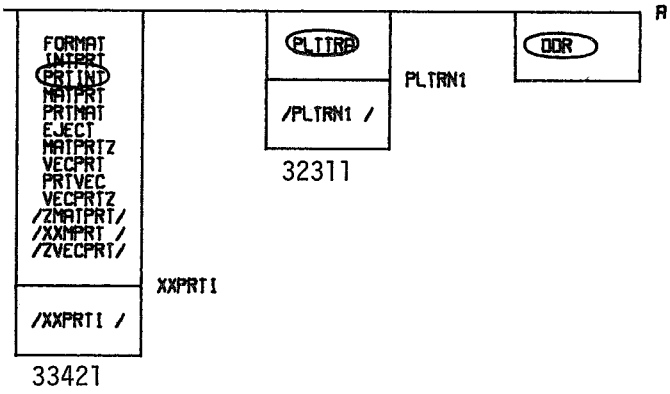


Figure 11. Overlay Structure for Link 8 on the CDC 6000.

LINK 9

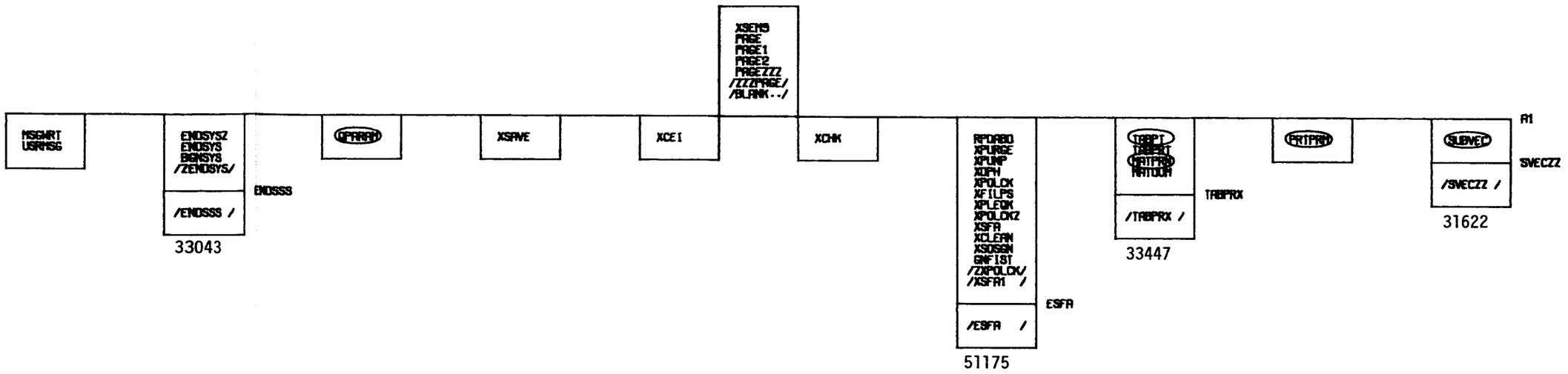
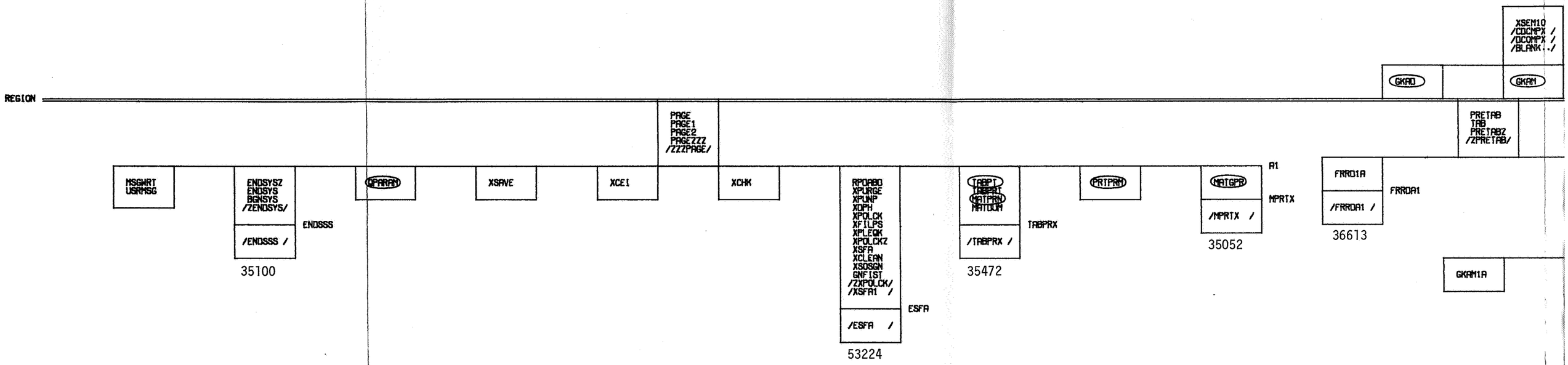
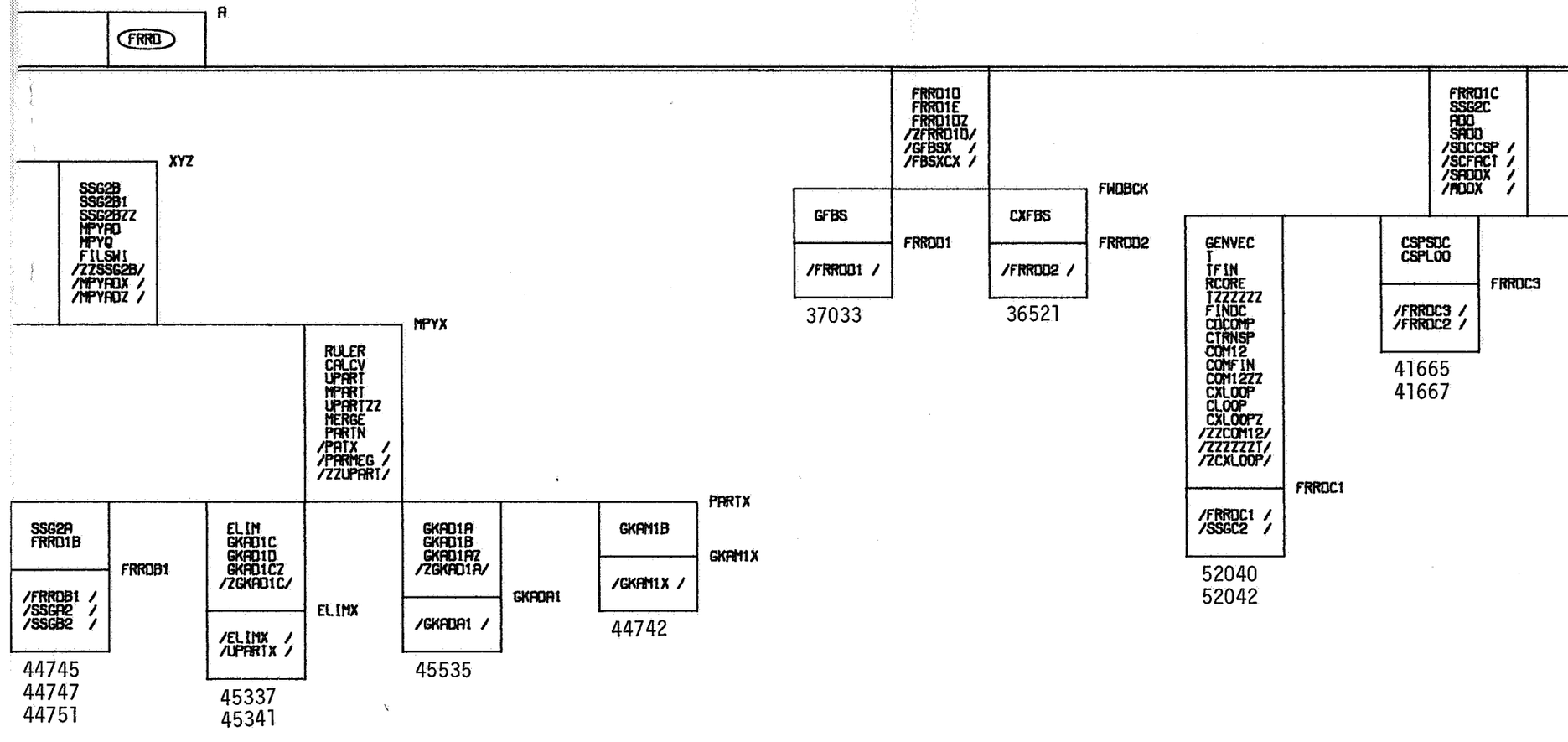


Figure 12. Overlay Structure for Link 9 on the CDC 6000.


REGION
MSGHRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
35100
OPARAM
XSAVE
XCE1
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCHK
RPORBD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
53224
TABPT
TABPRT
MATPRN
MATDUM
/TABPRX /
TABPRX
35472
PRTPRM
MATGPR
/MPRTX /
MPRTX
A1
35052
FRRD1A
/FRRDA1 /
FRRDA1
36613
GKAD
GKAM
XSEM10
/CDCMPX /
/DCOMPX /
/BLANK../
PRETAB
TAB
PRETABZ
/ZPRETAB/
GKAM1A


A
FRRO
XYZ
SSG2B
SSG2B1
SSG2BZZ
MPYAO
MPYQ
FILSWI
/ZZSSG2B/
/MPYAOX /
/MPYAOZ /
MPYX
RULER
CALCV
UPART
MPART
UPARTZZ
MERGE
PARTN
/PATX /
/PARMEG /
/ZZUPART/
PARTX
SSG2A
FRRO1B
FRRDB1
/FRRDB1 /
/SSGA2 /
/SSGB2 /
44745
44747
44751
ELIM
GKAD1C
GKAD1D
GKAD1CZ
/ZGKAD1C/
ELIMX
/ELIMX /
/UPARTX /
45337
45341
GKAD1A
GKAD1B
GKAD1AZ
/ZGKAD1A/
GKADA1
/GKADA1 /
45535
GKAM1B
GKAM1X
/GKAM1X /
44742
FRRO1O
FRRO1E
FRRO1OZ
/ZFRRO1O/
/GFBSX /
/FBSXCX /
FWOBCK
GFBS
FRRDD1
/FRRDD1 /
37033
CXFBS
FRRDD2
/FRRDD2 /
36521
GENVEC
T
TFIN
RCORE
TZZZZZZ
FINDC
CDCOMP
CTRNSP
COM12
COMFIN
COM12ZZ
CXLOOP
CLOOP
CXLOOPZ
/ZZCOM12/
/ZZZZZZZT/
/ZCXLOOP/
FRRDC1
/FRRDC1 /
/SSGC2 /
52040
52042
FRRO1C
SSG2C
ADO
SADO
/SOCCSP /
/SCFACT /
/SADOX /
/ADOX /
CSPSOC
CSPLOO
FRRDC3
/FRRDC3 /
/FRRDC2 /
41665
41667

LINK 10

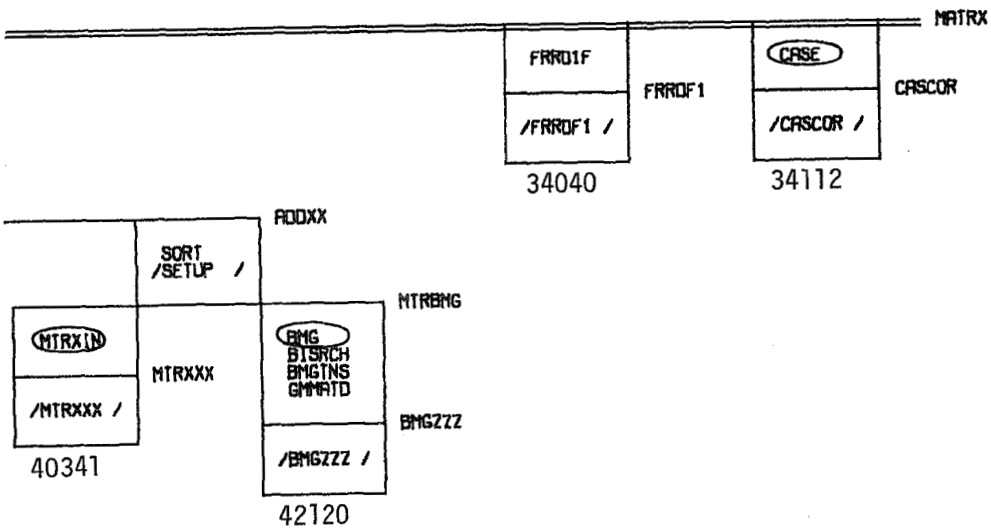
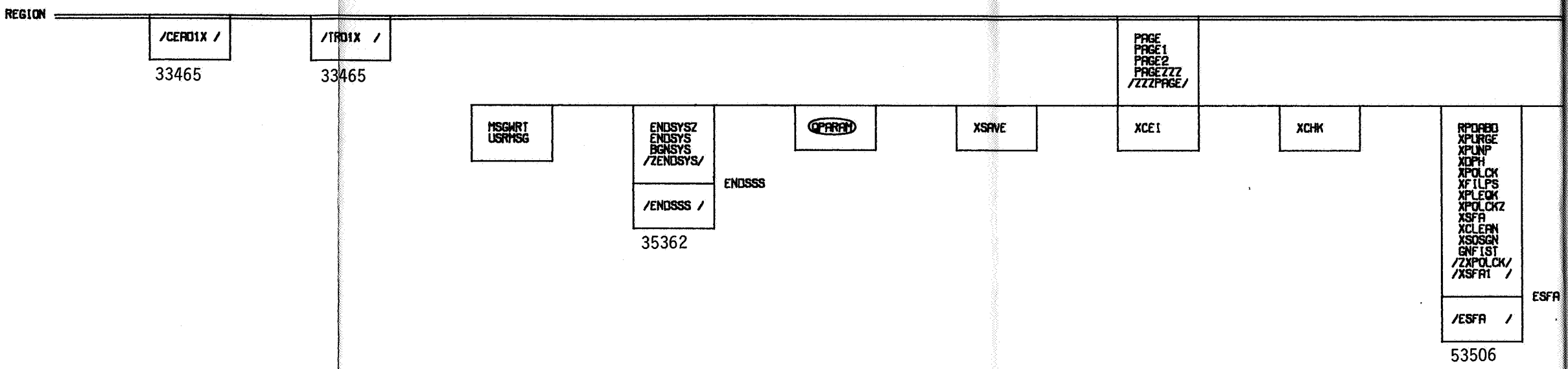


Figure 13. Overlay Structure for Link 10 on the CDC 6000.


REGION
/CEAD1X /
33465
/TRD1X /
33465
MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
35362
ENDSSS
QPARAM
XSAVE
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCE1
XCHK
RPDABD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
53506
ESFA

LINK 11

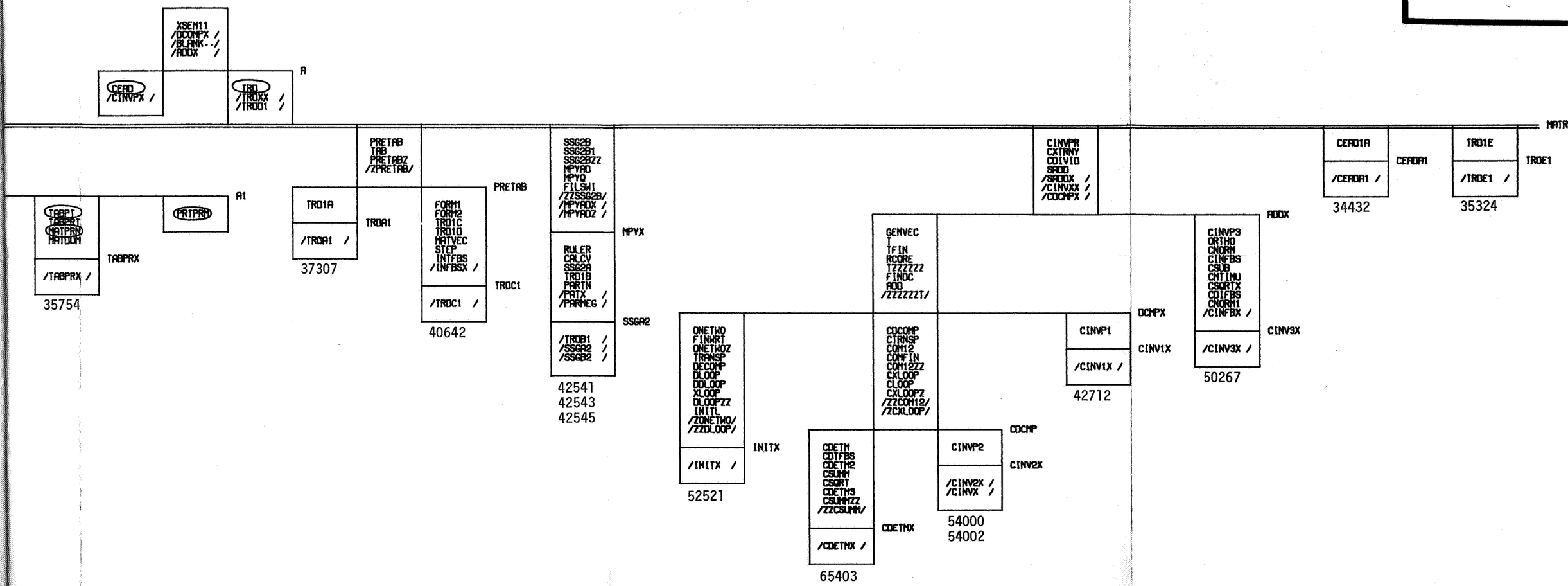
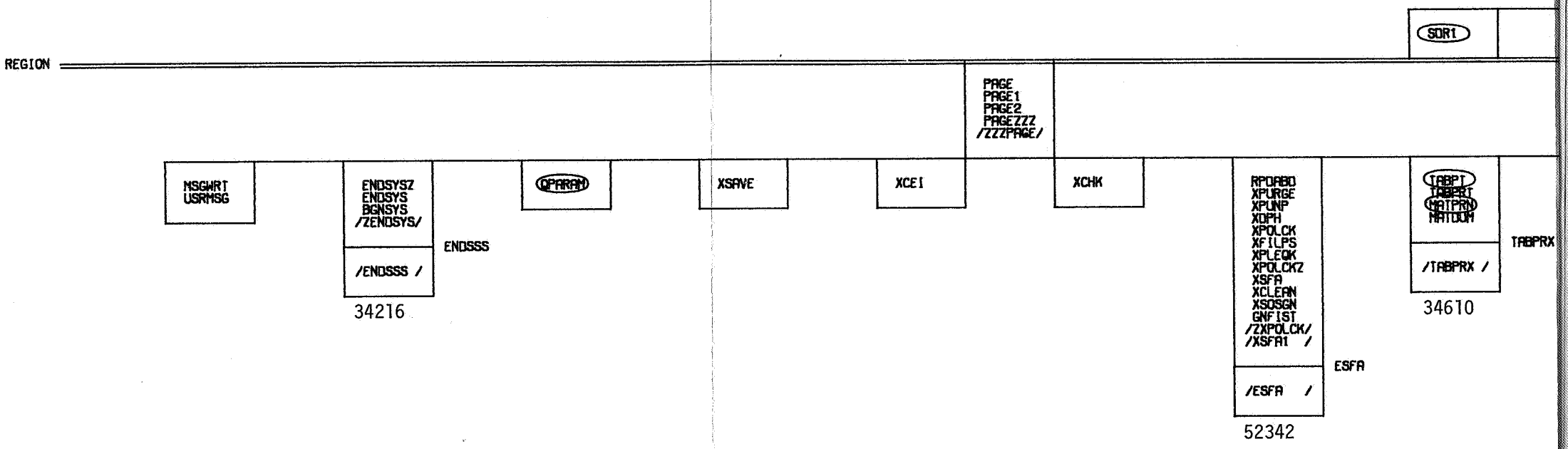


Figure 14. Overlay Structure for Link 11 on the CDC 6000.


REGION
SDR1
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
34216
QPARAM
XSAVE
XCEI
XCHK
RPDABD
XPURGE
XPUNP
XDPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
52342
TABPT
TABPRT
MATPRN
MATDUM
/TABPRX /
TABPRX
34610

LINK 12

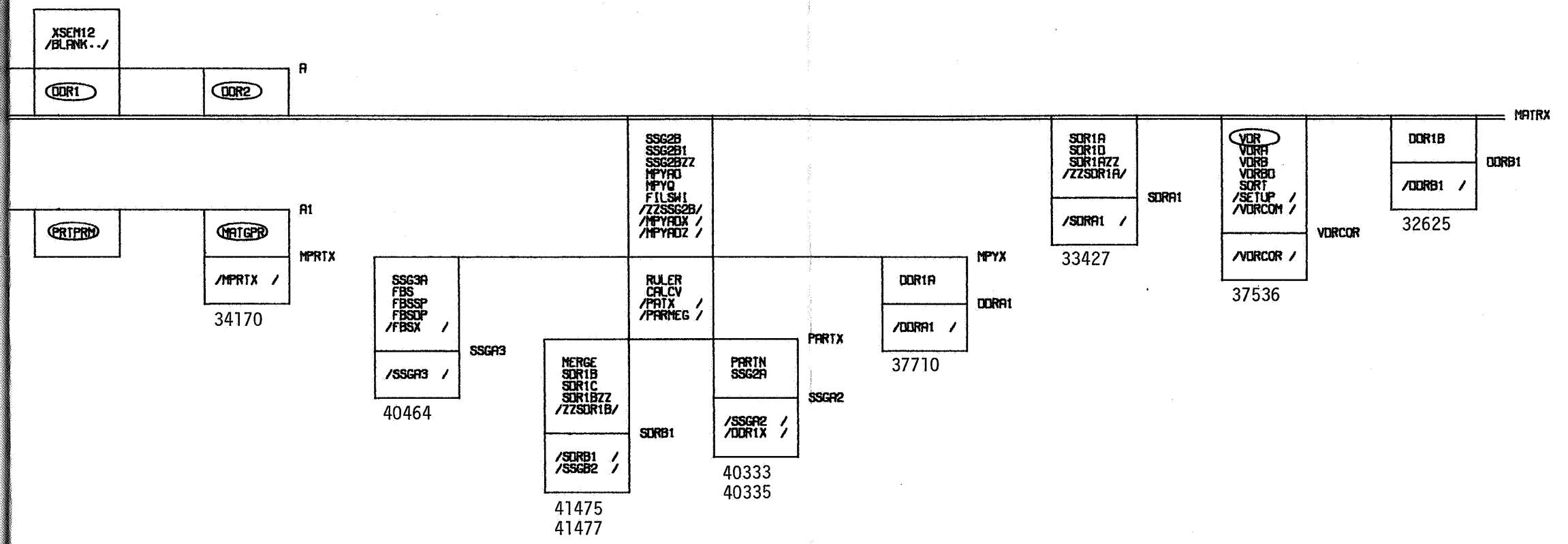
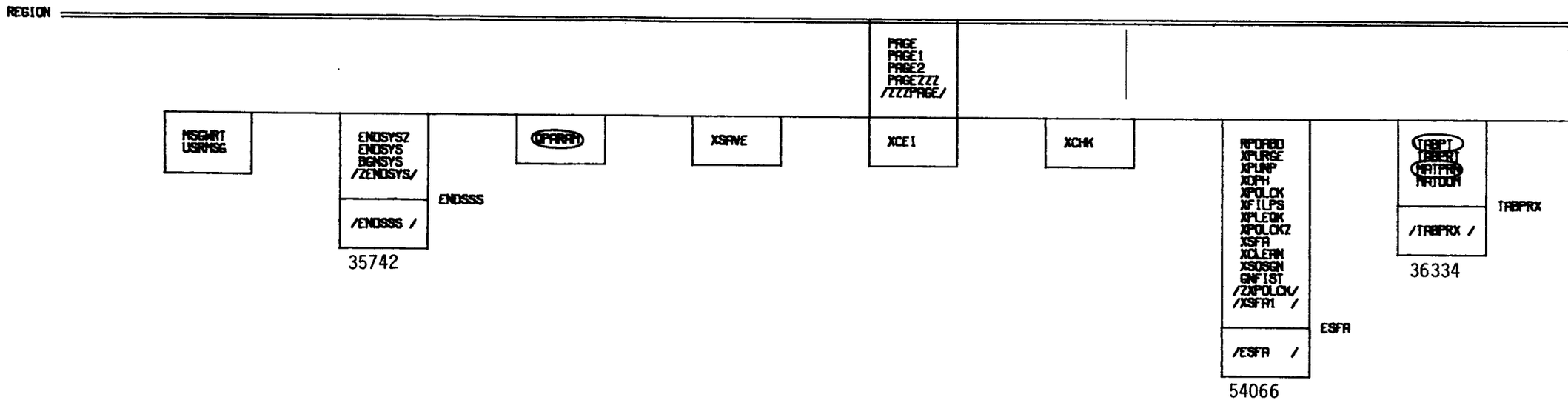


Figure 15. Overlay Structure for Link 12 on the CDC 6000.


REGION
MSGHRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
35742
XPARAM
XSAVE
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
XCE1
XCHK
RPDRBD
XPURGE
XPUMP
XDPH
XPOLCK
XFILPS
XPLEGK
XPOLCKZ
XSFR
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFR1 /
/ESFR /
ESFR
54066
TRBPT
TRBERT
MRTPRG
MRTDOM
/TRBPRX /
TRBPRX
36334

XSEM13
SORT
/BLANK../

SDR2
SDR2BD
/SDR2X1 /
/SDR2X2 /
/SDR2X4 /

DSMG1

PLA3

PLA4

A

SDR2A
SDR2AA
/SETUP /

PRTPRM

A1

PREMAT
MAT
PREMATZ
PLAMAT
INVERS
/MAIN /
/MATOUT /
/ZPREMAT/
/PLAGP /

SDR2B
/SDR2X5 /
/SDR2X6 /

ASDR2B

GMMATD
PRETRD
TRANSD
PRETRDZ
INVERD
/ZPRETRD/

DSPLA4

SROD1
STUBE1
SPANL1
SELAS1
STRPL1
SQDPL1
STRQD1
STRBS1
SQDME1
STRME1
SBAR1
SSOLD1
SAXIF1
SSLOT1

SDRA2

/SDRA2 /

62452

SCONE1

STRIR1
STRAP1
AI
BINT
AK
AM
AJ
COEF
F89
FF100
IFAC
FJAB
F6219
F6211

STORD1
ROMBER
F4
F5
F6
AMATRX
SCRLM
SOLVE1

SDUM11
SDUM21
SDUM31
SDUM41
SDUM51
SDUM61
SDUM71
SDUM81
SDUM91

DS1ABD
DS1A
DS1B
/DS1ADP /
/DS1AAA /
/DS1AET /

DCONE

DSPLEL

DBAR
DQDMEM
DROD
DSHEAR
DTRMEM
DTRIA
DQUAD
DTRBSC

DS1AXX

/DS1AXX /

103343

DDUM1
DDUM2
DDUM3
DDUM4
DDUM5
DDUM6
DDUM7
DDUM8
DDUM9

PLA4BD
PLA42
PLA4B
PKBAR
PKQDM
PKROD
PKQAD1
PKQAD2
PKQDMS
PKQDM1
PKQDPL
PKTQ1
PKTQ2
PKTRBS
PKTRI1
PKTRI2
PKTRM
PKTRMS
PKTRM1
PKTRPL
PKTROD
PKTRQ2
/PLA42D /
/PLA42E /
/PLA42C /
/PLA42S /
/PLA4ES /
/PLA4UV /

PLA42X

/PLA42X /

77720

LINK 13

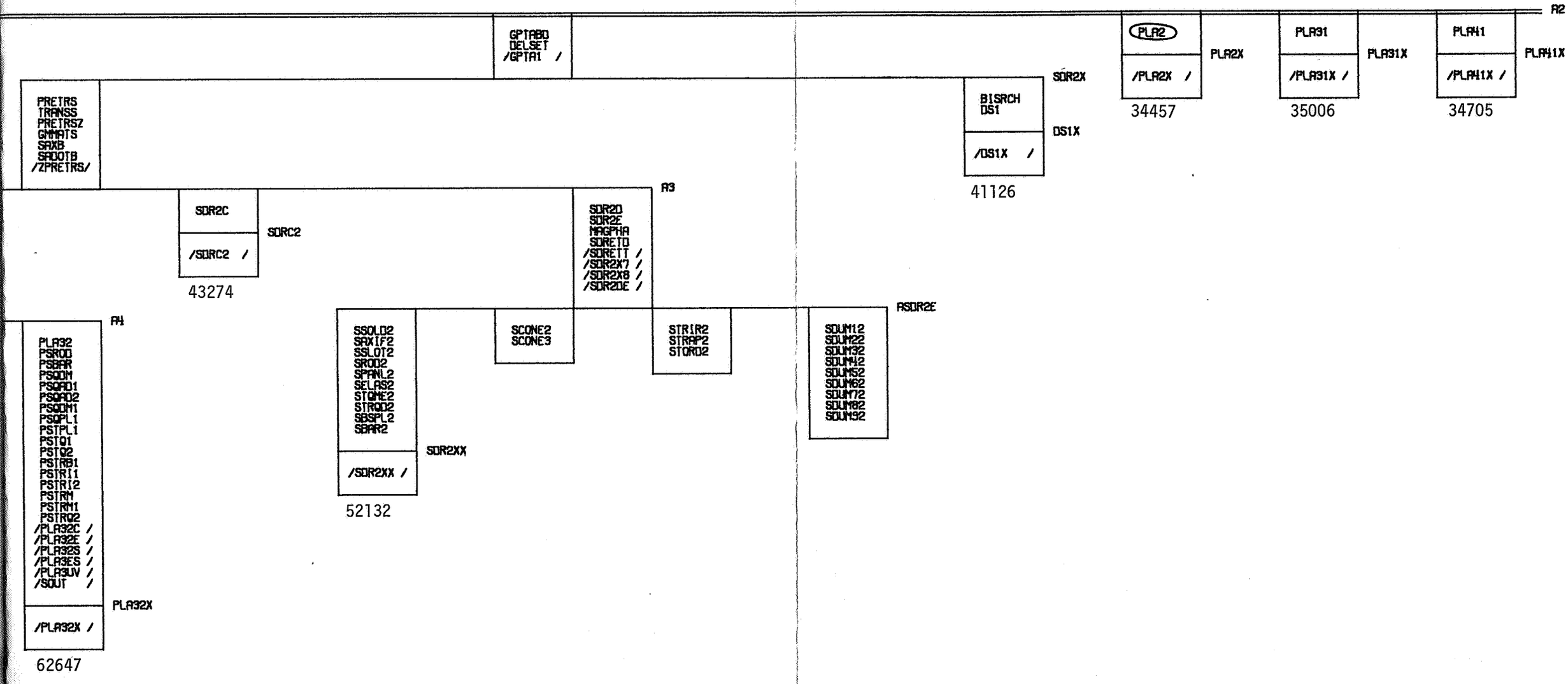
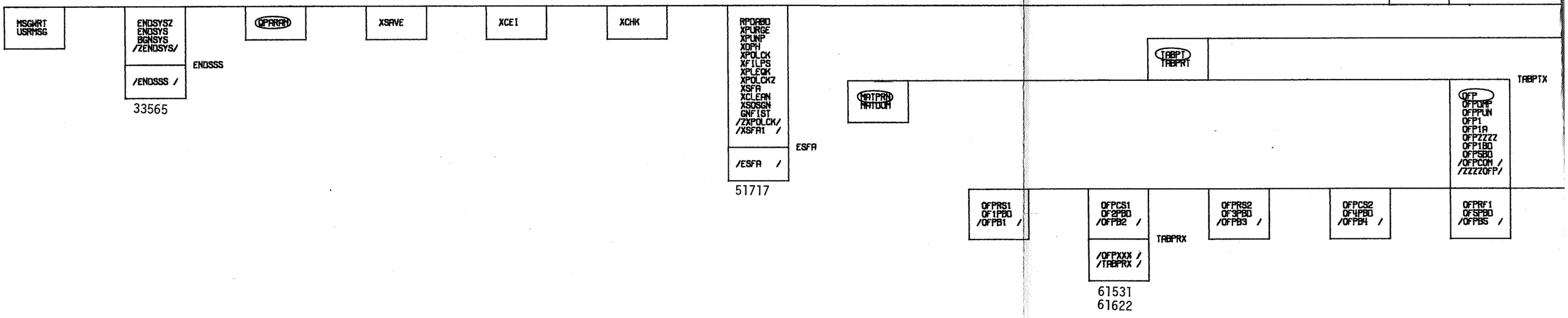


Figure 16. Overlay Structure for Link 13 on the CDC 6000.


MSGWRT
USRMSG
ENDSYSZ
ENDSYS
BGNSYS
/ZENDSYS/
/ENDSSS /
ENDSSS
33565
QPARAM
XSAVE
XCEI
XCHK
RPDRBD
XPURGE
XPUNP
XOPH
XPOLCK
XFILPS
XPLEQK
XPOLCKZ
XSFA
XCLEAN
XSOSGN
GNFIST
/ZXPOLCK/
/XSFA1 /
/ESFA /
ESFA
51717
MATPRM
MATDOM
TABPT
TABPRT
TABPTX
TABPIT
PAGE
PAGE1
PAGE2
PAGEZZZ
/ZZZPAGE/
QFP
OFPDMP
OFPPUN
OFP1
OFP1A
OFPZZZZ
OFP1BD
OFPSBD
/OFPCOM /
/ZZZZOFP/
OFPRS1
OF1PBD
/OFPB1 /
OFPCS1
OF2PBD
/OFPB2 /
/OFPXXX /
/TABPRX /
TABPRX
61531
61622
OFPRS2
OF3PBD
/OFPB3 /
OFPCS2
OF4PBD
/OFPB4 /
OFPRF1
OFSPBD
/OFPB5 /

XSEM14
/BLANK../

SDR3

PRTPRM

SDR3A
/SDR3ZZ /
34715
A2
SDR3ZZ

XYTRAN
SDR1
/SETUP /
/XYWORK /

XYCHAR
XYGRAF
XYPRPL
/XYPPPP /

XYDUMP
XYFIND
XYOUT
XYTICS
XYLOG
/XYTRZZ /
44733
XYTRAN
XYTRZZ

OUTPT1
TPSWIT
FORFIL
/OUT1XX /
34027
OUT1XX

OUTPT2
/OUT2XX /
33700
OUT2XX

OUTPT3
PRONTA
/PHOMIX /
/OUT3XX /
33742
A1
OUT3XX

OFP

OFPCF1
OFGPB0
/OFPB6 /

OFPRF2
OF7PB0
/OFPB7 /

OFPCF2
OF8PB0
/OFPB8 /

OFPMIS
OF9PB0
/OFPB9 /

LINK 14

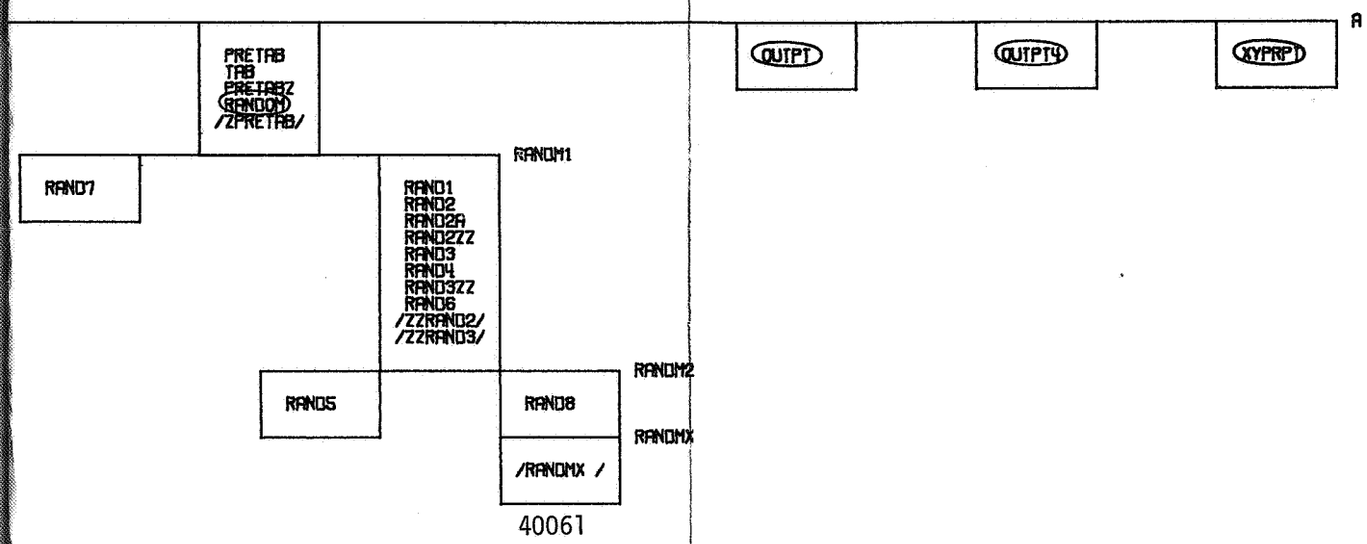


Figure 17. Overlay Structure for Link 14 on the CDC 6000.

5.6 THE CDC 6400/6600 LINKAGE EDITOR

5.6.1 Introduction

5.6.1.1 Concept of the Linkage Editor

The linkage editor has been designed to provide an efficient and effective means of utilizing core storage for medium to large programs. The existing loader for the CDC 6400/6600 systems has the following disadvantages:

1. Only two levels of overlay are provided beyond the root segment.
2. An overlay segment must be explicitly called. Consequently, the overlay structure must be known when the program is coded.
3. An overlay segment may be entered at one point only. Consequently, downward calls are extremely limited.
4. No facility exists to explicitly position named common blocks.
5. Loading of overlay segments is accomplished from a sequential file, thus providing unnecessary search time.

The CDC 6400/6600 Linkage Editor in conjunction with its partner, the Segment Loader, overcomes these disadvantages in the following ways:

1. An unlimited number of overlay levels is provided.
2. The programmer describes the overlay structure to the linkage editor after the program is coded. The linkage editor provides implicit segment loading.
3. Complete communication between all levels of overlay is maintained.
4. Linkage editor control statements may be used to explicitly position subprograms and named common blocks.
5. The overlay segments are maintained in an indexed file. Consequently, every segment is immediately available to the segment loader.

As may be seen from Figure 1, the primary input sources to the linkage editor include:

1. Object decks (relocatable binary decks)
2. Control statements

3. A call library from which unsatisfied external references are resolved.

Another source of input (not shown in Figure 1) is a file containing executable links from a previous linkage editor run. This feature allows changes or additions of links while not altering previous links to which no changes are required.

The file produced by the linkage editor contains three portions:

1. A sequence of object decks suitable for loading by the CDC loader. The main program in this sequence, named XBØØT, reads the remainder of the file containing the executable links and writes it on the disk as an indexed file. XBØØT reads Link 0 into central memory and transfers control to the entry point which initiates execution of the problem program. This sequence of decks is terminated by a null record.

2. Three records:

   (1) Link 0 directory record;

   (2) Link 0 symbol dictionary containing entry points and common blocks in Link 0 and their associated addresses;

   (3) Link 0 executable record.

3. A directory record for each succeeding link and one logical record per segment containing executable instructions and data.

This sequence of records is terminated by a directory record which contains the word ENDLINKS.

Link 0 remains in central memory at all times during program execution. Link 0 contains no overlay segments. The linkage editor supplies a routine named XLØADER when Link 0 is constructed. XLØADER accomplishes the loading of segments and links when requested. Segment load requests are supplied automatically by the linkage editor through tables called ENTAB$ (see section 5.6.3.2) which are written as a part of the text for each segment which may require additional segment loading. An additional table, SEGTAB$ (see section 5.6.3.2), which is constructed by the linkage editor as a part of the root segment of every link, is used by XLØADER to facilitate segment loading.

Major divisions of a program are links. Each link consists of a self-contained overlay structure and might be thought of as a complete program in itself. All routines in a link communicate freely with Link 0 routines. Consequently, Link 0 may be thought of as logically

belonging to every link. For many programs, a single link in addition to Link 0 will be sufficient. Because of its size, however, NASTRAN has been divided into 14 links.

5.6.1.2 Functions of the Linkage Editor

The basic function of the linkage editor is the linking of separately assembled or compiled subprograms into a link. The link is in a format suitable for loading and execution.

Although this linking or combining of subprograms is its primary function, the linkage editor also:

1. Incorporates subprograms from a library file to resolve undefined external references.
2. Constructs an overlay program in a format suitable for loading and execution.
3. Rearranges control sections and renames external references as directed by linkage editor control statements.
4. Reserves storage for common control sections generated by CØMPASS and FØRTRAN.
5. Provides processing options and diagnostic messages.

5.6.1.3 Subprogram Linkage

Processing by the linkage editor makes it possible for the programmer to divide his program into several subprograms which may be separately assembled or compiled. The linkage editor combines these subprograms into a link with contiguous storage addresses. The link is written in an indexed file. The linkage editor can process more than one link in a single job step. Each link is written with a unique link number.

5.6.1.4 Input Sources

Input to the linkage editor consists of one or more sequential files (libraries) containing subprograms in relocatable format as produced by CØMPASS or FØRTRAN, and linkage editor control statements contained in INPUT, the standard input file.

External references that are undefined after processing all subprograms cause the automatic library call mechanism to search for subprograms that will resolve the references. When these subprograms are found, they are processed by the linkage editor and become part of the link.

5.6.1.5 Programs in an Overlay Structure

To minimize main storage requirements, the programmer can organize his program into an overlay structure by dividing it into segments according to the functional relationshp of the subprograms. Two or more segments that need not be in main storage at the same time can be assigned the same storage addresses, and can be loaded at different times. The programmer uses linkage editor control statements to specify the relationship of segments within the overlay structure.

5.6.1.6 Options and Diagnostic Messages

The linkage editor can produce a storage map and a cross-reference table that show the arrangement of control sections in the link and how they communicate with each other. A list of the linkage editor control statements that were processed can be produced. Additionally, processing options that negate the effect of minor errors and specify the disposition of input and output files can be specified by the programmer.

Throughout processing by the linkage editor, errors and possible error conditions are printed. Serious errors cause a link not be written on the output file.

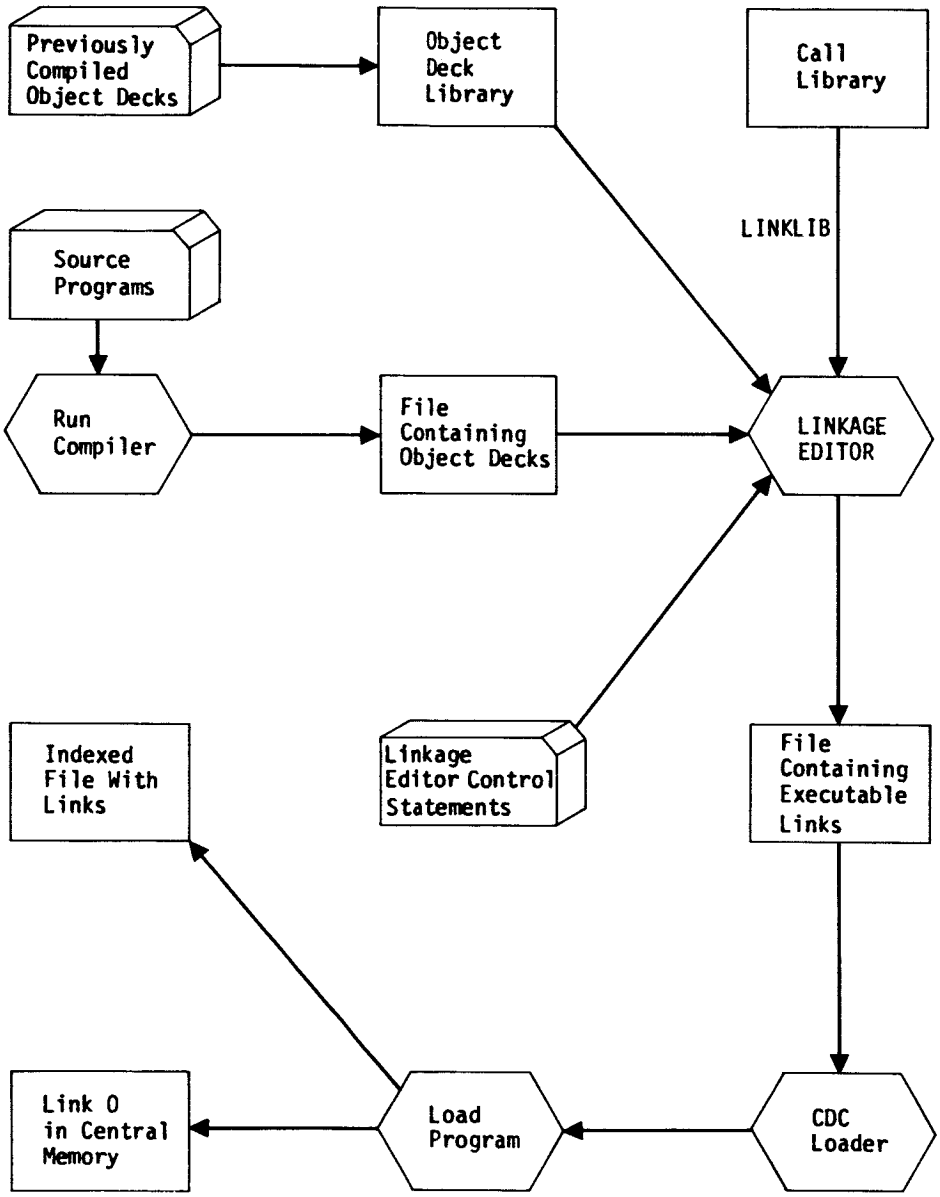


Figure 1. Linkage editor processing.

5.6.2 Preparing for Linkage Editor Processing

5.6.2.1 Object Decks

An object deck (relocatable binary deck), which is produced by the FØRTRAN compiler or CØMPASS assembler, consists of the following tables:

1. Program Identification and Length (PIDL), which defines a) subprogram identification and length and b) each of the common blocks referenced by the subprogram;
2. Entry Point (ENTR), which defines each of the entry points to the subprogram and its relative location;
3. Text (TEXT), which defines instructions and data for relocation;
4. Fill (FILL), which contains information to relocate previously defined address fields (in particular, references to common blocks);
5. Link (LINK), which indicates each external reference by the subprogram and its relative location;
6. Replication (REPL), which permits the repetition of a block of data.

Any other tables which may be contained in an object deck are ignored by the linkage editor. For a complete description of the format of these tables, see the SCØPE Reference Manual, Appendix D.

5.6.2.2 Libraries

All object decks that are to be processed by the linkage editor are contained in libraries. A library is a sequential file (which may reside on tape or disk) consisting of one or more logical records with one object deck per logical record.

A file named LINKLIB must always be defined for linkage editor processing. This file contains object decks for automatic library call plus object decks which are required in constructing the initial load portion of the output file.

There is no theoretical limit to the number of libraries which may be defined for linkage editor processing. Subprograms of the same name may appear in more than one library.

5.6.3 Designing an Overlay Program

5.6.3.1 Overlay Tree Structure

In order to place a program in an overlay structure, the programmer should be familiar with the following terms:

1. A control section consists of all instructions and data defined for a subprogram or a common block.

2. A segment is the smallest functional unit (one or more control sections) that can be loaded as one logical entity during program execution.

3. A path consists of a segment and all segments in the same region between it and the root segment (first segment). The root segment is a part of every path in every region. When a segment is in main storage, all segments in its path are also in main storage.

4. A region is a continguous area of main storage within which segments can be loaded independently of paths in other regions. An overlay program can be designed in single or multiple regions.

5. A link is a collection of one or more segments which comprise a logical subdivision of the program. Link 0 (consisting of one segment only) is in main storage at all times. It is the first link to receive control when execution of the program is initiated. The root segment of any other link resides in main storage at all times that that link is being executed. An overlay program must consist of at least one link other than Link 0.

6. A tree is the graphic representation that shows how segments can use main storage at different times. It does not imply the order of execution.

The design of an overlay program requires the organization of the control sections of the program in an overlay tree structure. The tree structure is developed considering:

1. The amount of available main storage.

2. The frequency of use of each control section.

3. The dependencies between control sections.

4. The manner in which control should pass within a path, from one path to another, and from one region to another.

When the programmer has determined the overlay structure for a program, he prepares ØVERLAY, INSERT and REGIØN statements that will segment the program in that manner. The use of these control statements is described in section 5.6.4.

5.6.3.2 Overlay Characteristics

During execution of an overlay program, the segment loader uses tables that were generated by the linkage editor and incorporated into the text of applicable segments. Since these tables are an integral part of the program, their size must be considered when planning the use of available main storage. These tables are described as follows.

1. Input/Output Control Table

There is one Input/Output Control Table (LINKO$) in the root segment of Link 0 only which contains a File Environment Table (FET), a circular buffer, a master index and a subindex. The LINKO$ table is used by the segment loader to read requested segments into central memory. LINKO$ is the first control section in Link 0. Its size is determined as follows:

$$\text{Length in words} = \text{PARAM(1)} + \text{PARAM(4)} + \text{PARAM(5)} + 4 \ .$$

Section 5.6.4.2 contains definitions of the parameters.

2. Segment Table

There is one Segment Table (SEGTAB$) in the root segment of each link except Link 0. The segment table is used to keep track of: (1) the relationship of the segments in the program; (2) which segments are in main storage or scheduled to be loaded; (3) the main storage address and length of each segment; and (4) the entry address of the link.

SEGTAB$ is the first control section in the root segment of each link. Its size is determined as follows:

$$\text{Length in words} = n + 2,$$

where n is the number of segments in the link.

3. Entry Table

There can be an Entry Table (ENTAB$) in each segment of the program. The loader

uses the entry table to determine the segment to be loaded when an external reference is made to a segment not in the path.

An entry table may be produced as the last control section of a segment. An ENTAB$ entry is created for a symbol to which control is to be passed. The symbol is defined in a segment not in the path. The size of ENTAB$ is determined as follows:

$$\text{Length in words} = 3n + \sum_{i=1}^{n} \delta_i,$$

where n is the number of unique external references not in the path and $\delta_i = MAX(m_i-6,0)$, m_i = number of arguments for each external reference not in the path.

4. Dump Control Word

In the text produced by the linkage editor for each segment, a uniquely formatted word which identifies the control section is written immediately prior to each control section. This word is recognized by the storage dump routine XDUMP in order to produce relative addresses for each control section.

5.6.3.3 Overlay Communication

There are two ways in which the programmer can have his program request the overlay facilities of the segment loader:

1. By a CALL statement (FØRTRAN language) or RJ instruction (CØMPASS language) which causes a segment to be loaded and control to be passed to the symbol defined in that segment.

2. By a CALL LINK(N) (FØRTRAN language) or the equivalent in the CØMPASS language, where N is the link number, which causes segment one (the root segment) of the requested link to be loaded and control to be passed to the symbol named on the linkage editor control statement ENTRY.

5.6.3.4 Reserving Storage

In FØRTRAN and CØMPASS the programmer can create control sections that reserve main storage areas containing no data or instructions. Referred to as "common", these control sections are produced by the language translator. These common areas are either named or blank (unnamed).

During processing, the linkage editor collects these common areas. If more than one blank common area is found, the largest blank common area is contained in the link. If two or more

common areas have the same name, the largest common area having that name is reserved in the link. All references to a common area (named or blank) refer to the largest area defined. This largest area is the one which is retained.

If the linkage editor encounters data or text for the same common area in more than one subprogram, only data from the first subprogram encountered are retained and a diagnostic message is generated for any subsequent data definitions.

When object decks which reference common areas are to be placed in an overlay structure, the linkage editor automatically "promotes" the common areas to the root segment (unless otherwise directed by an INSERT control statement, see section 5.6.4.8). The position of a promoted common area in relation to other control sections in the root segment is generally unpredictable.

Note: Blank common is treated by the linkage editor as a named common block with the special name BLANK.. and is listed on the storage map with this name. Consequently, it is possible to position this control section with the statement INSERT BLANK...

5.6.3.5 Processing Options

1. List of control statements

The linkage editor automatically produces a listing of all control statements unless the programmer selects the NØLIST option in the LINKEDIT statement (see section 5.6.4.2). In the latter case, only the LINKEDIT, LIBRARY and ENDLINKS statements are listed (see sections 5.6.4.2, 5.6.4.3 and 5.6.4.12 respectively for details).

2. Storage map and cross-reference table

The linkage editor automatically produces a storage map of each link unless the programmer selects the NØMAP option in the LINKEDIT statement. For each segment, the storage map lists the control sections in ascending order according to their assigned address. Included with each control section is a list of all entry point names and assigned addresses.

When the XREF option in the LINKEDIT statement is specified, the linkage editor produces a table of all references to each entry point in the link. Additional options (PARAM(7) parameter, see section 5.6.4.2) allow the table to be extended to include all references from the link to LINK 0 entry points and an additional table of all external references from each subprogram to be produced.

The NØMAP and XREF options are mutually exclusive. Therefore, if XREF is selected, NØMAP is ignored and a storage map is produced.

3. The LET option

When the LET option of the LINKEDIT statement is selected, the linkage editor disregards all errors except two and writes the link on the output file. The two errors which preclude the link from being written are: (1) an undefined entry point to the link; and (2) insufficient storage space to form the link to be written.

5.6.4 Linkage Editor Control Statements

5.6.4.1 General Statement Format

All linkage editor control statements are coded from the following possible forms:

operation	operand
VERB	a, b(c), KEYWØRD, KEYWØRD = a, KEYWØRD = b(c),
	KEYWØRD(i) = n, a = a, b(c) = a,n

where

a is an unsubscripted symbol,

b is a subscripted symbol,

c is a subscript symbol,

KEYWØRD is an explicit name or option,

i is an integer subscript,

n is an integer value.

The operation field must contain the name of the operation to be performed. The operand field must contain one or more symbols or subscripted symbols (except REGIØN, END and ENDLINKS which have no operands). Operands in the operand field are separated by a comma or blank (or both). Two or more symbols within parentheses are similarly separated. A keyword must be written exactly as shown.

The operation field begins with the first nonblank column on the card. The operand field is separated from the operation field by at least one blank column.

The LINKEDIT and LIBRARY control statements may be continued on subsequent cards by coding a comma as the last nonblank column. The continuation begins with the first nonblank column of the succeeding card. These two control statements are the only ones which may be continued.

5.6.4.2 The LINKEDIT Statement

The LINKEDIT statement specifies input and output file names and status, processing options and size characteristics of the link(s) to be link-edited.

operation	operands
LINKEDIT	INFILE = name(a),ØUTFILE = name(b), LET,NØLIST,NØMAP,XREF,PARAM(i) = n

INFILE — specifies the name of a file which was previously produced by the linkage editor. INFILE is named only when previously link-edited links are to be updated.

a — must be coded T or C. T specifies that the file is a sequential file on tape or disk. C specifies that the file is an indexed file on disk and, therefore, a common file as defined by SCØPE.

ØUTFILE — specifies the name of the file on which the initial load program and the links will be written. ØUTFILE must always be named.

b — must be coded T or C. The links are written internally by the linkage editor on an indexed file. If C is coded, the links are written directly on the file specified by ØUTFILE, which must be a common file. If T is coded, the initial load program and the links are copied from the internal file to the specified sequential file (tape or disk).

LET — directs the linkage editor to ignore the effect of most errors.

NØLIST — directs the linkage editor to suppress the listing of control statements.

NØMAP — directs the linkage editor to suppress storage maps.

XREF directs the linkage editor to list a table of external references to each entry point in each link.

Keyword	Description	Default Value
PARAM(1)	Length of FET + circular buffer for all files used by the linkage editor	530
PARAM(2)	Maximum number of object decks in all libraries	1000
PARAM(3)	Maximum size of any table in an object deck	500
PARAM(4)	Maximum number of links	32
PARAM(5)	Maximum number of segments in any link	128
PARAM(6)	Maximum length (in words) of any control section for which text is defined	5000
PARAM(7)	Additional options if XREF is selected =1: produce a table of references from each subprogram =2: list all references to entry points in Link 0 =3: provide both of the above	0

Placement: The LINKEDIT statement must be the first statement of the input record. Only one such statement may appear in a job step.

Notes: (1) The files named on INFILE and ØUTFILE may be the same; however, if so, their status must be the same (i.e., both T or both C)

(2) If XREF is selected, NØMAP is ignored

(3) If XREF is not selected, PARAM(7) is ignored

Examples:

```
LINKEDIT  ØUTFILE=LINKS(T),LET,XREF
LINKEDIT  INFILE=ØLDLNKS(T),ØUTFILE=NEWLNKS(T),NØLIST,PARAM(1)=1050
LINKEDIT  INFILE=ABS(C),ØUTFILE=ABS(C),PARAM(6)=8000
LINKEDIT  ØUTFILE=MYFILE(T)
```

5.6.4.3 The LIBRARY Statement

The LIBRARY statement names each file which may possibly occur on INCLUDE control statements (see Section 5.6.4.5).

operation	operands
LIBRARY	$name_1$,$name_2$,...
or	
LIBRARY	LIB=$name_1$,$name_2$,...

name	specifies the name of a sequential file containing object decks.
LIB	concatenated file containing object decks from all named files.

Placement: The LIBRARY statement must appear immediately after the LINKEDIT statement. Only one such statement may appear in a job step.

Example:

```
LIBRARY  MASTER,NEWDCKS
```

5.6.4.4 The LINK statement

The LINK statement specifies the link number and directs the linkage editor to initiate processing of a link.

operation	operand
LINK	n

n	is a nonnegative integer specifying the link number.

Placement: The first LINK statement must appear immediately following the LIBRARY statement. Subsequent LINK statements must appear immediately following an END statement. If Link 0 is being processed, it must be the first link to be processed.

Example:

```
LINK  0
```

5.6.4.5 The INCLUDE Statement

The INCLUDE statement directs the linkage editor to include the named object deck from the specified library in the link currently being processed.

operation	operands
INCLUDE	name(deck,BLKDATA(comname))

name	specifies the name of a sequential file which was previously defined in the LIBRARY statement.
deck	specifies the name of an object deck contained in the file.
BLKDATA	indicates that the deck to be included is a BLØCK DATA sub-program.
comname	is the name of the first mentioned common block in the BLØCK DATA sub-program.

Placement: An INCLUDE statement may appear in any position between the LINK and END statements. Subprograms will be included in the order in which INCLUDE statements are encountered.

Examples:

```
INCLUDE  MASTER(MAIN)
INCLUDE  NEWDCKS(MØD1,MØD2,MØD3)
INCLUDE  MASTER(BLKDATA(CØM1),BLKDATA(CØM2))
```

5.6.4.6 The REGIØN Statement

The REGIØN statement indicates the beginning of a new region.

operation
REGIØN

Placement: The REGIØN statement follows statements which define the overlay structure for a previous region, and it indicates the beginning of a new region.

5.6.4.7 The ØVERLAY Statement

The ØVERLAY statement indicates the beginning of an overlay segment.

operation	operand
ØVERLAY	name

name is the symbolic origin of a segment. The symbol is not related to external symbols in the link.

Placement: The ØVERLAY statement may appear in any position between the LINK and END statements. If a REGIØN statement is coded, an ØVERLAY statement must appear immediately following the REGIØN statement. An ØVERLAY statement may not be coded for Link 0.

Examples:

1. Single region structure (no REGIØN statement necessary)

```
INCLUDE  MASTER(SUB1)
INCLUDE  MASTER(BLKDATA(CØM1))
ØVERLAY  ALPHA
INCLUDE  NEWDCKS(MØD1)
ØVERLAY  BETA
INCLUDE  NEWDCKS(MØD2,MØD3)
ØVERLAY  BETA
```

```
INCLUDE  MASTER(PRØGA)
ØVERLAY  ALPHA
INCLUDE  MASTER(PRØGB,PRØGC)
```

Figure 2 depicts a tree diagram for the above example.

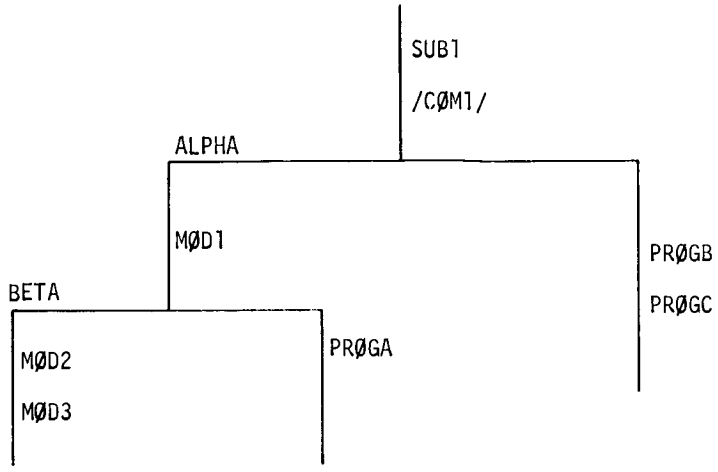


Figure 2. Tree diagram of a single region overlay structure.

2. Multiple region structure

```
INCLUDE  ØBJ(A,B,C)
ØVERLAY  ØNE
INCLUDE  DECKS(AA,BB)
ØVERLAY  TWØ
INCLUDE  ØBJ(D)
ØVERLAY  TWØ
INCLUDE  DECKS(CC,DD)
ØVERLAY  ØNE
INCLUDE  ØBJ(E,F,G)
REGIØN
ØVERLAY  THREE
INCLUDE  ØBJ(I,J)
```

```
ØVERLAY  THREE
INCLUDE  DECKS(EE)
ØVERLAY  FØUR
INCLUDE  DECKS(FF,GG)
ØVERLAY  FØUR
INCLUDE  ØBJ(K)
```

Figure 3 depicts a tree diagram for the above example.

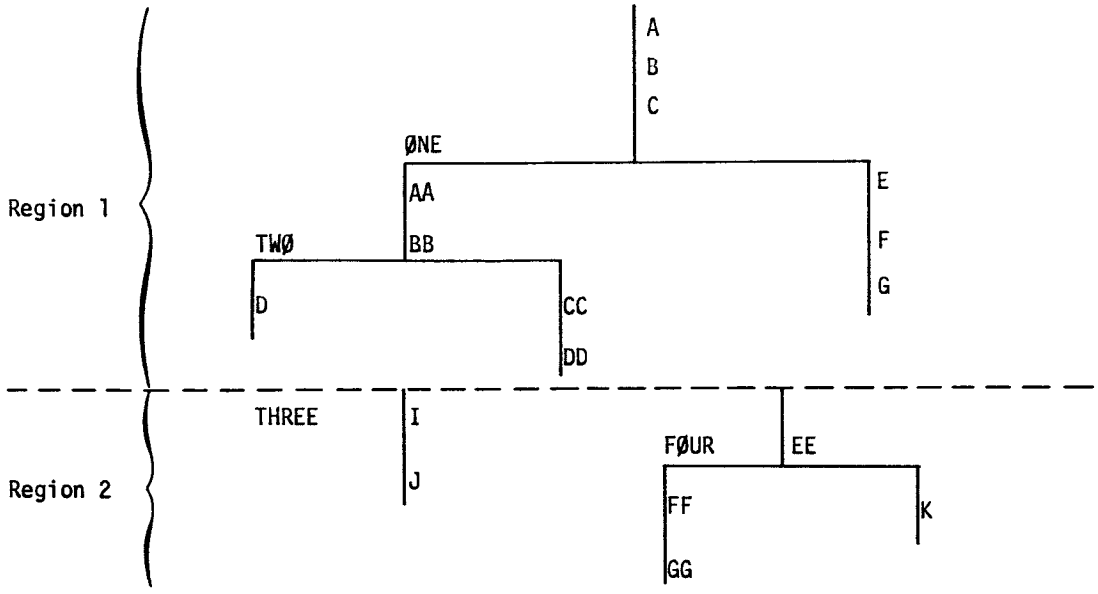


Figure 3. Tree diagram of a multiple region overlay structure.

5.6.4.8 The INSERT Statement

The INSERT statement positions control sections in overlay segments.

operation	operands
INSERT	name

name — specifies the name of a control section that is to be positioned.

Placement: The INSERT statement is placed in the control statement sequence following an ØVERLAY statement that defines the segment in which the control section is to be placed.

Caution: A control section should be named only once on an INSERT statement since a control section can appear only once within a link. If the same control section appears on more than one INSERT statement, the last statement encountered will control positioning and previous statements will be ignored.

Examples:

```
INSERT  CØM1
INSERT  CØM2,CØM3
```

5.6.4.9 The RENAME Statement

The RENAME statement changes external references to a symbol to a new symbol either globally (throughout the link) or locally (within a subprogram).

operation	operand	
RENAME	oldname=newname	[global]
RENAME	oldname(subprogram)=newname	[local]

oldname is the symbol to which an external reference exists.

newname is the symbol to which the external reference is to be made.

subprogram is the name of the subprogram in which the change is to be made.

Placement: The RENAME statement may appear in any position between the LINK and the END statements.

Notes: (1) Only one rename may be coded on a single statement.

(2) No error occurs if no references are made to oldname. If reference is made to oldname and newname is not specifically included, the automatic call logic will be invoked.

Examples:

```
RENAME  SQRT=SQRTXX
RENAME  DUMP(MØD1)=RETURN
```

5.6.4.10 The ENTRY Statement

The ENTRY statement specifies the symbolic name of the entry point in the link to which control will be transferred after thelink is loaded.

operation	operand
ENTRY	name

name — is the symbol defining the entry point for the link. The name must be defined in the root segment of the link. For Link 0, name must be the name of a main program. For any link other than Link 0, name must be the name of a subroutine.

Placement: The ENTRY statement may appear in any position between the LINK and the END statements.

Examples:

```
ENTRY  MAIN
ENTRY  SUB1
```

5.6.4.11 The END Statement

The END statement specifies the conclusion of control statements for the current link being processed.

operation
END

Placement: The END statement must appear following all statements which define the link. There must be one END statement for each LINK statement.

5.6.4.12 The ENDLINKS Statement

The ENDLINKS statement defines the end of all processing by the linkage editor.

operation
ENDLINKS

Placement: The ENDLINKS statement must immediately follow an END statement. One such statement is required.

5.6.5 Examples of Linkage Editor Processing

In the following examples, it is assumed that the file containing the call library (LINKLIB) and a file containing the linkage editor program (LINKEDT) are contained on separate magnetic tapes. These examples are intended to illustrate various deck setups.

Conditions of Problem			
Example	Source Program	Previously Compiled Decks	Execution
A	yes	in input stream	yes
B	no	on tape	no
C	no	input stream and on tape	yes

Example A

```
JØB,P1,T100,CM60000.
MAP(ØFF)
RUN(S,,,,,NEW)
REWIND(NEW)
CØPYBR(INPUT,ØLD,n)
REWIND(ØLD)
REQUEST LINKEDT,HI. reel#,RØL
REQUEST LINKLIB,HI. reel#,RØL
CØMMØN(LINKS)
LINKEDT.
RETURN(LINKLIB)
RETURN(LINKEDT)
LINKS.ATTACH
RELEASE(LINKS)
EXIT.
RELEASE(LINKS)
UNLØAD(LINKLIB)
```

```
     UNLØAD(LINKEDT)
     7
      8
       9
          {FØRTRAN or CØMPASS source programs}
     7
      8
       9
          {n object decks}
     LINKEDIT  ØUTFILE=LINKS(C)
     LIBRARY  NEW,ØLD
     LINK  0
(1)  RENAME  SYSTEM=SYSTEM.
          {INCLUDE statements}
     ENTRY  entry point
     END
     LINK  1
     RENAME  SYSTEM=SYSTEM.
          {INCLUDE,OVERLAY, etc. statements}
     ENTRY  entry point
     END
     ENDLINKS
     7
      8
       9
          {data for problem program}
     6
      7
       8
        9
```

Example B

```
     JØB,P1,T100,CM60000.
     MAP(ØFF)
     REQUEST ØBJECT,HI. reel#,RØL
     REQUEST LINKLIB,HI. reel#,RØL
     REQUEST LINKEDT,HI. reel#,RØL
     REQUEST LINKFIL,HI. SAVTP,RIL
     LINKEDT.
```

```
RETURN(ØBJECT)
RETURN(LINKLIB)
RETURN(LINKEDT)
RETURN(LINKFIL)
EXIT.
UNLØAD(ØBJECT)
UNLØAD(LINKLIB)
UNLØAD(LINKEDT)
UNLØAD(LINKFIL)
7
8
9
LINKEDIT  ØUTFILE=LINKFIL(T),LET,XREF,PARAM(7)=2
LIBRARY  ØBJECT
LINK  0
RENAME  SYSTEM = SYSTEM.
   {INCLUDE statements for Link 0}
ENTRY  entry point
END
LINK  1
RENAME  SYSTEM=SYSTEM.
   {INCLUDE, ØVERLAY, etc. statements for Link 1}
ENTRY  entry point
END
ENDLINKS
6
7
8
9
```

Example C

```
JØB,P1,T200,CM70000.
MAP(ØFF)
CØPYBR(INPUT,ØBJ,n)
REWIND(ØBJ)
REQUEST MASTER,HI. reel#,RØL
```

```
REQUEST LINKLIB,HI. reel#,RØL
REQUEST LINKEDT,HI. reel#,RØL
REQUEST LINKFIL,HI. reel#,RIL
LINKEDT.
RETURN(MASTER)
RETURN(LINKLIB)
RETURN(LINKEDT)
LINKFIL.
RETURN(LINKFIL)
EXIT.
UNLØAD(MASTER)
UNLØAD(LINKLIB)
UNLØAD(LINKEDT)
UNLØAD(LINKFIL)
7
8
9
   {n object decks}
LINKEDIT  INFILE=LINKFIL(T),ØUTFILE=LINKFIL(T),PARAM(6)=90000
LIBRARY  MASTER,ØBJ
LINK  2
RENAME  SYSTEM=SYSTEM.
   {INCLUDE, ØVERLAY, etc. statements for Link 2}
ENTRY  entry point
END
ENDLINKS
7
8
9
   {data for problem program}
6
7
8
9
```

In Example A, the output of the linkage editor is written on a common file and executed from that file. This method is most efficient for "compile-and-go" type code check runs.

In Example B, the output of the linkage editor is written on tape. This would be the most common form of a run in which most of the coding errors have been eliminated and the executable program is saved on tape for subsequent repeated executions.

In Example C, it is assumed that a previously link-edited file exits (created, for example in Example B) and that it is desired to add a new link (or modify an existing link). In this case, the input and output files are both the same (although this is not necessary). The output of the linkage editor is written on tape and the problem program is executed from this tape file.

Note: (1) To avoid possible conflict with a user (viz. NASTRAN) named common with the name SYSTEM, the CDC system routine has been reassembled with the name SYSTEM. and has been placed on LINKLIB with the name SYSTEM.. In order that other library routines may be properly linked, the statement RENAME SYSTEM=SYSTEM. is recommended for all links.

In the example illustrated in Figure 4, the following linkage editor control statements will produce the indicated overlay structure.

```
LINKEDIT  ØUTFILE=LINKS(T)
LIBRARY  LIBA,LIBB
LINK  0
RENAME  SYSTEM=SYSTEM.
INCLUDE  LIBA(MAIN)
INCLUDE  LIBB(UTIL1,UTIL2)
INCLUDE  LIBA(UTIL3)
ENTRY  MAIN
END
LINK  1
RENAME  SYSTEM=SYSTEM.
INCLUDE  LIBB(START,MØD1)
ØVERLAY  A
INCLUDE  LIBA(MØD2)
INCLUDE  LIBB(MØD3)
INSERT  CØM1
```

```
ØVERLAY  A
INCLUDE  LIBA(MØD4)
ØVERLAY  B
INCLUDE  LIBB(MØD5)
INCLUDE  LIBA(MØD6)
INSERT  CØM2
ØVERLAY  B
INCLUDE  LIBB(MØD7)
INSERT  CØM3
ENTRY  START
END
ENDLINKS
```

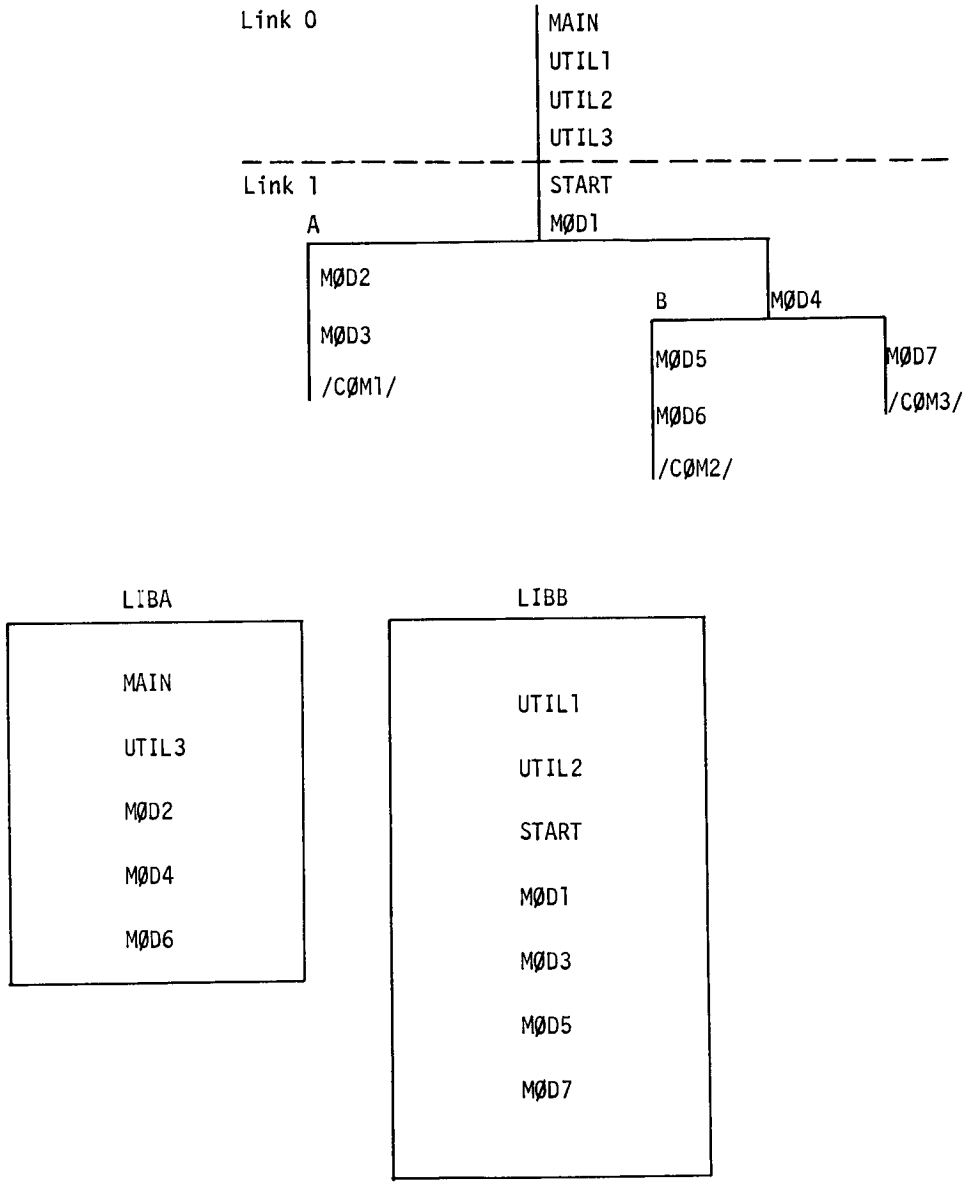


Figure 4. Example of a two-link overlay structure.

5.6.6 Storage Requirements for the Linkage Editor

Figure 5 illustrates the layout of core storage for the linkage editor. For the discussion below, it is assumed that the linkage editor has not itself been link-edited. A link-edited version of the linkage editor is available. A memory saving of approximately $4000_{10}(10000_8)$ words results.

The principal open-ended table is the Symbol Chain Table. A three-word entry is created in this table for each subprogram name, entry point, common block and unique external reference not in the path. For a link other than Link 0, a three-word entry for each entry point and common block in Link 0 is also created. A conservative estimate for the requirements of this table is as follows:

Link 0: length in words = 4* (no. of entry points + common blocks),

Link ≠ 0: length in words = 6* (no. of entry points + common blocks)
+3* (no. of entry points + common blocks in Link 0).

The largest table is likely to be the Working Storage Table. It must hold all instructions and data for the largest control section for which text is defined. If this figure is not known, a linkage editor run can be made. The storage map will be printed even if the link is not written. A scan of the lengths listed (in octal) will identify the largest control section. Note that common blocks for which no data are defined are not to be used in defining the maximum.

Field length for the linkage editor may be estimated from the following:

$$\text{field length}_{10} = 15000 + \text{MAX}(10*N,2000) + \text{MAX}(T,2000) + 3*\text{PARAM}(1) \quad ,$$

where

N = number of subprograms defined on INCLUDE statements,

T = length of largest subprogram or common block for which instructions or data are defined,

and

PARAM(1) is defined in section 5.6.4.2.

If default values for the linkage editor are used, a program of less than 200 decks would require a field length of $23{,}600_{10} \simeq 60{,}000_{8}$.

Efficiency of the linkage editor may be improved by increasing the buffer size (PARAM(1)). For NASTRAN, PARAM(1) = 2080 is used. Additionally, one deck requires $16{,}000_{10}$ words of text storage (PARAM(6) = 16000). Consequently, for a link of 300 decks, the field length works out as

$$\text{field length}_{10} = 15000 + 3000 + 16000 + 6240 = 40240_{10} \simeq 120000_{8} \ .$$

5.6.7 Link-edited Linkage Editor

The Linkage Editor object decks may be link-edited themselves. The materials released with Level 15 may be used to do this as follows:

```
JØB,P1,T100,CM120000.
MAP(ØFF)
REQUEST,TAPE3,HY.                          Object Tape
CØPYBF(TAPE3,X)
CØPYBF(TAPE3,LINKEDT)
CØPYBF(TAPE3,LINKLIB)
RETURN(TAPE3)
REQUEST,TAPE2,HY.                          Source Tape
CØPYBF(TAPE2,X,2)
CØPYBF(TAPE2,ØLDPL)                        SUBSYS decks
RETURN(TAPE2)
UPDATE(Q,L=1)
REWIND(LINKEDT)
CØPYBF(LINKEDT,LKDT)
LKDT(CØMPILE)
REQUEST,TAPE,HY.                           SAVE TAPE for executable linkage editor
CØPYBF(EDT,TAPE)
RETURN(TAPE)
EXIT.
UNLØAD(TAPE)
```

UNLOAD(TAPE2)

UNLOAD(TAPE3)

7_{8_9}

*COMPILE,LKED

$6_{7_{8_9}}$

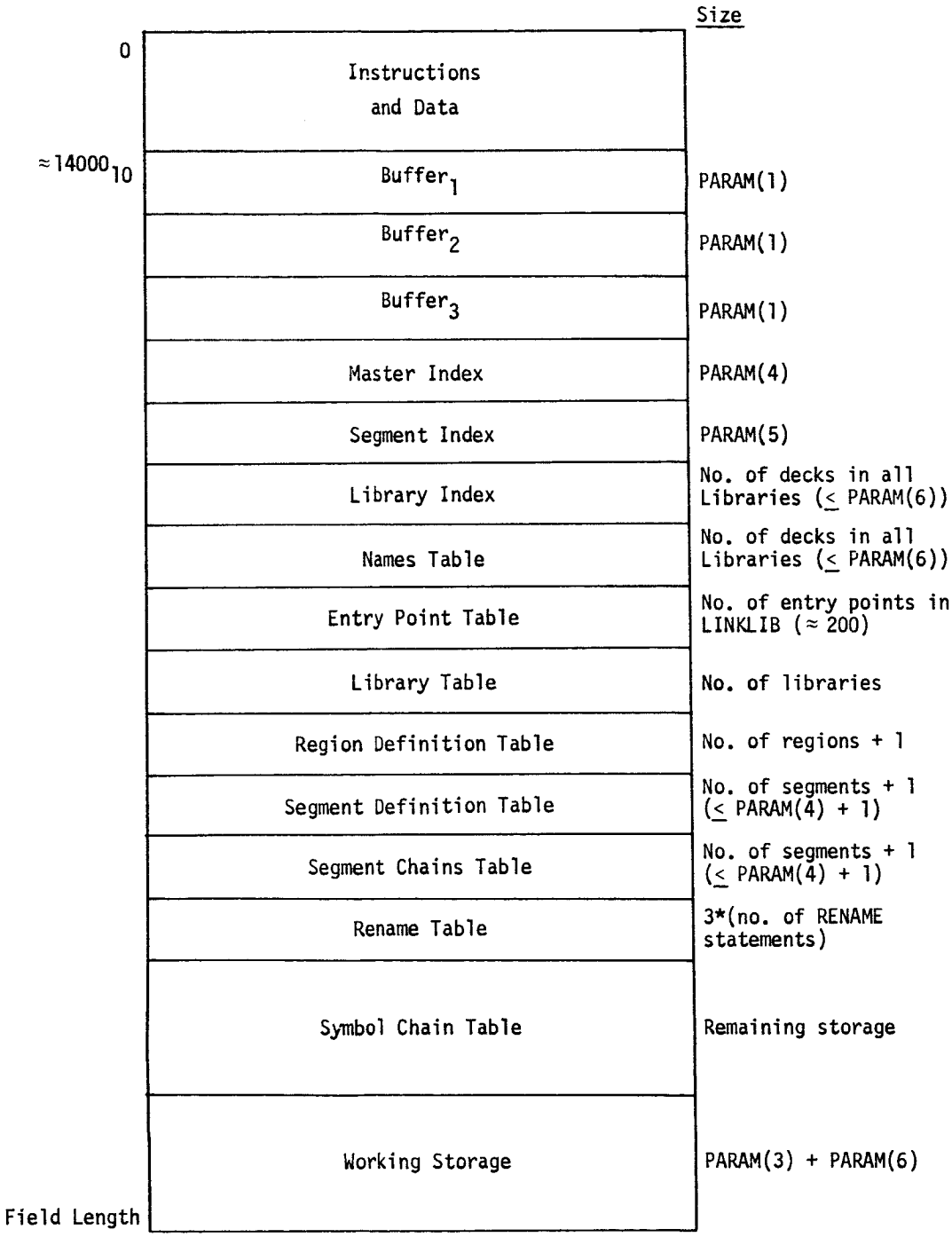


Figure 5. Layout of core storage for the linkage editor.

6.1 INTRODUCTION

Modifications and additions are continuously made to large programming systems. NASTRAN will not be an exception to this rule. Section 6.2 presents the FØRTRAN IV language restrictions that must be followed in order to produce equivalent object code across the computing machines on which NASTRAN operates. The remaining sections discuss areas of the program which experience, gained during program development, has shown to be those areas most subject to modifications and additions.

6.2 FØRTRAN IV LANGUAGE RESTRICTIONS

NASTRAN was developed in the FØRTRAN IV programming language to the greatest extent possible in order to simplify the task of conversion from the development machine, which, for the majority of program development, was the IBM 7094/7040(44) DCS, to third generation computing systems. The same FØRTRAN IV code can execute differently across computing machines. This fact is all but too well known to those who have labored through the task of conversion from one computing system to another. For this reason, modifications and additions to NASTRAN must be accomplished with FØRTRAN code that will produce equivalent object code across computing machines. The basic set of rules governing programming in FØRTRAN IV for NASTRAN is incorporated in the following manual in the IBM Systems Reference Library: IBM 7090/7094 IBSYS Operating System, Version 13, FØRTRAN IV Language, File No. 7090-25, Form C28-6390-3. The following is a list of exceptions to the rules set forth in this manual.

1. An integer constant may not be greater than $2^{31}-1$.
2. Subscripted variables should contain no more than 3 subscripts.
3. A reference to the first variable in a subscripted array must contain the subscript 1, e.g., A(1) = 0.0 .
4. A CØNTINUE statement requires a FØRTRAN statement number.
5. The PAUSE statement is not to be used.
6. The NAMELIST statement is not to be used.
7. Implied DØ's in DATA statements are not allowed.
8. The last statement of a DØ loop may not be a logical IF statement. It is recommended that it be a CØNTINUE statement. It is also recommended that each DØ loop have its own CØNTINUE statement.
9. BLØCK DATA subprograms may contain only type (e.g., REAL, INTEGER), DIMENSIØN, CØMMØN, DATA and comment statements.
10. All Hollerith data should be defined in the form 4H.....
11. Do not use octal (Ø) or hexidecimal (Z) in DATA or FØRMAT statements.
12. Specification statements should precede any executable statement.

13. The order of specification statements should be as follows:

    CØMPLEX

    DØUBLE PRECISIØN

    REAL

    INTEGER

    LØGICAL

    DIMENSIØN

    CØMMØN

    EQUIVALENCE

    EXTERNAL

    DATA

    Arithmetic Statement Functions

14. The variables in blank CØMMØN or a block of CØMMØN should be ordered as follows: complex, double precision, real, integer and logical.

15. Variables stored as single precision cannot be referenced as double precision variables (via the FØRTRAN EQUIVALENCE statement) because of the different internal word storage format for single and double precision words on the Univac 1108.

16. Caution must be exercised to insure that types (REAL, INTEGER, etc.) of FØRTRAN function values agree in the function subprogram and in the calling program. This agreement between types is necessary for machines (e.g., IBM S/360) on which REAL and INTEGER values of FØRTRAN functions are returned in different registers.

17. Do not attempt to extend the length of arrays through the EQUIVALENCE statement.

18. Caution must be exercised when using the EQUIVALENCE statement. One should not use the EQUIVALENCE statement to give different variable names to the same cell, since modern compilers, because of their optimization techniques, do not guarantee that the values of the equivalenced variables will be the same. Hence EQUIVALENCE should be used only between variables which have non-intersecting use spans in a program.

19. Nonstandard returns in a SUBRØUTINE statement must immediately follow the left parenthesis which starts the names of the subroutine's arguments, e.g. SUBRØUTINE XYZ (*,*,A,B) is the correct form; SUBRØUTINE XYZ (*,A,*,B) is not acceptable. On the CDC computers, use SUBRØUTINE XYZ(A,B),RETURNS(RETURN1,RETURN2).

20. There must be agreement with respect to the number of arguments and the type of each argument in the argument list of a calling program and the subprogram called.

21. For consistency with current NASTRAN practice, deck (or member) names for subroutines should agree with the primary entry point names. Deck names for Block Data subprograms should end with the characters "BD".

22. FUNCTIØN subprograms whose type is not implicit must be typed in the FUNCTIØN statement. For example, use

```
DØUBLE PRECISIØN FUNCTIØN ABC(X)
```

and not

```
FUNCTIØN ABC(X)
DØUBLE PRECISIØN ABC
```

23. The name of a FUNCTIØN subprogram must appear somewhere within the subprogram.

24. All subscripted variables appearing in EQUIVALENCE statements must be subscripted. E.g., use EQUIVALENCE (A(1),X(1)) instead of EQUIVALENCE (A,B).

6.3 THE EXECUTIVE CONTROL DECK

The capabilities of the Executive Control Deck may be changed or increased by modifying existing control card functions or addition completely new card types. Executive control cards are processed within two modules of the Preface: XCSA, (Executive Control Section Analysis, Section 4.2) and XGPI (Executive General Problem Initialization, Section 4.7). Some cards are handled completely within XCSA, while others are only partially checked by XCSA and then passed to XGPI, via the Executive Control Table (Section 2.4.2.5), for final processing.

To modify the content or function of an existing control card, first locate the proper section within module XCSA. The block of FØRTRAN statements related to the processing of each type of card is appropriately commented. Also, it can be determined from these statements whether part of the processing is being passed to module XGPI. The required modifications can then be made within XCSA and/or XGPI.

To add a new control card type to those currently acceptable, the following steps should be taken. First, add the card type name to the local FØRTRAN array ECTT (Executive Control Type Table) within module XCSA, and increase the table length parameter (LECTT) by three for each new entry. The three word entry consists of two BCD words (4 characters/word) for the card type mnemonic and a one word integer flag indicating whether the card type is to be optional (=0) or required (=1) within the NASTRAN Executive Control Deck. Second, add a statement number to the computed-go-to branch vector. This branch vector transfers the XCSA logic to the correct card processing section within the module. Third, create the processing code, and add it to the module. If additional processing must be performed in XGPI, the Control Table format should be modified and the necessary logic added to the XGPI module.

6.3.1 The NASTRAN Card

A facility is provided whereby the default values in /SYSTEM/, which are initialized by the system Block Data subprogram, SEMDBD, or subroutine BTSTRP, can be altered at execution time. The contents of /SYSTEM/ are described in Section 2.4.1.8. Other locally used values may also be redefined.

The card which provides this capability is called the NASTRAN card. If this card is used, it must be the first card of the data deck (i.e., the card must precede the Executive Control

Deck). The NASTRAN card is a free field card (similar to cards in the Executive Control and Case Control Decks). Its format is as follows:

NASTRAN keyword$_1$=value, keyword$_2$=value, ...

where the list of allowable keywords is as follows:

1. BUFFSIZE - Defines the number of words in a GINØ buffer. Note: fixed length records written by GINØ are of length BUFFSIZE - 3. This keyword changes the first word of /SYSTEM/.

2. MAXØPEN - Defines the maximum number of files that may be open at any one point in the program. This keyword changes the 30th word of /SYSTEM/.

3. CØNFIG - Defines the computer configuration for use in the timing equations in the matrix decomposition subroutines SDCØMP, DECØMP and CDCØMP. This keyword changes the 28th word of /SYSTEM/.

4. MAXFILES - Defines the maximum number of files to be placed in /XFIAT/ by GNFIAT. This keyword changes the 29th word of /SYSTEM/.

5. SYSTEM(I) - I refers to the Ith word of /SYSTEM/. This is a general form of altering any word in /SYSTEM/. Note that BUFFSIZE and SYSTEM(1) are equivalent, and MAXFILES and SYSTEM(29) are equivalent.

6. KØN360 - Defines the 31st word of /SYSTEM/. Used only on the IBM 360-370 computers. This value sets the number of words of four bytes each to be reserved from the region for ØS service routines needed during execution. If the user is going to use FØRTRAN units for User Tapes or if local modifications are made to the program which require additional service routines at execution time, this value will have to be increased.

7. NLINES - Defines the 9th word of /SYSTEM/. This value sets the number of data lines per printed page. For 11" paper, an appropriate value is 50. For 8-1/2" paper, an appropriate value is 35.

8. TITLEØPT - Defines a local variable within SEMINT which is passed to TTLPGE to control the printing of the NASTRAN title page. See Section 3.3.13 for a description of subroutine TTLPGE.

Examples of use of the NASTRAN card follow.

```
NASTRAN    BUFFSIZE=878, SYSTEM(2)=3, MAXØPEN=10
```

The above card changes the 1^{st}, 2^{nd} and 30^{th} words of /SYSTEM/. SYSTEM(2)=3 changes the system output unit from 6 to 3.

```
NASTRAN    SYSTEM(4)=4, MAXFILES=21
```

The above card changes the 4^{th} and 29^{th} words of /SYSTEM/. SYSTEM(4)=4 changes the system input unit from 5 to 4 (which means that all subsequent data must be present on unit 4).

6.4 THE CASE CONTROL DECK

The Case Control Deck is processed by the IFP1 module, whose Module Functional Description can be found in section 4.3. A card can be added to the Case Control Deck by implementing the following steps.

1. Assignment of a Word in the CASECC Data Block (see section 2.3.1.1).

If the card datum is to be passed on, a word must be assigned in CASECC. Several words are currently empty in CASECC. If more space in the fixed portion of CASECC is needed, modules which use CASECC to prepare data blocks for the Output File Processor (ØFP) module (e.g., SDR2, VDR, PLA3), will need to be updated since they are sensitive to the length of CASECC. Otherwise, just change the value of LENCC in /IFP1A/. Some Case Control Cards only change cells in /SYSTEM/ and do not need space in CASECC.

2. Addition (or change of) a Key Word.

To add another key word simply lengthen /IFP1A/ by the number of new words, changing the IFPABD Block Data subprogram. The same procedure will allow you to change the spelling of a current keyword.

3. Identification of Card Type.

In IFP1 there are approximately 30 logical IF statements in a row. Simply add another one modeled after the existing statements with the new key word.

4. Addition of Card Dependent Code.

Add a small internal subroutine to process the new card. The simplest form of such an internal routine is to extract one integer from a card of the form SPC = 1. In this case set "IK" to the word assigned to the card in CASECC and transfer to the common code for this purpose. There are many examples of more complex cards under each card type. Changing these card dependent areas of code allows easy modification of existing card types.

5. Restart Implications

See the subroutine description for IFP1B in the Module Function Description for IFP1 for a description of the restart functions of IFP1.

6.5 THE BULK DATA DECK

The module which processes the Bulk Data Deck is the Input File Processor (IFP), whose Module Functional Description can be found in section 4.5. There are two primary reasons for adding or modifying a bulk data card. First, a new structural element or some other item is to be added to the NASTRAN system. This will require additional code in several other modules besides the Input File Processor (IFP); however, only IFP changes will be discussed here. Second, an alternate form of user input is desired for an already existing item. For example, the SPC1 card is an alternate form of the SPC card. In some cases, an alternate form can be accommodated on the same card. An example of this technique is found on the SPØINT card. The advantage gained in this case is that changes to the NASTRAN system are isolated to the Input File Processor.

There are three major references for the programmer who desires to make modifications or additions to the Input File Processor. Section 2 of the User's Manual gives a functional description of each bulk data card. Section 2.3.2 of the Programmer's Manual describes the format of the output data blocks generated by the Input File Processor, and section 4.5 of the Programmer's Manual contains a description of the processing flow which occurs within IFP. Any programmer responsible for making changes to the Input File Processor would be well advised to select a card which is similar to the one he is changing or implementing and "follow it through" the code, using the three references described above to guide him.

In most cases, the work required to add a new card will amount to adding entries to already existing tables in the IFP Block Data subprograms. The detailed steps for adding a new card to the Input File Processor are listed below.

1. Add the card name and corresponding table data to the IFP data tables contained in Block Data Subprograms IFX1BD, IFX2BD, IFX3BD, IFX4BD, IFX5BD, IFX6BD, and if needed, IFX7BD. The meaning of these entries is discussed in section 4.5.7.

2. Add an entry in the IFP code to call one of the IFP secondary routines IFS1P, IFS2P, IFS3P, or IFS4P, wherein the card dependent processing takes place, and add the necessary card dependent code to the appropriate secondary routine.

3. If the new card is to be used in conjunction with a Rigid Format, appropriate entries must be made in the restart bit tables in /IFXO/ and in the Rigid Format tables. See section 1.10 for details.

6.6 RIGID FORMATS

The following steps will allow the addition of a new NASTRAN Rigid Format.

1. Compile and test the DMAP sequence throughly by running problems on it using APP DMAP or by using the ALTER feature with an existing Rigid Format.

2. All Rigid Formats must be classified FØRCE or DISPLACEMENT. A call tc a subroutine which stores the new Rigid Format must be added to subroutine XRGDFM of module XCSA (see section 4.2). The subroutines which contain current Displacement Rigid Formats are called LDi, i = 01, 02, ..., 12. Dummy calls are already setup for Displacement Rigid Formats LD45-LD50. They correspond to solutions 13 through 19. By choosing to use solutions 13 through 19 and creating the appropriate LDi routine, this step can be skipped.

3. An LDi routine must be written. The LDi routine must write the DMAP sequence, the Decision Tables, the File Name Table, and the Card Name Table on the NPTP. The format is as follows:

Record 1:

This record contains the coded DMAP sequence, 4 characters per word. Note that every DMAP instruction must end with the character: $. In the existing LDi programs the data for this record are stored in the RD array.

Record 2:

Number of Words	Contents
1	Number of DMAP instructions (NDMAP).
1	Number of words in the decision table for each DMAP instruction (NBIT), $1 \leq NBIT \leq 5$.
NBIT*DMAP	Decision table for each instruction with the entries for irstructions not in this subset set to zero. The words cannot be all zero. The zeroing of the subset entries can be accomplished by a call to XSBSET. (See XCSA MFD write-up). In the existing LDi programs, this table is stored in the IS1 array.
1	Number or entries in the File Name Table (NFILE). This number may be zero if no File Name Table is desired.

Number of Words	Contents
3*NFILE	File Name Table - Each entry consists of 2 BCD words giving the data block name of any data block in the Rigid Format and one integer giving its bit position in the Decision Table. In the existing LDi programs, the File Name Table is stored in the JNM array.
1	Number of entries in the Card Name Table (NCARD). This number may be zero if no Card Name Table is desired.
3*NCARD	Card Name Table - Each entry consists of 2 BCD words giving the card Name of any NASTRAN Data Card and one integer giving its bit position in the Decision Table. In the existing LDi programs, the Card Name Table is stored in the INM array.

To modify an existing rigid format the appropriate tables (Decision, Card Name, File Name or DMAP) should be changed. Their locations in the existing LDi routines are detailed above.

6.7 FUNCTIONAL MODULES

A functional module communicates with the NASTRAN Executive System, and hence indirectly with other functional modules, only through its input data blocks, its output data blocks and its DMAP parameters. Hence a modification to a functional module which disturbs neither its output data blocks nor its DMAP parameters can be made without changing any other functional modules. If a modification to a functional module affects its output data blocks or its DMAP parameters, it must be determined (by referring to section 4, Module Functional Descriptions, of the Programmer's Manual and/or section 3, Rigid Formats, of the User's Manual) what modules use these output data blocks and DMAP parameters as input. If these modules are numerous, or if the changes to them are very extensive, it may be more profitable to write a new module(s) to accomplish the task at hand.

To add a functional module to the system three changes must be made: 1) update the Module Properties List (MPL), the Executive table which contains the (DMAP) name of the module, the number of input data blocks, the number of output data blocks, the number of scratch data blocks and the DMAP parameter list (see the description of the MPL in section 2.4 for more details); 2) update the Link Specification Table (LNKSPC), the Executive table which contains the (DMAP) name of the module, the module's entry point name and the link residence keys for the four machine types (see the description of the LNKSPC table in section 2.4 for more details); and 3) update one or more link driver routines, XSEMi, (see section 3.3.7) so that the module is called from one or more links. Steps 2 and 3 have been automated within the NASTRAN system. These automated procedures are described in sections 6.11.3.1 and 6.11.3.2 respectively. 4) Add the modules to the overlay structure for the appropriate link(s). The means of accomplishing this task is machine dependent, but a basic picture of the module and its subroutines and their relationships to other NASTRAN subroutines should be drawn. An updated Link Map such as those in section 5 should be made. 5) To actually add the module section 5 must be consulted for the particular computer which NASTRAN is operating on.

In addition considerable number of documentation changes must be made. These are described briefly for each manual.

1) Programmer's Manual:

A new subsection for section 4.0 must be written to describe the module. The various table of contents and indexes must be updated including sections 4.1.2 and 4.1.3. The overlay maps in

section 5 must be updated.

2) User's Manual:

If the module is to be a "user module" it should also be documented in section 5 of the User's Manual. Any new error messages must be documented in section 6. The module name should be added to the dictionary in section 7.

3) Theoretical Manual:

No additions are required here unless the module has some significant analytic developments which need to be documented.

6.8 ADDING A STRUCTURAL ELEMENT

6.8.1 Introduction to the Problem

This section defines the programming interfaces necessary to add a new structural element to NASTRAN. We assume the reader of this section has:

1. A good working knowledge of FØRTRAN IV
2. Experience in programming on a large-scale scientific computer, including use of overlays. (Preferably this experience has been on one of the computers on which NASTRAN is operational: IBM 360, ØS; UNIVAC 1108, Exec 8; or CDC 6600, SCOPE 3.0)
3. A working knowledge of matrix algebra, viz., addition, multiplication and inversion of matrices

We also assume the reader has had prior experience with neither structural analysis nor the NASTRAN program. Furthermore, we assume that a structural analyst has written mathematical specifications for a structural element, and that the reader must design, code, and checkout NASTRAN FØRTRAN subroutines that conform to these mathematical specifications.

6.8.1.1 Introduction to Structural Analysis

A scientific programmer must gain a minimal understanding of the physics and mathematical techniques involved in the application at hand. The following paragraphs, condensed from section 3 of the Theoretical Manual, give this minimal analytical background.

From a theoretical viewpoint, the matrix equation

$$[K]\{u\} = \{P\} \quad , \tag{1}$$

completely describes the formulation of a static (the most basic) structural problem. [K] is called a stiffness matrix, {P} is called a load vector and {u}, the unknown of the equation, is called a displacement vector. NASTRAN generates [K] and {P} from available information about the structure. Once Equation 1 has been formed, it is solved for each specified loading condition. Stresses in the structural elements and other desired results are then obtained from {u} by a set of data recovery operations.

NASTRAN embodies a lumped element approach, i.e., the distributed physical properties of a structure are represented by a model consisting of a finite number of idealized substructures or elements that are interconnected at a finite number of points. All input and output data pertain to the idealized structural model.

The idealized structural model in NASTRAN consists of "grid points" (G) to which "loads" (P) are applied, and at which degrees-of-freedom are defined, and "elements" (E) that are connected between the points, as shown in Figure 1. Two general types of grid points are employed. They are:

1. Geometric grid point - a point in three-dimensional space at which three components of displacement and three components of rotation are defined. The coordinates of each grid point are specified by the user. Components of displacement and rotation can be eliminated as degrees-of-freedom by means of "single-point constraints".

2. Scalar point - a point in vector space at which one degree-of-freedom is defined. A geometric grid point contains from one to six scalar points. Scalar points may exist that are not associated with grid points. Such points can be coupled to geometric grid points by means of scalar structural elements and by constraint relationships.

The structural element is a convenient localizing concept for specifying many of the properties of the structure, including material properties, mass distribution and some types of applied loads. Structural elements are defined on "connection" cards by referencing the grid points to which they are interconnected. In a few cases, all of the information required to generate structural matrices for the element is given on the connection card. In most cases, the connection card refers to a "property" card, on which the cross-sectional properties of the element are given. Adding a new structural element to NASTRAN necessitates designing and implementing a new connection card and, if defined, a new property card.

There are four general classes of structural elements:

1. Metric elements connected between geometric grid points. Examples include rod, plate, and shell elements.

2. Scalar (or zero-dimensional) elements connected between pairs of scalar points, or between one scalar point and "ground". Since each geometric grid point contains a number

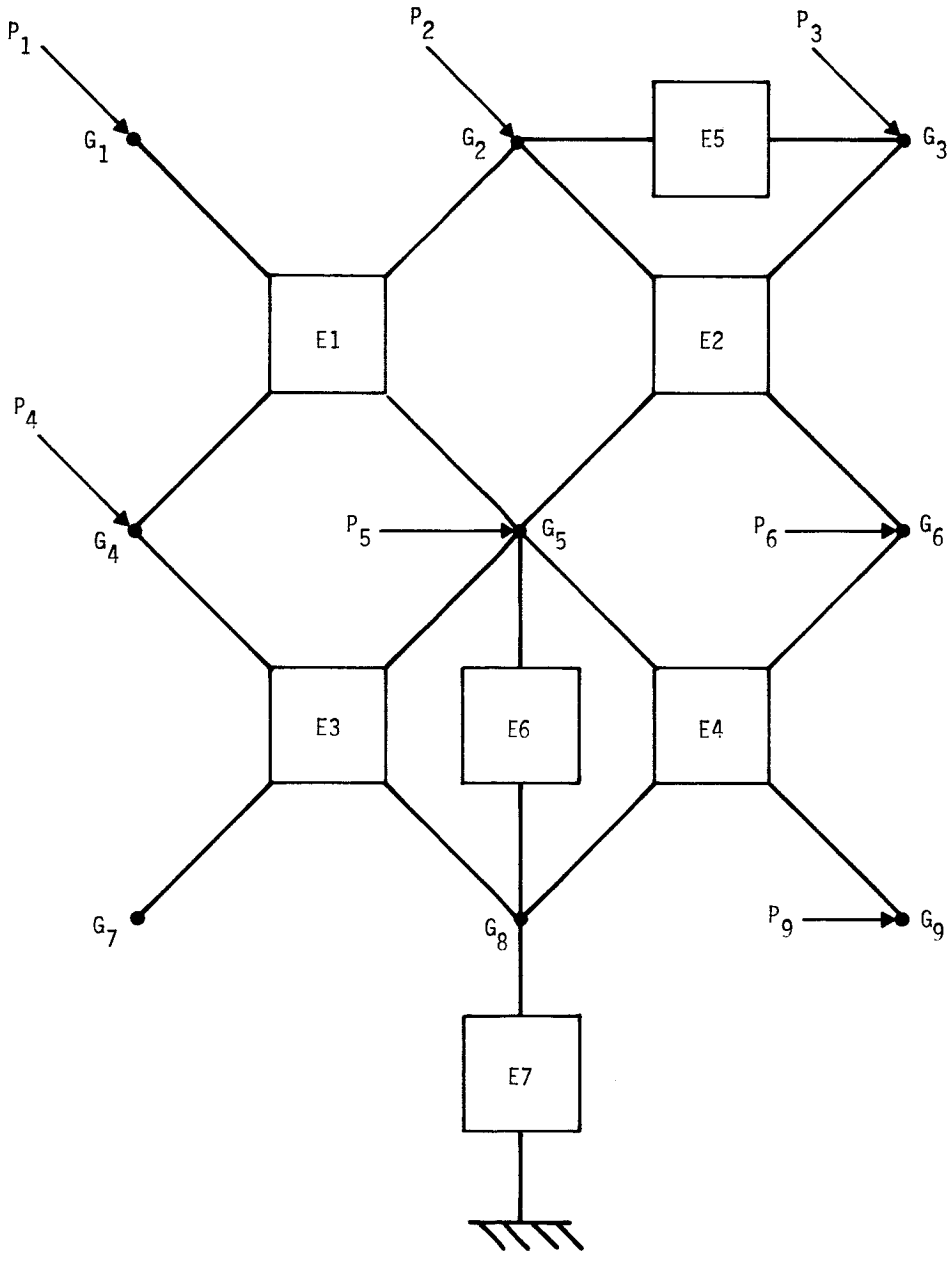


Figure 1. Topology of the idealized structural model.

of scalar points corresponding to specific components of motion, scalar elements can be connected between selected components of motion at geometric grid points.

3. General elements, whose properties are defined in terms of deflection influence coefficients (i.e., compliance matrices), and which may be interconnected between any number of geometric and scalar grid points. An important application of general elements is the representation of large components of structure by test data.

4. Constraint elements (or Constraints). The existence of a constraint element implies a linear relationship among the degrees-of-freedom to which it is attached. This relationship is of the form

$$\sum_g R_{cg} u_g = Y_c \quad , \tag{2}$$

where u_g are degrees-of-freedom and Y_c is an enforced displacement. A linear relationship among the forces of constraint is also implied, since it is required that the forces of constraint do no work.

The remainder of this section will concentrate on class 1, metric elements, and, from this point on, the phrase "structural element" or simply "element" shall mean metric structural element as defined above.

6.8.1.2 General Problem Flow

NASTRAN consists of a number of subprograms, or modules, that are executed according to a sequence of macro-instructions. The NASTRAN Executive System (NES) controls the flow of this sequence. Twelve such sequences, called Rigid Formats, are permanently stored in NES and can be selected by means of control cards. Each rigid format corresponds to a particular type of structural analysis. Detailed explanations of each rigid format can be found in section 3 of the User's Manual.

Since a stiffness matrix [K] must be generated for all rigid formats, structural elements interact with all twelve rigid formats. However, if the reader has a minimal understanding of rigid format 1, Basic Static Analysis; rigid format 4, Static Analysis with Differential Stiffness; and rigid format 6, Piecewise Linear Analysis; then he will have enough background to add a new

element. Rigid formats 4 and 6 are minor variations of rigid format 1. Therefore, if all the module changes for rigid format 1 have been completed, only a few additional modules must be changed to add the new element to the differential stiffness and piecewise linear analysis element libraries. With these points in mind, the following subsection discusses the Basic Static Analysis rigid format in some detail.

6.8.1.2.1 Basic Static Analysis

Figure 2 shows a simplified flow diagram for Basic Static Analysis. Each block in the flow diagram represents a number of NASTRAN modules. Not every module has to be changed to add an element. Those that do have to be changed are called element-dependent; those that do not have to be changed are called element-independent.

In block 1 of Figure 2, the Input Data Processor, as the name implies, reads and analyzes the information on input data cards and reorganizes it into data blocks consisting of lists of similar quantities. NASTRAN input data cards reside in three separate decks: the Executive Control Deck, the Case Control Deck and the Bulk Data Deck. Section 2 of the User's Manual describes the contents of each of these decks. The reader need only be concerned with the Bulk Data Deck, for it is in this deck that the new element's connection and property information will be found. The Input File Processor (IFP) module analyzes each card of the Bulk Data Deck for correctness of format and distributes the data in the Bulk Data Deck to various data blocks. The primary function of the Executive Control Section Analysis (XCSA) module is to read and analyze the cards in the Executive Control Deck. XCSA also contains tables necessary for problem restarts, and it is in these tables that updates must be made. Detailed explanations of IFP and XCSA changes will be found in Sections 6.8.3.1 and 6.8.3.2, respectively.

In block 2 of Figure 2, the Geometry Processor generates coordinate system transformation matrices, tables of grid point locations, a table defining the structural elements connected to each grid point, and other miscellaneous tables such as those defining static loads and temperatures at grid points. The Geometry Processor consists of: Geometry Processor - Phase 1 (GP1); Geometry Processor - Phase 2 (GP2); Geometry Processor - Phase 3 (GP3); and the Table Assembler (TA1). Section 6.8.3.3 explains Geometry Processor interfaces which are minimal.

The Structures Plotter generates tape output for an automatic plotter that will plot the structure (i.e., the location of grid points and the boundaries of elements) in one of several available three-dimensional projections. The Structures Plotter is particularly useful for the detection of errors in grid point coordinates and in the connection of elements to grid points. The Structures Plotter may also be used at the end of the program to superimpose images of the deformed and undeformed structure. The Structures Plotter consists of the Plot Set Definition Processor (PLTSET) module and the Structural Plotter (PLØT) module.

The Structural Matrix Assembler generates stiffness and mass matrices referred to the grid points from tabular information generated by the Input File Processor and the Geometry Processor. NASTRAN uses the mass matrix in static analysis for the generation of gravity loads and inertia loads on unsupported structures. The Structural Matrix Assembler consists of three modules: Structural Matrix Assembler - Phase 1 (SMA1), which generates the stiffness matrix for structural elements; Structural Matrix Assembler - Phase 2 (SMA2), which generates the mass matrix; and Structural Matrix Assembler - Phase 3 (SMA3), which generates stiffness matrix contributions from general elements. Since we are not concerned with general elements (see Section 6.8.1.1), programming interfaces in SMA3 are not discussed. Sections 6.8.3.5 and 6.8.3.6 discuss SMA1 and SMA2 interfaces respectively.

In block 5 of Figure 2, the stiffness matrix is reduced to the form in which its matrix equation is finally solved through the imposition of single-point and multipoint constraints, and the optional use of matrix partitioning. No element-dependent code exists in block 5.

In block 6 of Figure 2, the Static Solution Generator - Phase 1 (SSG1) module generates load vectors $\{P_i\}$ from a variety of sources: concentrated loads at grid points; pressure loads on surfaces; gravity loads; temperature loads; and enforced deformations. The only types of loads that will concern the reader are thermal and enforced deformation loads, both of which are calculated using the stiffness properties of the structural elements. However, thermal and enforced deformation loads do not exist for all elements. The SSG1 interfaces are discussed in section 6.8.3.7. Module SSG2, which is element-independent, reduces the load vectors $\{P_i\}$ to final form by the application of constraints and matrix partitioning.

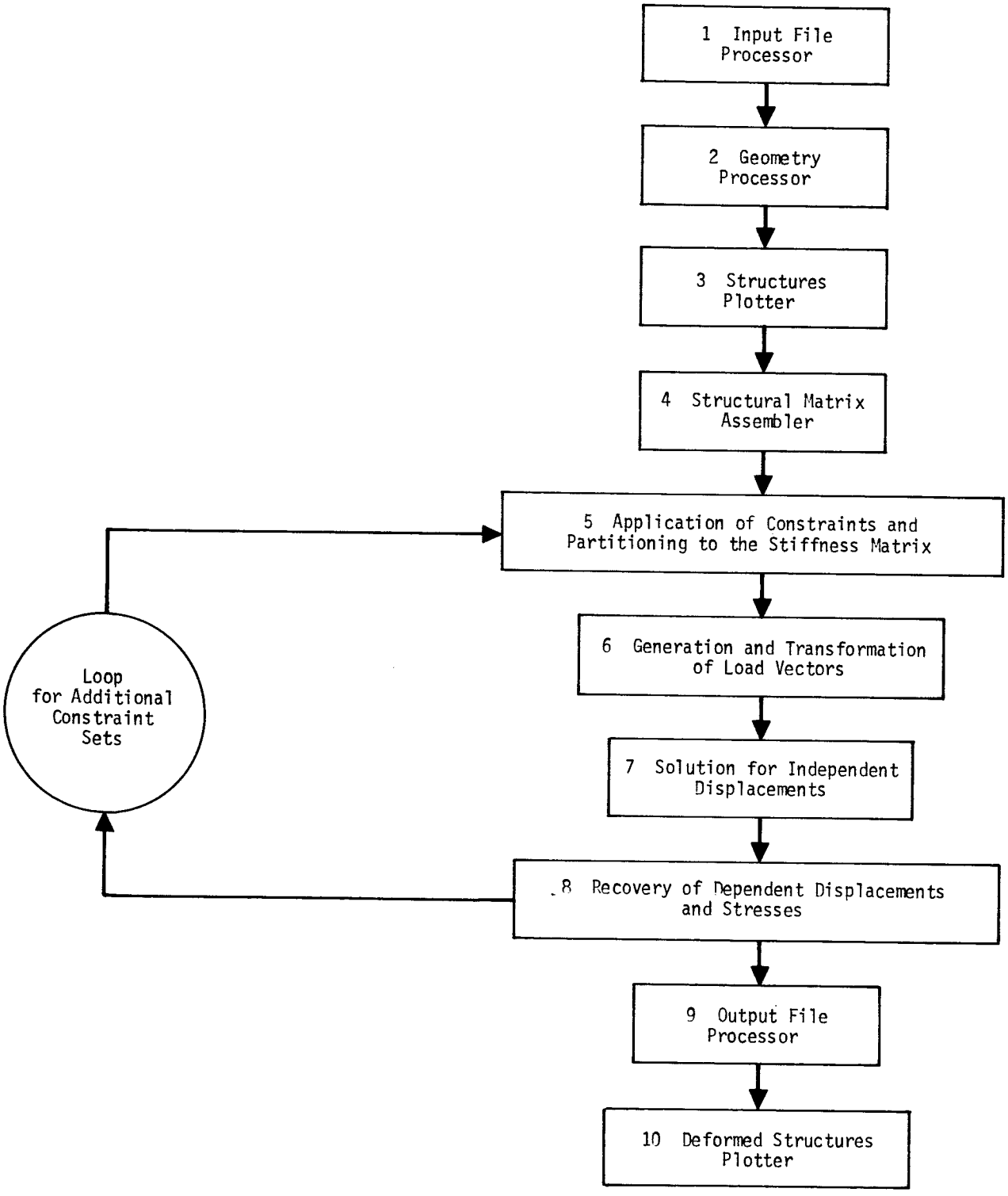


Figure 2. Simplified flow diagram for basic static analysis.

In block 7 of Figure 2, the solution for the independent displacements $\{u_i\}$ is accomplished in two steps: decomposition of the stiffness matrix [K] into upper and lower triangular factors; and solution for the $\{u_i\}$ corresponding to the specific load vectors, $\{P_i\}$, by means of successive substitutions into the equations represented by the triangular factors of [K] (the so-called forward and backward passes). Modules RBMG2 and SSG3, both of which are element-independent, accomplish this solution.

In block 8 of Figure 2, module SDR1, which is element-independent, determines dependent displacements. The internal forces and stresses in each element are then computed in the Stress Data Recovery - Phase 2 (SDR2) module from knowledge of the displacement components at the grid points of the elements and the intrinsic structural equations of the element. SDR2 programming interfaces are discussed in Section 6.8.3.8.

Finally in block 9 of Figure 2, the Output File Processor (ØFP) module formats the element forces and stresses that were computed in SDR2 for printing on the system output file. ØFP interfaces are discussed in Section 6.8.3.9.

6.8.1.2.2 Static Analysis With Differential Stiffness

Figure 3 shows a simplified flow diagram for rigid format 4, Static Analysis with Differential Stiffness. A comparison between Figures 2 and 3 shows that the first eight blocks of Figure 2 and 3 are identical.

Contributions to the differential stiffness matrix are not defined for all elements currently in NASTRAN, and they may not be defined for a new element. The differential stiffness matrix, which is a first order approximation to large deformation effects and which is directly proportional to the level of the applied loads, is generated in block 11 of Figure 3 in the Differential Stiffness Matrix Generator (DSMG1) module. Section 6.8.3.10 discusses DSMG1 programming interfaces.

The differential stiffness matrix is reduced to final form in block 12 in precisely the same way that the structural stiffness matrix is reduced to final form in block 5. It is then added to the structural stiffness matrix, and the solution and data recovery portions of the program are re-executed. Additional solutions may be obtained for conditions in which the differential stiffness matrix and the applied load vector are multiplied by a sequence of constant factors,

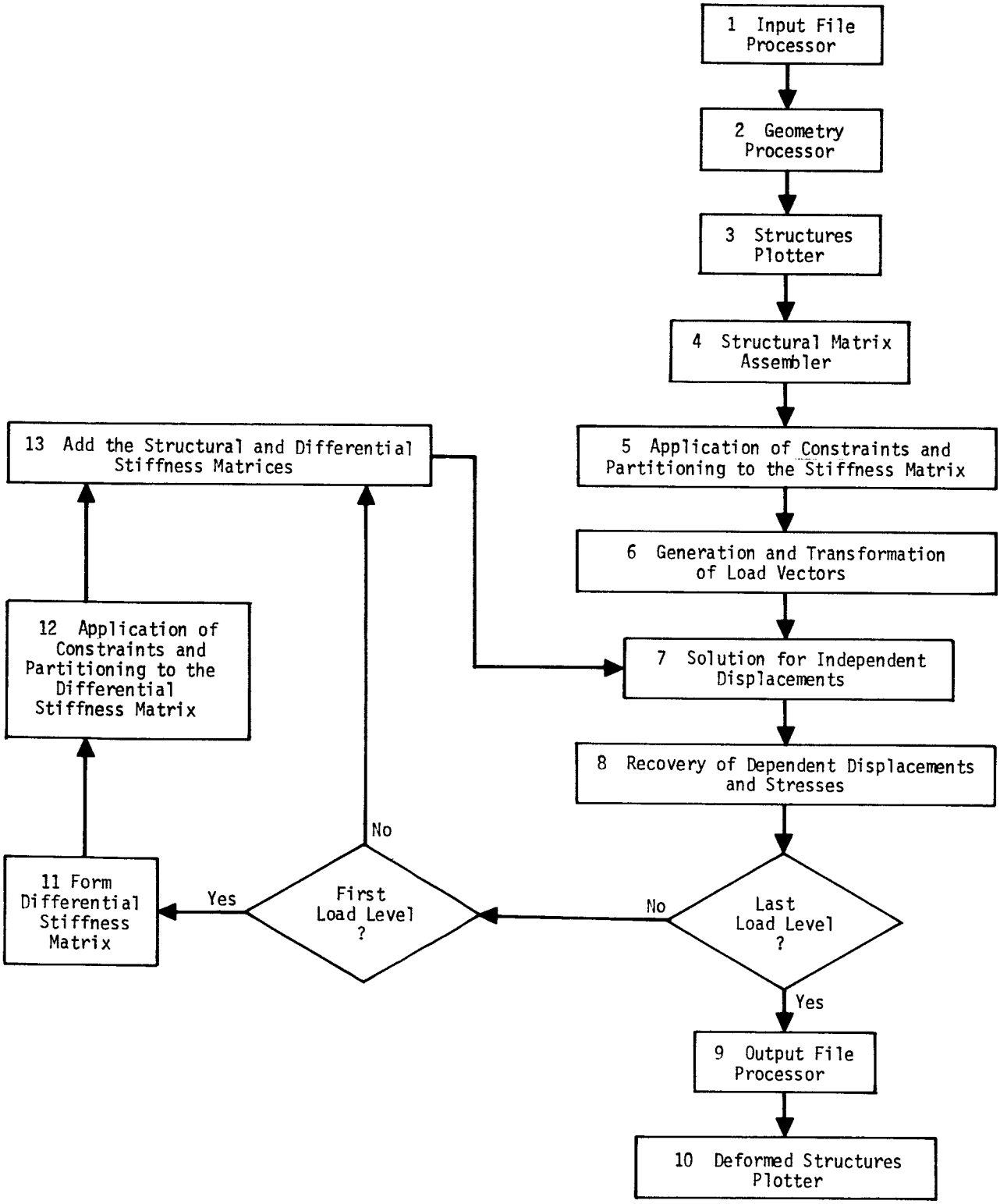


Figure 3. Simplified flow diagram for static analysis with differential stiffness.

corresponding to different levels of the same loading condition. All modules corresponding to blocks 12 and 13 are element-independent.

6.8.1.2.3 Piecewise Linear Analysis

Figure 4 shows a simplified flow diagram for rigid format 6, Piecewise Linear Analysis. In piecewise linear analysis, solutions are obtained for structures with nonlinear, stress-dependent, material properties. The load level is increased to its full value by small increments, such that stiffness properties can be assumed to be constant over each increment. After each increment the combined strains in nonlinear elements due to all load increments are used, in conjunction with stress-strain tabular functions, to determine the appropriate stiffnesses for the next load increment. Piecewise linear analysis is not defined for all elements currently in NASTRAN and it may not be defined for a new element.

Blocks 1 through 4 of Figure 4 are identical to blocks 1 through 4 of Figures 2 and 3. Blocks 4A and 4B are performed by the Piecewise Linear Analysis - Phase 1 (PLA1) module. PLA1 classifies all elements as linear or nonlinear. An element is said to be linear if its modulus of elasticity E, defined on a MAT1 bulk data card, is not defined to be stress-dependent on a TABLES1 bulk data card. PLA1 generates the linear stiffness matrix using the element routines of the SMA1 module, and the nonlinear elements comprise the ESTNL and ECPTNL data blocks. The ESTNL and ECPTNL data blocks, used subsequently in modules PLA3 and PLA4 respectively, have the same general formats as the EST and ECPT data blocks from which they are derived. PLA1 reads the EST and ECPT, and, for each element entry, appends stress information about the element. Modules PLA3 and PLA4 update the appended stress information each time these modules are executed in the loop that extends from block 5 to block 21 in Figure 4. Section 6.8.3.11 discusses PLA1 interfaces.

Block 5 in Figure 4 is identical to block 5 in Figures 2 and 3 and is element-independent. Block 6 contains module SSG1, which is no different in this rigid format from the two previously discussed. Block 17 is element-independent, and block 7, identical to block 7 in Figures 2 and 3, is also element-independent.

Block 8A denotes module SDR1 which is, as indicated above, element-independent. Note that the SDR2 module, block 8B, is outside the loop.

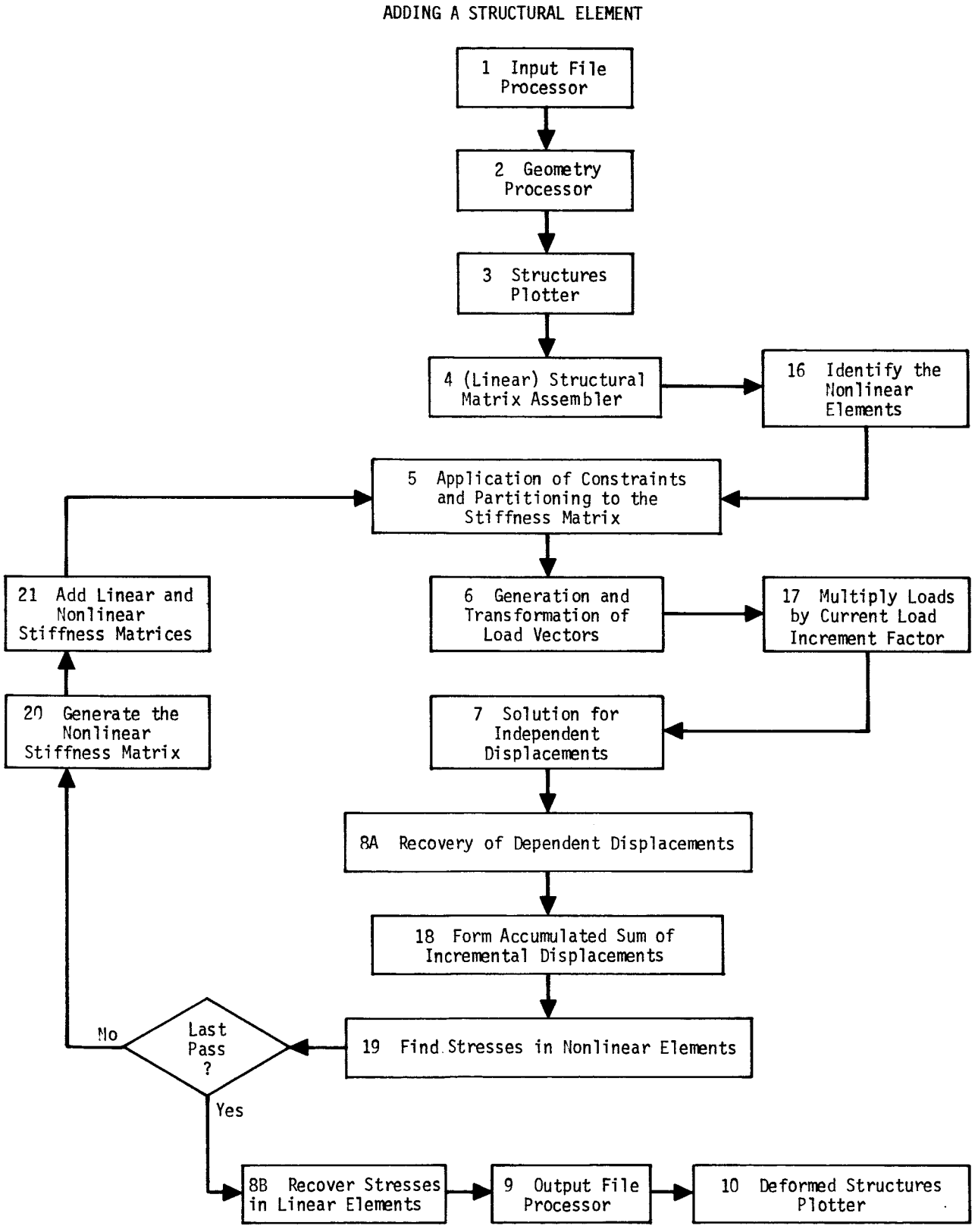


Figure 4. Simplified flow diagram for piecewise linear analysis.

Block 18 denotes module PLA2 which is element-independent, and in block 19 the stresses in the nonlinear elements are computed in the Piecewise Linear Analysis - Phase 3 (PLA3) module. This module is similar to the element stress data recovery portions of the SDR2 module. PLA3 interfaces are discussed in Section 6.8.3.12.

In block 20 of Figure 4, the Piecewise Linear Analysis - Phase 4 (PLA4) module generates the stiffness matrix associated with the nonlinear elements. PLA4 is very similar in structure to SMA1, and PLA4 interfaces are discussed in Section 6.8.3.13.

Block 21 completes the Piecewise Linear Analysis rigid format loop. The module here adds the linear stiffness matrix, which is constant throughout the loop, to the nonlinear stiffness matrix, which varies each time through the loop.

6.8.1.3 Summary

Summarizing Section 6.8.1, we have seen that:

1. NASTRAN embodies a lumped element approach wherein the distributed physical properties of a structure are represented by a model consisting of a finite number of idealized substructures or elements that are interconnected at a finite number of points.

2. The reader, who is an experienced FORTRAN scientific programmer, who knows the basics of matrix algebra but knows little or nothing about structural analysis, must design, code and checkout subroutines that will add the capability of a new element to the NASTRAN element library.

3. A major component of NASTRAN is an Executive System which controls the sequence of module executions according to options specified by the user.

4. Certain of the modules in NASTRAN are element-dependent and hence must be changed.

5. Some element-dependent modules have to be changed substantially; other element-dependent modules have to be changed only either to update tables, whose definitions are isolated to Block Data programs, or to skip element-dependent data which will not be used in certain modules (e.g., if differential stiffness and piecewise linear analysis are not defined for the element, no substantial changes need be made to DSMG1 and the piecewise linear analysis modules). The modules that have to be changed substantially are: IFP, SMA1, SMA2, SDR2 and

ØFP. Those modules which are in the second category are: XCSA, the Geometry Processor modules, PLTSET, SSG1, DSMG1, PLA1, PLA3 and PLA4.

6.8.1.3.1 Modules Which Must be Changed

The following summary lists the names of the modules that must be changed, the section of the Programmer's Manual that describes the module, the purpose of the module, and the reason for the change.

1. Name and Reference: Input File Processor (IFP); Section 4.5

   Purpose: To read and analyze the information on input data cards that define the mathematical model of the structure; and then to distribute these data items to data blocks consisting of lists of similar quantities.

   Reason for Change: When adding a new element, the user must define a connection card and, in most cases, a property card. He defines structural elements on connection cards by referencing the grid points that define the boundary of the element, (e.g., see the CRØD card in section 2.4 of the User's Manual). In most cases, the connection card refers to a property card, on which the cross-sectional properties of the element are given (see the PRØD card in section 2.4 of the User's Manual). In a few cases, the connection card gives all the information required to generate the structural matrices for the element.

2. Name and Reference: Executive Control Section Analysis (XCSA); Section 4.2

   Purpose: To read and analyze the Executive Control Deck; also it contains tables for problem restarts.

   Reason for Change: The names of the new connection and property cards must be added to the Card Name Tables, which are a subset of the restart tables.

3. Name and Reference: Geometry Processor, consisting of modules GP1, GP2, GP3, and TA1; sections 4.21, 4.22, 4.25, and 4.26, respectively.

Purpose: For GP1, to generate the coordinate system transformation matrices; for GP2, to convert external grid point numbers on connection cards to internal numbers; for GP3, to process static loads and temperature data; for TA1, to process and collect element connection data, element property data, element geometry data, and, if applicable, element temperature data into two different data blocks for later processing. One data block, the Element Connection and Properties Table (ECPT), is used in matrix assembler modules SMA1, SMA2 and DSMG1; the other, the Element Summary Table (EST), is used in load generation and element data recovery modules SSG1 and SDR2.

Reason for Change: Common block GPTA1 must be updated. Descriptive information in this common block completely describes element interfaces in these four modules.

4. Name and Reference: Structural Matrix Assembler - Phase 1 (SMA1); Section 4.27

Purpose: To generate the stiffness matrix exclusive of general elements.

Reason for Change: A subroutine, called an "element routine" which generates the element stiffness matrix for the new element must be coded.

5. Name and Reference: Structural Matrix Assembler - Phase 2 (SMA2); Section 4.28

Purpose: To generate the mass matrix.

Reason for Change: An element routine which generates the element mass matrix for the new element must be coded.

6. Name and Reference: Static Solution Generator - Phase 1 (SSG1); Section 4.41

Purpose: To compute the static loads selected by the user

Reason for Change: Element-dependent code which generates load vector contributions due to thermal or enforced deformation loads must be added to SSG1.

7. Name and References: Stress Data Recovery - Phase 2 (SDR2); Section 4.46

   Purpose: To recover internal forces and stresses in each element using the EST data block.

   Reason for Change: Two element routines which recover element stresses and forces for the new element must be coded.

8. Name and Reference: Output File Processor (ØFP); Section 4.70

   Purpose: To format and print data prepared for output by other functional modules.

   Reason for Change: To incorporate formats for the element stresses and forces computed in SDR2.

9. Name and Reference: Differential Stiffness Matrix Generator - Phase 1 (DSMG1); Section 4.49

   Purpose: To generate the differential stiffness matrix

   Reason for Change: If the added element is to have contributions to the differential stiffness matrix, a new element routine must be coded.

10. Name and Reference: Piecewise Linear Analysis - Phase 1 (PLA1); Section 4.52

    Purpose: To partition all elements into two classes, linear and nonlinear; and to build the data blocks ESTNL and ECPTNL, which are similar in form to the EST and ECPT, and which are used in modules PLA3 and PLA4 respectively.

Reason for Change: If the new element is to be admissible to the class of elements for which piecewise linear analysis is defined, data that will be appended to the element's ECPT and/or EST entry to form its ECPTNL and/or ESTNL entry must be initialized.

11. Name and Reference: Piecewise Linear Analysis - Phase 3 (PLA3); Section 4.54

Purpose: To compute element stresses for nonlinear elements; to update the ESTNL data block with accumulated element stress information.

Reason for Change: To code a new element routine which will compute stresses and update accumulated stress information for the element.

12. Name and Reference: Piecewise Linear Analysis - Phase 4 (PLA4); Section 4.55

Purpose: To generate the stiffness matrix for nonlinear elements; to update ECPTNL data block with accumulated element stress information.

Reason for Change: To code a new element routine which will compute stiffness matrix contributions and update accumulated stress information for the element.

6.8.2 General Guidelines

Before proceeding with the details (given in section 6.8.3) of coding in each of the modules listed in section 6.8.1.3.1, this section gives general guidelines, some of which will be applicable to all the modules to be changed, while some will be applicable to only a certain class of modules.

6.8.2.1 FØRTRAN Rules

As indicated in section 6.2 NASTRAN is written almost entirely in FØRTRAN IV. Since the program operates on three machines (IBM 360, UNIVAC 1108 and CDC 6600), the NASTRAN design team chose a subset of FØRTRAN IV to be the "language" for NASTRAN coding. To plan for the possibility that an element added locally will be incorporated into the global NASTRAN system

Table 1 gives the classification of the modules listed in section 6.8.1.3.1.

Table 1. Classification of Modules to be Changed

A. Data Processing Modules

Name	Function
IFP	Processes the Bulk Data Deck
XCSA	Describes the Card Name Table for problem restarts
GPTABD(1)	Describes connection/property characteristics of each element used by modules GP1, GP2, GP3, TA1, etc.
PLA1	Preprocessor for the Piecewise Linear Analysis rigid format
ØFP	Formats and prints answers

B. Structural Modules

Name	Function
SMA1	Generates the stiffness matrix
SMA2	Generates the mass matrix
SSG1	Generates load vectors
SDR2	Computes element stresses and forces
DSMG1	Generates the differential stiffness matrix
PLA3	Computes element stresses for nonlinear elements
PLA4	Generates the stiffness matrix for nonlinear elements

(1) GPTABD is a Block Data subprogram

(i.e., become operational on all NASTRAN computers) without unnecessary conversion problems, it is suggested that the programmer follow the NASTRAN FØRTRAN rules given in Section 6.2 for all module changes.

6.8.2.2 Classification of Modules

The modules in NASTRAN can be classified in many different ways. For the purposes of this section we classify the modules that must be changed to add a new element into two categories: data processing modules and structural modules. The data processing modules are those whose output data blocks are used either as input data blocks to other data processing modules or as input data blocks to the structural modules. ØFP is also classified as a data processing module. The structural modules are those whose output data blocks are the matrices and vectors needed for the solution of the structural problem.

6.8.2.3 Data Processing Modules

We discuss the data processing modules with respect to the data blocks output from them. A data block is a set of data, a matrix or a table, occupying a file, which can be thought of as a logical FØRTRAN unit. Section 2 gives detailed descriptions of the formats of the data blocks that are used in the twelve NASTRAN rigid formats. The formats are independent of rigid format. Table 2 gives the data blocks needed for element generation along with their use as input to the structural modules.

6.8.2.4 Structural Modules

The structural modules perform the actual floating-point arithmetic operations to generate matrices and load vectors and to recover element stress and force data. The structural modules contain element routines that: a) receive their inputs from the module driver; b) perform matrix operations to generate element-dependent matrices or vectors; and c) transfer their outputs to the driver or a module utility routine so they can be incorporated into a data block.

The structural modules are further classified into two classes: the matrix generation modules, consisting of SMA1, SMA2, DSMG1, and PLA4; and the load vector generation and data recovery modules, consisting of SSG1, SDR2, and PLA3.

Table 2. Data Blocks Needed for Element Generation

Data Block Name	Output From Module	Input to Modules
MPT	IFP	SMA1, SMA2, SSG1, SDR2, DSMG1, PLA1, PLA3, PLA4
DIT	IFP	SMA1, SMA2, SSG1, SDR2, DSMG1, PLA1, PLA3, PLA4
EDT	IFP	SSG1, SDR2, DSMG1
CSTM	GP1	SMA1, SMA2, SSG1, SDR2, DSMG1, PLA1 PLA3, PLA4
SIL	GP1	SSG1, SDR2, DSMG1
GPTT	GP3	SSG1, SDR2, DSMG1
ECPT	TA1	SMA1, SMA2, DSMG1, PLA1
GPCT	TA1	SMA1, SMA2, DSMG1, PLA1, PLA4
EST	TA1	SSG1, SDR2, PLA1
ESTNL	PLA1	PLA3
ECPTNL	PLA1	PLA4

The matrix generation modules have the following common characteristics:

1. They use double precision arithmetic.

2. They use the following data blocks: MPT, DIT, CSTM and GPCT.

3. They use the ECPT data block (or a variation, the ECPTNL, in the case of PLA4) rather than the EST data block.

4. They use the utility routines GMMATD, INVERD, PREMAT and PRETRD.

5. They generate the matrices six columns (or rows since the matrices are symmetric) at a time.

The load vector generation and data recovery modules have the following common characteristics:

1. They use single precision arithmetic.

2. They use the following data blocks: MPT, DIT, EDT (except PLA3) CSTM, SIL, GPTT (except PLA3).

3. They use the EST data block (or a variation, the ESTNL, in the case of PLA3) rather than the ECPT data block.

4. They use the utility routines GMMATS, INVERS, PREMAT and PRETRS.

6.8.2.4.1 The EST versus the ECPT

The Table Assembler module (TA1), the last of the data processing modules to be executed, processes element connection data, element property data, element geometry data and, if applicable, an element temperature datum. TA1 merges these data into two different sorts for efficiency in subsequent processing. The Element Summary Table (EST) contains one logical record for each element type. For each element (record) in the EST, connection, property, geometry, and temperature data are grouped. The Element Connection and Properties Table is essentially the EST in a different sort. The ECPT contains one logical record for each grid or scalar point of the model. Each logical record contains EST data for each element connection to the grid or scalar point associated with the record.

The load vector generation and data recovery modules use the EST, and the matrix generation modules use the ECPT. Section 6.8.2.4.2.1 more fully describes the use of the ECPT. Table 3 shows the EST/ECPT data for a rod element. The last two columns give respectively the data block that contained the data and the bulk data card type where the user originally placed the data.

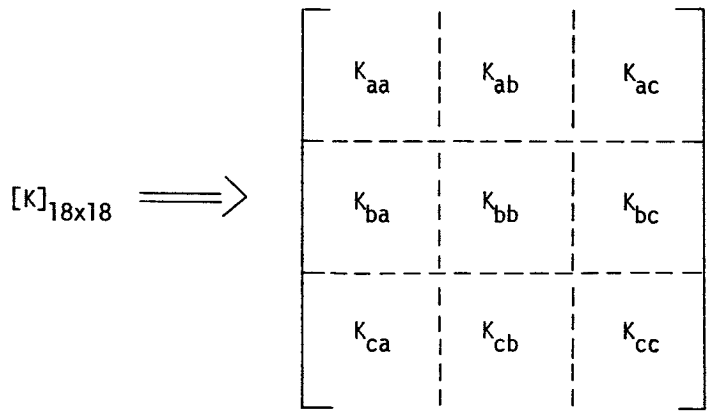
6.8.2.4.2 Matrix Generation Modules

The matrix [K] in Equation 1 of Section 6.8.1.1 is a global or system stiffness matrix. It is called global because it contains contributions from all structural elements of the mathematical model. On the other hand, associated with each element is an element stiffness matrix. The paragraphs below explain the relationship between element stiffness matrices and the global stiffness matrix. Although the remarks are directed towards stiffness matrices, they apply equally as well to mass and differential stiffness matrices.

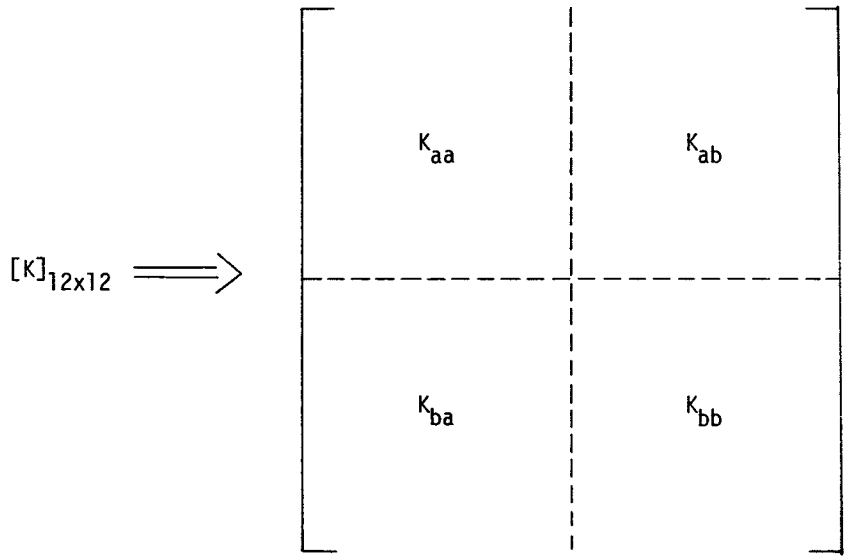
The stiffness matrix [K] for a structural element consists of a six-by-six matrix partition for each combination of the connected grid points. Each six-by-six partition relates the six degrees-of-freedom of two connecting grid points. For example, a RØD element connects two grid points "a" and "b". The element stiffness matrix partitions are $[K_{aa}]$, $[K_{ab}]$, $[K_{ba}]$ and $[K_{bb}]$. A triangular element (e.g., TRMEM) connects three grid points, and the element stiffness matrix consists of nine six-by-six partitions: $[K_{aa}]$, $[K_{ab}]$, $[K_{ac}]$, $[K_{ba}]$, $[K_{bb}]$, $[K_{bc}]$, $[K_{ca}]$, $[K_{cb}]$ and $[K_{cc}]$. Figure 5 shows the position of these partitions in the overall element stiffness matrix for triangular membrane and rod. Figure 6 shows the way in which six-by-six element stiffness matrix partitions are related to a global stiffness matrix. It shows a structure consisting of four grid points and two elements, a triangular membrane and a rod. The six-by-six partition $[K_{33}]$ for the triangular membrane element is added to the six-by-six partition $[K_{33}]$ for the rod element. The partitions $[K_{14}]$, $[K_{41}]$, $[K_{24}]$ and $[K_{42}]$ are zero since no element connects either points 1 and 4 or points 2 and 4. In the program, an element routine in a matrix generation module will pass a six-by-six partition to a module utility routine through the calling sequence. The utility routine will add the partition to the proper cells in open core. The module utility routine that performs this addition is called an "insertion" routine.

Table 3. EST/ECPT Data for a Rod Element

Word	Item	Type	Data Block	Card Type
1	Element ID	Integer	ECT	CRØD
2	Scalar Index for Grid Point A	Integer	ECT	CRØD
3	Scalar Index for Grid Point B	Integer	ECT	CRØD
4	Material ID	Integer	EPT	PRØD
5	Area (A)	Real	EPT	PRØD
6	Polar Moment of Inertia (J)	Real	EPT	PRØD
7	Torsional Stress Coefficient (C)	Real	EPT	PRØD
8	Nonstructural Mass (MU)	Real	EPT	PRØD
9	Coordinate System ID for Grid Point A	Integer	BGPDT	GRID
10	X-Coordinate of Grid Point A	Real	BGPDT	GRID
11	Y-Coordinate of Grid Point A	Real	BGPDT	GRID
12	Z-Coordinate of Grid Point A	Real	BGPDT	GRID
13	Coordinate System ID for Grid	Integer	BGPDT	GRID
14	X-Coordinate of Grid Point B	Real	BGPDT	GRID
15	Y-Coordinate of Grid Point B	Real	BGPDT	GRID
16	Z-Coordinate of Grid Point B	Real	BGPDT	GRID
17	Element Temperature	Real	GPTT	TEMP



Triangular membrane element (3 grid points)



Rod element (2 grid points)

Figure 5. Element stiffness matrix partitions for a triangular membrane and a rod.

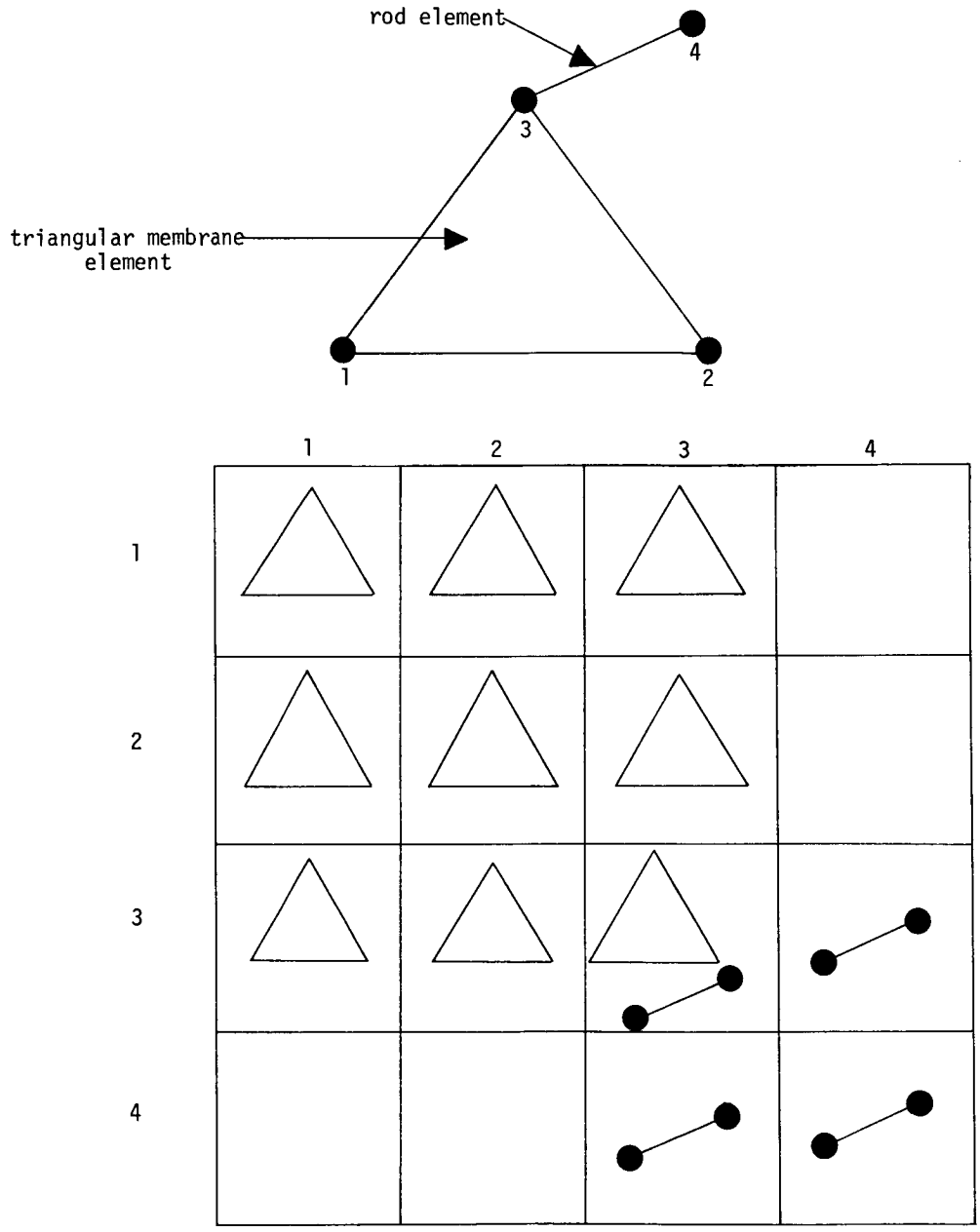


Figure 6. A simple structure and the associated global stiffness matrix.

6.8.2.4.2.1 Generation of Matrices Six Columns at a Time

Since a structural element will affect terms in the global matrices only in rows and columns related to its interconnected grid points, each column i, say, (or row i since the global matrices are symmetric) may be formed using only elements connected to the grid point associated with column i. NASTRAN forms the global matrices six columns at a time. The data block that enables this to be done is the Element Connection and Properties Table (ECPT), output from the Table Assembler (TA1) module. Each record of the ECPT corresponds to a grid point (or scalar point) of the model, and, conversely every grid point (and scalar point) of the model corresponds to a record of the ECPT. The point to which a record of the ECPT corresponds is called the pivot point of the record. Each record contains the connection, property, geometry, and temperature data for all elements connected to the pivot point. Hence data for an element will appear n times in the ECPT, where n is the number of points defining the element.

To generate a particular six-by-six element stiffness matrix partition $[K_{ij}]$, it is often necessary to generate the entire element stiffness matrix [K]. However, only those partitions $[K_{ij}]$, where i is the pivot point and j = 1, 2, ..., n (n being the number of grid points defining the element), are useful for the current ECPT record being processed, i.e., are useful for the current columns (or column if the pivot point is a scalar point) being generated. The unused partitions are recalculated and used when $j \neq i$ appears as a pivot point in a subsequent ECPT record. An alternative procedure for matrix generation, which is not used, would be to calculate all of the element matrices once and store them on an auxiliary storage unit for use when needed. This alternative procedure is less efficient for large problems, where efficiency really counts, because the recalculation time is less than the time required to recover element matrices from the auxiliary unit.

Although the matrices generated by SMA1, SMA2, DSMG1 and PLA4 are symmetric, NASTRAN generates complete columns and retains them for efficiency in succeeding matrix operations. This is necessary because all matrix operations are performed one column at a time (see section 2 of the Theoretical Manual). Moreover, the availability of symmetric matrices by rows or columns is advantageous in some of the matrix operations.

6.8.2.4.2.2 Element Stiffness Matrix Partitions

Although the actual equations for the element stiffness matrices are different for each element, they follow a definite pattern. The six-by-six element stiffness matrix partition, $[K_{ij}]$, for the six columns related to point j and the six rows related to point i is given by

$$[K_{ij}] = [T_i]^T[K_e][T_j] \quad , \tag{3}$$

where $[T_i]$ and $[T_j]$ are the global coordinate system orientation matrices associated with grid points i and j, and $[K_e]$ is an element stiffness matrix in a coordinate system that is element-dependent. The matrices $[T_i]$ and $[T_j]$ are calculated from data in the CSTM data block, and $[K_e]$ is calculated from: a) connection, property, geometry, and temperature data from the ECPT data block; and b) material property data from the Material Property Table (MPT) and the Direct Input Table (DIT) data blocks.

6.8.2.5 Utility Routines

A number of utility routines are available to all the structural modules. The matrix generation modules use double precision versions of these routines; the load vector generation and data recovery modules use corresponding single precision versions. These utility routines are:

1. GMMATD - General Matrix Multiply and Transpose (Double Precision). Section 3.4.32 describes GMMATD. A particular restriction is that all matrices in the calling sequence are stored by rows.

2. INVERD - In-core Matrix Inverse (Double Precision). Section 3.4.34 describes this standard matrix inversion routine.

3. PREMAT (with secondary entry point MAT) - Material Property Utility (Single Precision). PREMAT stores portions of the MPT and DIT data blocks in core, and MAT retrieves them when called by an element routine. See Section 3.4.36.

4. PRETRD (with secondary entry point TRANSD) - Utility for Modules that Use the CSTM Data Block (Double Precision). PRETRD reads the CSTM data block into core, and element routines call TRANSD to generate the matrices [T] in Equation 3. See Section 3.4.37.

Single precision versions of these routines exist for use in modules SSG1, SDR2, and PLA3, all of which use single precision arithmetic. These single precision routines are: GMMATS, INVERS, and PRETRS (with secondary entry point TRANSS), and they are documented in Section 3.4.33, 3.4.35, and 3.4.38 respectively. The outputs of the MAT routine are single precision, and the element routines of the double precision matrix generation modules store them in double precision cells or convert them to double precision via the DBLE function prior to arithmetic calculations.

6.8.3 Specific Checklists

This subsection contains specific checklists for the modules that must be changed to add a new element to NASTRAN. These checklists should be used in conjunction with the program source code and the NASTRAN documentation, particularly the Module Functional Descriptions in Section 4 and the Structural Element Descriptions in Section 4.87.

6.8.3.1 Input File Processor (IFP)

An element connection (e.g., CNEWEL) bulk data card must be designed and added to the set of admissible bulk data cards. An element property card (e.g., PNEWEL) may have to be added. IFP processes both of these bulk data cards.

There are four major references for the IFP programmer: Section 2.4 of the User's Manual gives a functional description of each bulk data card; Section 2.3.2 of the Programmer's Manual describes the format of the output data blocks generated by IFP; Section 4.5 of the Programmer's Manual contains a description of the processing that occurs within IFP; and the source listings contain implemented element-dependent code.

6.8.3.1.1 Card Design

Before proceeding with the actual coding interfaces in IFP, it is necessary to discuss some aspects of the designs of the cards.

The element mnemonic, minus the "C" for "connection", must be no more than six characters, so the entire mnemonic is less than or equal to seven characters. This restriction is necessary because the card may be used as a double-field card (see Section 2.4 of the User's Manual). A

similar restriction of course holds for the property card. For consistency and ease of use, follow the existing convention that the connection and property cards have the same mnemonic, except for the leading "C" and "P".

On the connection card, field 2 must be the element identification number (a positive integer), and field 3 must be, if a property card is defined, the property identification number (a positive integer). The next fields are reserved for the grid point identification numbers (positive integers) for the connecting grid points. The order of the grid points on the connection card defines the positive orientation of the element. Other connection information follows. If no property card is defined, the material identification number (again a positive integer) follows. Before card design is initiated, the reader should study existing connection cards documented in Section 2.4 of the User's Manual.

Field 2 of the property card must be the property identification number (a positive integer). Field 3 is the material identification number (a positive integer) which will be used, during program execution, to reference a material identification number on a MAT1, MAT2 or MAT3 material property card. The remaining fields are used for the element properties, which for the most part are real numbers. Required element properties must be listed first. This is done so that if a continuation card(s) is necessary to define all the allowed properties, it may be possible to define all the required element properties for a particular application with only the first card (e.g., see the PBAR card). Additionally, those properties that may lead to ill-conditioned element stiffness matrices or to operating system interrupts (division by zero, for example) should be restricted. Typical restrictions might be areas and thicknesses must be positive.

6.8.3.1.2 Coding Changes

IFP is, for the main part, table-driven. Entries in common blocks control the card data processing. These entries are initialized in seven Block Data subprograms, IFXiBD, i = 1, 2, ..., 7.

After the reader updates the Block Data subprograms, he updates a computed-go-to statement which performs a branch on internal card identification number (one of the entries in the tables).

The statement number to which the branch is made is a call to one of the subroutines IFS1P, IFS2P, IFS3P or IFS4P, wherein card-dependent code must be added. Specific checklists follow.

6.8.3.1.2.1 Block Data Updates

1. The names (mnemonics) of the connection and property cards must be added to /IFPX1/, which is initialized in Block Data subprogram IFX1BD. The position of the names in this table defines the internal card identification number. Currently, over two-hundred (200) cards are defined. For the purposes of this discussion, let us assume that exactly two-hundred (200) cards are defined. The new connection and property cards will then have internal card numbers 201 and 202 respectively. The names must be defined as the first words of the I5 array in IFX1BD.

2. /IFPX2/, initialized in Block Data subprogram IFX2BD, contains two words per card type in the order of ascending internal card identification numbers. The first word of each pair gives the GINØ output file number, and the second gives the approach acceptability flag (see Tables 1 and 2 in section 4.5). All connection cards are output on the GEØM2 data block, which for IFP purposes is designated file number 8; and property cards are output on the EPT data block, which for IFP purposes is designated file number 2. We make the assumption for our present purposes that the element is acceptable for any problem approach: force, displacement or DMAP. Hence, the four words to be updated are: 8, 0, 2, 0. These four words should be added to words 41 through 44 of the array I3 in IFX2BD.

3. /IFPX3/, initialized in Block Data subprogram IFX3BD, contains two words per card type in the order of ascending internal card identification numbers. IFP uses the first word of each pair as the Conical Shell Problem flag; the second word contains the number of words to be output to the GINØ output file. No element connection or property cards other than CCØNEAX and PCØNEAX are allowed for a Conical Shell Problem; all second words of the pairs in /IFPX3/ are set to zero. Hence, the four words to be updated are: -1, 0, -1, 0. These four words should be added to words 41 through 44 of the array I3 in IFX3BD.

4. /IFPX4/, initialized in Block Data subprogram IFX4BD, contains two words per card type in the order of ascending internal card identification numbers. The first word of each pair is the smallest multiple of 4 greater than or equal to the number of required data items on the card, and the second word is 4 more than the smallest multiple of 4 greater than or equal

to the number of allowed data items on the card. Mathematically, let r be the required number of data items; let a be the allowed number of data items ($r \leq a$); let F be the value of the first word of the pair; and let G be the value of second word of the pair. Then:

$$F = 4\left[\frac{r+4}{4}\right] \text{ and } G = 4 + 4\left[\frac{a+2}{4}\right]$$

where [x] is the greatest integer $\leq x$. For example, on the CBAR card (see Section 2.4.2 of the User's Manual), the data items on the continuation card are not required so that r = 8. Clearly, a = 16. Hence, F = 8 and G = 20. The four words must be added to words 41 through 44 of the array I3 in IFX4BD.

5. /IFPX5/, initialized in Block Data subprogram IFX5BD, contains two words per card type in the order of ascending internal card identification numbers. The first word of each pair is an index into /IFPX7/, and the second word is the field-2-uniqueness-check flag. For every bulk data card, each field except the first (the card mnemonic which is always BCD) is defined as either blank, integer, real, BCD, or double precision. An internal code has been established (0 = blank, 1 = integer, 2 = real, 3 = BCD, 4 = double precision, 5 = anything is permitted). Hence, a string of integers each between 0 and 5 describes a card's format. The length of the string is the number of fields allowed, including interior blank fields (e.g., fields 2, 4 and 5 on a BARØR card) but not including trailing blank fields. This string is contained in /IFPX7/, and the first word of the pair in /IFPX5/ is an index to the first word of this string. Before adding a new string, the reader should search /IFPX7/ to see if an existing string corresponds to the strings needed for the new "C" and "P" cards. We can make a check for duplicates in field 2 on both the "C" and "P" cards. We can do this because: (a) no duplicates are permitted in the set of all element identification numbers (similarly for the set of property identification numbers associated with an element type); (b) the Bulk Data Deck is sorted prior to IFP processing; and (c) IFP "looks at" two successive cards at a time.

6. /IFPX6/, initialized in Block Data subprogram IFX6BD, contains two words per card type in the order of ascending internal card identification numbers. IFP uses the two words as header information in the logical record associated with the card type (all the cards of one type are written in one logical record). The first word defines a card-type identification code, and the second word defines a bit position in a 96-bit "trailer." Modules that read,

via utility subroutine LØCATE, data blocks output by IFP use these two items. For the connection card, all the assigned card-type identification codes and trailer bit positions for GEØM2, which are listed in Section 2.3.2.2 must be searched and new unique ones chosen. The identification code can be any positive integer, but the trailer bit position must be between 1 and 96. A similar search and choice must be made for the two similar numbers for the property card that will reside on the EPT data block, documented in Section 2.3.2.5.

7. /IFPX7/, initialized in Block Data subprogram IFX7BD, contains format code strings. See paragraph 5 above for details.

6.8.3.1.2.2 Main Program and Card-Dependent Code Changes

The Block Data subprograms having been updated, make the following changes:

1. Update, in subroutine IFP, the computed-go-to statement which branches on internal card identification number. This statement follows the comment statement

C CALLS SECØNDARY RØUTINE TØ EXAMINE EACH TYPE ØF CARD

2. Add card-dependent code to one of the four card-dependent subroutines, IFSiP, i = 1, 2, 3, 4. IFS1P processes most of the connection and property cards. Therefore, for consistency, the programmer will probably choose it. Observe that the same code is used for card types which are similar in format. The Bulk Data Card Descriptions in section 2 of the User's Manual in effect lay down the coding specifications. Observe that:

a. The reader must update one of the three computed-go-to statements at the beginning of IFSiP (note that K is the internal card number, KX = K - 100, and KY = K - 200).

b. The integer array M does not contain the card mnemonic, so that M(1) contains field 2, M(2) contains field 3, etc.

c. N is the number of words to be written on the output file. It must be set in the card-dependent code.

d. M is EQUIVALENCEd to the real array RM which must be used for floating-point comparisons or operations.

e. If the new card(s) has a format identical to an existing one, the reader might choose to use the existing code.

6.8.3.2 Executive Control Section Analysis (XCSA)

XCSA is responsible for the transmission to the remainder of the program of the restart tables associated with the rigid format selected by the user. However, only a single portion, the Card Name Tables, of the restart tables must be updated. Each rigid format and its associated restart tables are stored in a subroutine. For rigid format i (i = 01, 02, ..., 09, 10, 11, 12), the routine name is LDi.

Two entries must be updated in LDi, one for the new "C" card and one for the new "P" card. Assume the new "C" card is CNEWEL and the new "P" card is PNEWEL. Then the entries are:

$$4HCNEW, 4HEL_{\wedge\wedge}, 2$$

and

$$4HPNEW, 4HEL_{\wedge\wedge}, 3$$

where $_{\wedge}$ denotes a BCD blank. The numbers 2 and 3 refer to bit positions of entries in a master execution mask (see Sections 3.i + 1.3.1, (i = 1,2, ..., 12) of the User's Manual). These updates must be made after the last entry in the DATA statement for the array INM. All 12 LDi subroutine programs must be so updated.

The last three statements in each LDi subroutine are:

```
CALL WRITE (NPTP, INM, m, 1)
RETURN
END
```

Change the argument m in the CALL WRITE statement. The CALL WRITE statement writes n words of the INM array (onto the New Problem Tape, NPTP, with an end-of-record mark). The number m, which varies with the LDi routine, must be incremented by 6.

6.8.3.3 Geometry Processor and Table Assembler Modules (GP1, GP2, GP3, and TA1)

Data in common block /GPTA1/ entirely controls processing of element data in GP1, GP2, GP3 and TA1. Block Data program GPTABD initializes these data. Section 2.5.2.1 contains a description of /GPTA1/. When adding an element, the reader must change /GPTA1/ in the following ways:

Words for Table Header	Change
1	Increase this word, the number of entries, by 1. Call this new number of element entries n.
2	Increase this word, the pointer to the first word of the last element entry, by the number of words per entry, currently 24.

Words for New Element Entry	Change
1,2	Include the new element's connection card mnemonic, e.g., CNEWEL.
3	Assign a new element-type identification number (this number should be n for consistency).
4 thru 24	Complete these items in accordance with definitions in Section 2.5.2.1.

NOTE WELL: Structural modules that read the ECPT, EST, ECPTNL and ESTNL data blocks will use the new element-type identification number, n. Hence, this number must be determined and communicated early in the development process to all involved.

6.8.3.4 Plot Set Definition Processor (PLTSET)

This section has been deleted.

6.8.3.5 Structural Matrix Assembler - Phase 1 (SMA1)

A principal interface in adding a new element is to change SMA1, which generates element stiffness matrix partitions and which, on option, generates element structural damping matrix partitions. The changes are of two kinds: module Block Data and module driver changes; and the addition of an element subroutine.

6.8.3.5.1 Block Data and Module Driver Changes

At least two changes, and possibly a third, must be made to Block Data program SMA1BD. All the changes pertain to variables contained in /SMA1CL/. These changes are:

1. Update the array NWØRDS, which defines the number of words in the element's ECPT entry. The position in the array is dictated by the internal element-type identification number defined in /GPTA1/ (see Section 6.8.3.3).

2. Update the array IØVRLY, which defines the overlay segment in which the new element routine is to reside. (An explanation of IØVRLY can be found in Section 4.27.9.3, and the SMA1 overlay structure is illustrated in Section 5).

3. If the number of overlay segments for element routines must be increased, then the variable NLINKS must be incremented by one.

The following two changes must be made to the module driver, subroutine SMA1A:

1. Update the computed-go-to statement at FØRTRAN statement number 180 which performs a branch on internal element-type identification number. For some existing elements, that do not contribute to the stiffness matrix, e.g., CØNM1, insert a transfer to read the next element type. Most elements do contribute to the stiffness matrix, and for these elements a transfer is made to an element routine call statement.

2. Insert a call to the new element stiffness matrix routine. This call must be followed by a transfer (GØ TØ) statement to read the next element type. This call statement has, in general, no arguments. The element's ECPT entry is passed to the element routine via /SMA1ET/. The name of the element routine should begin with "K" followed by the connection card mnemonic minus the initial "C", e.g., KNEWEL.

6.8.3.5.2 Coding the KNEWEL Subroutine

When coding the new element subroutine, follow this check list:

1. Document the element's ECPT entry at the beginning of the routine via comments.

2. Maintain the order of FØRTRAN specification statements given in Section 6.2.

3. Restrict the common block interfaces to the following:

   a. /SMA1IØ/. Only variables IFKGG and IF4GG are used.

   b. /SMA1CL/. Only variables IØPT4, K4GGSW and NPVT are used.

   c. /SMA1ET/. This block is 100 words in length and is the means of communicating the element data from the ECPT data block to the element subroutines. Since the data in /SMA1ET/ are mixed (real and integer), an EQUIVALENCE must be used.

   d. /MATIN/ and MATØUT/. These are input and output data common blocks for the material property utility subroutine MAT (see Section 3.4.36). The outputs from MAT in /MATØUT/ are single precision, and they must be stored in double precision locations prior to arithmetic computations.

   e. /SMA1DP/. This common block contains double precision variables which, for most programs, would be subroutine local variables. It is used so that open core (see Section 1.5) for SMA1 can be as long as possible. The use of this common block implies that element subroutines are not reentrant.

4. Make a test to insure that the scalar index number (internal number for a grid point) for one of the connecting grid points matches the pivot point, NPVT.

5. Perform all arithmetic operations in double precision.

6. Use the utility routines GMMATD, TRANSD, INVERD and MAT.

7. Call SMA1B (Section 4.27.8.3) to "insert" the six-by-six matrix partitions. If IØPT4 is nonzero, compute the structural damping matrix. Obtain six-by-six partition of the structural damping matrix by multiplying a six-by-six stiffness matrix partition by a scalar. viz., GSUBE (g_e) obtained from MAT via /MATØUT/. SMA1B performs the actual scalar multiplication. If the structural damping matrix is computed, set K4GGSW equal to 1. Use the variables IFKGG and IF4GG in the calling sequence for SMA1B to signal the insertion of a stiffness matrix partition and a structural damping matrix partition respectively.

6.8.3.6 Structural Matrix Assembler - Phase 2 (SMA2)

SMA2 generates the mass matrix and the viscous damping matrix. Currently in NASTRAN, elements contribute to one or the other but not both. However, from the point of view of an element-routine writer, they are functionally the same. The structure of the SMA2 module is very similar to module SMA1. We coded two modules because problem restarts can be handled more efficiently with separate modules and because separate modules allow more efficient utilization of open core.

Like SMA1, the SMA2 module changes are of two kinds: module Block Data and module driver changes; and the addition of an element subroutine.

6.8.3.6.1 Block Data and Module Driver Changes

At least two changes, and possibly a third, must be made to Block Data program SMA2BD. The changes are the same as those outlined in the first paragraph of section 6.8.3.5.1, with the exception that the common block that contains the three variables NWØRDS, IØVRLY and NLINKS is /SMA2CL/ instead of /SMA1CL/. However, the overlay structure for the SMA2 element routines is different from that of SMA1, so IØVRLY and NLINKS, although functionally the same as the variables of the same names in SMA1, do have different values.

Make the following changes to the module driver, subroutine SMA2A:

1. Update the computed-go-to statement at FØRTRAN statement number 180 which performs a branch on internal element-type identification number. Some elements, e.g., ELAS1, contribute neither to the mass nor viscous damping matrix, in which case insert a transfer to read the next element type. Most elements do contribute to either the mass matrix or the viscous damping matrix, and for these elements insert a call to the element routine. For elements for which both lumped mass and coupled mass routines are defined, test the variable ICMBAR to determine which one to call. If ICMBAR is less than zero, call the lumped mass routine; otherwise call the coupled mass routine.

2. Insert a call to the new element routine. Following this call, add a GØ TØ statement to transfer program control to read the next element type. An element's ECPT entry is passed to the element routine via /SMA2CL/. Begin the subroutine name for mass matrix routines with "M" followed by the element mnemonic, e.g., MNEWEL.

6.8.3.6.2 Adding the New Element Routine

The rules which must be followed in coding an element routine for SMA2 are similar to those for coding SMA1 element routines given in Section 6.8.3.5.2. References to this section are made in the following checklist:

1. Same as No. 1 in Section 6.8.3.5.2.
2. Same as No. 2 in Section 6.8.3.5.2.
3. Restrict the common block interfaces to the following:
   a. /SMA2IØ/. Only variables IFMGG and IFBGG are used.
   b. /SMA2CL/. Only variables BGGIND and NPVT are used.
   c. /SMA2ET/. This 100 word block performs the same function as /SMA1ET/ in SMA1.
   d. /MATIN/ and /MATØUT/. See comment in Section 6.8.3.5.2.
   e. /SMA2DP/. The comments about /SMA1DP/ in Section 6.8.3.5.2 apply here also.
4. Same as No. 4 in Section 6.8.3.5.2.
5. Same as No. 5 in Section 6.8.3.5.2.
6. Same as No. 6 in Section 6.8.3.5.2.
7. Call SMA2B to perform the six-by-six partition insertions (see Section 4.28.8.3).
8. If the element routine contributes partitions to the viscous damping matrix, set BGGIND to 1 at the beginning of the routine.
9. "Lift" as much code as possible from the element stiffness routine KNEWEL of module SMA1.

6.8.3.7 Static Solution Generator - Phase 1 (SSG1)

Subroutine EDTL (which has a secondary entry point, TEMPL) processes the EST data block one element at a time to compute temperature and enforced deformation loads. When an element is added to NASTRAN, update EDTL whether or not temperature or enforced deformation loads are defined for the new element. If the element has thermal or enforced deformation loading, the reader must code an element routine.

6.8.3.7.1 EDTL Changes

Make the following changes to subroutine EDL:

1. Add an entry to the local array NECPT. NECPT(I) is the number of words in the EST entry for the element whose internal element-type identification number is I (recall I is set in GPTABD, see Section 6.8.3.3).

2. Change the computed-go-to element type to reflect the new element. If the new element does not have thermal or deformation loads defined, insert a transfer (to FORTRAN statement number 610) to skip the entire EST record; if it does, change the computed-go-to statement so that it points to element-dependent code in EDTL.

3. Add element-dependent code to EDTL which will:

   a. Read the EST entry into /TRIMEX/.

   b. Look-up the temperature at each grid point associated with the element. This look-up is accomplished via a call to subroutine FGPTT (see Section 4.41.11.27).

   c. Call the element routine, passing the temperatures at the grid points and the beginning of the load vector array (at CØRE(1)) through the calling sequence.

6.8.3.7.2 Coding the Element Routine

When coding the element routine follow this checklist:

1. Same as No. 1 in Section 6.8.3.5.2.

2. Same as No. 2 in Section 6.8.3.5.2.

3. Restrict the common block interfaces to the following:

   a. /TRIMEX/. This block is 100 words in length and contains the element's EST entry.

   b. /MATIN/ and /MATØUT/. These are used as input and output blocks for subroutine MAT.

4. Perform all arithmetic operations in single precision.

5. Use subroutine MAT to fetch material properties; MPYL and MPYLT are module utilities available for in-core matrix multiplication (subroutine GMMATS may alternatively be used); BASGLB and GLBBAS are module utilities that compute coordinate system transformation

matrices (TRANSS may alternatively be used). See Section 4.41.11 for information on MPYL, MPYLT, BASGLB and GLBAS.

6. The scalar index numbers (internal degree-of-freedom numbers) in the element's EST entry are direct pointers into the load vector where the loading contributions should be added, i.e., the element routine does its own "insertion".

7. "Lift" as much code as possible from the element stiffness routine KNEWEL of module SMA1.

6.8.3.8 Stress Data Recovery - Phase 2 (SDR2)

The SDR2 module is divided into five stages. Two of the stages, stage III and stage V, deal with recovery of stress and force data for elements. In the following paragraphs, we will call these two stages phase 1 and phase 2, respectively.

Phase 1 computes and saves on a scratch file for phase 2 processing element stress matrices along with element properties, which are dependent upon the element. Phase 2 uses the outputs of phase 1 in conjunction with displacement vectors $\{u_i\}$ to compute final stress and force data in the elements.

Make changes to a module Block Data program and the driver routines for phase 1 and phase 2; also code two element routines, Sxxxx1 and Sxxxx2, where "xxxx" are four letters of the element's mnemonic, e.g., xxxx might be NEWL.

6.8.3.8.1 Driver Routine Changes

In subroutine SDR2B, the phase 1 driver, update the computed-go-to statement that performs a branch on element type, and add a call to Sxxxx1.

In subroutine SDR2E, the phase 2 driver, update the computed-go-to statement, and add a call to Sxxxx2. To output complex stresses and forces, increase the dimension of the CØMPLX array, and add a pointer string for stresses and forces if one does not currently exist. If complex stresses and forces are not permitted, set the two CØMPLX pointers in Block Data subprogram containing /GPTA1/ to 0.

6.8.3.8.2 The Element Routines

The following set of rules apply to both element routines:

1. Same as No. 1 in Section 6.8.3.5.2.
2. Same as No. 2 in Section 6.8.3.5.2.
3. Perform all arithmetic operations in single precision.
4. Use the utility routines TRANSS and GMMATS.

6.8.3.8.2.1 The Phase 1 Element Routine Sxxxx1

The following two items apply to the phase 1 element routine:

1. Restrict the common block interfaces to the following:

   a. /SDR2X5/. The EST entry is contained in /SDR2X5/. At the conclusion of Sxxxx1, /SDR2X5/ contains the outputs of the routine: stress matrices and miscellaneous element properties. Output the scalar index numbers of the EST entry for use in phase 2.

   b. /SDR2X6/. Use for scratch storage.

   c. /MATIN/ and /MATØUT/. Used by MAT.

2. MAT is available to Sxxxx1, but not to Sxxxx2.

6.8.3.8.2.2 The Phase 2 Element Routine Sxxxx2

The following remarks apply to Sxxxx2:

1. The common block interfaces are:

   a. /SDR2XX/. This block defines open core where the phase 2 driver stores the displacement vector.

   b. /SDR2X4/. Three words are used, the 36^{th}, 38^{th}, and 39^{th}. Word 36 is an index into /SDR2XX/. It points to the first word of the displacement vector. Word 38 is an element loading temperature, and word 39 is an element deformation. If thermal and deformation loading were not defined in SSG1, do not use these latter two words.

c. /SDR2X7/. This block contains the computed element stresses. The element identification number, the first word of the EST entry, must always be the first word of /SDR2X7/.

d. /SDR2X8/. Computed element forces are stored here. The element identification number must be the first word.

2. The scalar index numbers are indexes to those components of the displacement vector needed for stress and force computations.

6.8.3.9 Output File Processor (ØFP)

ØFP prints, with headings, element stress and/or force output. Each new element needs a unique heading and entries to describe the output format desired. This heading is in addition to the standard title, subtitle, and label that will be printed from information in the Case Control Deck. Page ejection is element-independent and automatic, with headings reprinted on each page of output until all data records have been printed.

6.8.3.9.1 ØFP Design

ØFP is, like IFP, essentially table-driven. This technique allows ØFP to avoid many lengthy format statements. In ØFP standard format statements contain the headings, and the formats for the items data record are built from tables.

Before modifying ØFP, the programmer should be familiar with the documentation references for ØFP, particularly those describing element stress and force output. Section 4.70 and the source listings for the subroutines described in that section are where the general descriptions for ØFP can be found. Sections 2.3.51 and 2.3.52 describe the specific makeup for element stress and force data blocks. ØFP will expect any new element type identification record to have a similar format as the other element types (see the description of record 1 in Section 2.3.28.15). ØFP also assumes that the number, order, and type of the new element's data record(s) have been determined (see description for record 2 of Section 2.3.28.15). Normally, SDR2 has set these data records for ØFP depending on the required output. The coding changes for ØFP will depend on a) the headings desired and b) the number, order, and type of items in the data record.

6.8.3.9.2 Adding the Headings

New elements may require many different headings, such as forces for the real case, forces for the complex case, stresses for the real case, and stresses for the complex case. And then all of these cases can be in SØRT I or SØRT II format. Changes have to be made for each case.

Each heading in ØFP consists of five lines of output. Each line is printed by a separate write statement, so if any two lines are the same, then the same statement can be used. Thus, when the analyst and the programmer are deciding on wording and spacing of the headings, they should lay them out in a consistent manner. They may be able to use existing formats for some lines.

The basic heading pointer is contained in the doubly subscripted B array (see Section 4.70.9). The actual line pointers are in the C array, and format statements in subroutines ØFP1 and ØFP1A contain the output headings. The pointer to the B array is set in word 2 of each input identification record (SDR2 has set this word correctly for the new element). The reader then computes CPØINT, where CPØINT is an index into the C array. To do this, word 2 of record 1 and the element-type identification number (see Section 6.8.3.3) are needed for each desired type of output. CPØINT indexes from 0 to 1440 are in Block Data program ØFP2BD, CPØINT indexes from 1441 to 2880 are in Block Data program ØFP3BD, and CPØINT index from 2881 to 4320 are in Block Data program ØFP4BD. The value of C(CPØINT) is a pointer into the D array, which will define the format string for the data record. The values of the next five entries in the C array, (C(CPØINT + 1) to C(CPØINT + 5)) are used as numbers in a computed-go-to statement in ØFP1. Each of these five numbers refers to a write statement, which prints one line of the heading. ØFP1 is so large that the computed-go-to statement has been continued in ØFP1A. Thus, new format statements and write statements should be added to ØFP1A. As new write statements are added, the computed-go-to near the beginning of ØFP1A and the test for the maximum number of write statements must be updated.

6.8.3.9.3 Adding the Data Record Code

C(CPØINT) is equal to DPØINT which is an index to the next available space in the D array. The D array is contained in the Block Data program ØFP1BD. The value of D(DPØINT) is a packed four-digit number. The right two digits give the number of output lines the data record will produce, and the left two digits give the number of data records used per line. If the left two digits are null, then only one data record is used per line.

Values for entries D(DPØINT + 1) to a D(DPØINT + N), whose value is 0, define pointers to the E array or ESINGL array. Positive values point to the E array by the formula (5*D(DPØINT + I) - 5), where I varies from 1 to N. Negative values in the D array are used as pointers into the ESINGL array by the formula |D(DPØINT + 1)|. Both the E array and the ESINGL array are contained in the Block Data program ØFP5BD. Both of these arrays contain pieces of a format statement, and the programmer strings the pieces together to space and place the data items correctly under the heading. The programmer can use the pieces that are listed or add more. The only rule is to exclude the ending comma from any piece of a format statement. In general, all the necessary format pieces to describe a line of a data record are included in the E and ESINGL arrays.

6.8.3.10 Differential Stiffness Matrix Generator - Phase 1 (DSMG1)

The element interfaces with DSMG1 are in two phases. Phase 1 reads the ECPT data block and, for each element, appends displacement vector components of the associated grid points, an average element loading temperature, and an element deformation. Phase 1 writes this appended ECPT entry onto a scratch file which has the same general format as the ECPT. Phase 2 processes the scratch file in a fashion similar to ECPT processing in SMA1, so the differential stiffness element routines reside in the phase 2 portion of the module.

6.8.3.10.1 Phase 1 Changes

When appending the components of the displacement vector to the ECPT element entry in subroutine DS1, either append the three translational components of displacement at each grid point or append all six components of displacement at each grid point. The test for this determination is made immediately after FØRTRAN statement number 300.

If an element type is not in the differential stiffness set (DSARY(I)=0), phase 1 does not write its ECPT entry on the scratch file.

6.8.3.10.2 Phase 2 Changes

Change the computed-go-to statement in subroutine DS1A that performs a branch on element-type identification number, and insert a call to the new element routine. Name the new element routine DNEWEL. The computed-go-to statement in DS1A need not be changed if the element is not in the differential stiffness set.

6.8.3.10.3 Coding the DNEWEL Subroutine

When coding the new element subroutine, follow this checklist:

1. Document the element's appended ECPT entry at the beginning of the routine via comments.
2. Same as No. 2 in Section 6.8.3.5.2.
3. Restrict the common block interfaces in DNEWEL to the following:
   a. /DS1AAA/. The first word is the pivot point.
   b. /DS1AET/. The appended ECPT entry from the scratch file is stored here. See Section 6.8.3.5.2, paragraph 3(c).
   c. /DS1ADP/. This is the element "scratch" or local variable common block. See Section 6.8.3.5.2, paragraph 3(e).
   d. /MATIN/ and /MATØUT/. Input and output blocks for MAT.
4. Same as No. 4 in Section 6.8.3.5.2.
5. Same as No. 5 in Section 6.8.3.5.2.
6. Same as No. 6 in Section 6.8.3.5.2.
7. Use subroutine DS1B to perform the insertions (see Section 4.49.8.3). Insert only those six-by-six partitions corresponding to the pivot point.
8. "Lift" as much code as possible for DNEWEL from KNEWEL in SMA1.

6.8.3.11 Piecewise Linear Analysis - Phase 1 (PLA1)

Make the following changes to module PLA1 if the added element is to be admissible to the set of elements for which Piecewise Linear Analysis is defined.

1. Change the computed-go-to statement (on element-type identification number), which reflects whether an element is in the set of elements for which Piecewise Linear Analysis is defined.

2. Add element-dependent code which initializes stress information appended to the ECPT and EST data blocks. The commented code in PLA1 along with the descriptions in Sections 2.3.34.3 and 2.3.34.4 for the ESTNL and ECPTNL data blocks respectively serve as models for the addition of this code.

3. Update the local array, PLAARY. PLAARY(I) = 1 if the I^{th} element type is an element for which Piecewise Linear Analysis is defined, and PLAARY(I) = 0 otherwise.

PLA1 uses the SMA1 module environment so the SMA1 element routines may be called to make contributions to the linear stiffness matrix. Hence all of the common blocks of SMA1 must be available to PLA1. Also the majority of the subroutines, including Block Data program SMA1BD, of module SMA1 must be available to PLA1. The only subroutines of SMA1 not needed are SMA1, SMA1A and DETCK (see Figure 13 in Section 5.2).

6.8.3.12 Piecewise Linear Analysis - Phase 3 (PLA3)

The element interfaces with PLA3 are in two phases. Phase 1, accomplished in subroutine PLA31, reads the ESTNL data block and, for each element, appends displacement vector components corresponding to the grid points of the elements. The output of phase 1 is a scratch file of appended ESTNL data to be processed in phase 2. Subroutine PLA32, the phase 2 driver, reads the scratch file and calls element routines which compute stresses and which update the accumulated stress data in the ESTNL entry.

6.8.3.12.1 PLA31 Changes

Make the following changes to subroutine PLA31:

1. Update the local arrays ESTWDS, which defines the number of words to be read from the ESTNL data block for each element, and NGPTS, which defines the number of grid points for each element. Both arrays are ordered by the internal element-type identification number defined in /GPTABD/ (see Section 6.8.3.3).

2. When appending the components of the displacement vector to the ESTNL element entry, either append the three translational components of displacement at each grid point or append all six components of displacement at each grid point. The default value is three. If six components per grid point are desired, update the logical IF statement between statement numbers 20 and 30.

6.8.3.12.2 PLA32 Changes

Make the following changes to subroutine PLA32:

1. Update the array ESTWDS, as defined in Section 6.8.3.12.1; the array NSTWDS, which defines the number of words per element written on the ØNLES data block; and the array NWDSP2, which defines the number of words per entry in the scratch file. These arrays are ordered by element-type identification number.

2. Change the computed-go-to statement which performs a branch on element-type identification number, and insert a call to the new element routine, PSNEWL.

6.8.3.12.3 Coding the PSNEWL Subroutine

When coding PSNEWL, follow this checklist:

1. Document the element's appended ESTNL entry at the beginning of the routine via comments.

2. Same as No. 2 in Section 6.8.3.5.2.

3. The common block interfaces are:

   a. /PLA32E/. Contains the element's appended ESTNL entry.

   b. /PLA32S/. Scratch block for variables local to PLA3 element routines.

   c. /PLA32C/. Contains two words GAMMA and GAMMAS, corresponding to γ and γ^* defined in Equations 2 and 3 of Section 4.54.

   d. /SØUT/. Contains the computed element stresses in the order expected by ØFP. The first word of /SØUT/ must be the element identification number, which is always the first word in the element's appended ESTNL entry.

   e. /MATIN/ and /MATØUT/. Input and output blocks for subroutine MAT.

4. Perform all arithmetic operations in single precision.

5. Use utility routines MAT, GMMATS, TRANSS, and INVERS.

6. After completion of the computations and prior to returning to PLA32, update the element routine, in the cells assigned to them in /PLA32E/, the new updated stress information. These updated data are used the next time PLA3 is executed.

7. Some of the code in PSNEWEL might be taken from subroutine KNEWEL of SMA1 and subroutines SNEWL1 and SNEWL2 of SDR2.

6.8.3.13 Piecewise Linear Analysis - Phase 4 (PLA4)

PLA4 has two phases. Phase 1, incorporated in subroutine PLA41, reads the ECPTNL data block, and, for each element, appends displacement vector components of the associated grid points. The appended element ECPTNL data are written on a scratch file in a format that is the same as that of the ECPTNL. The phase 2 driver, PLA42, processes the scratch file in a way similar to ECPT processing in SMA1, calling element routines which in turn generate stiffness matrix partitions of the nonlinear stiffness matrix.

6.8.3.13.1 Phase 1 Changes

Make the following changes to subroutine PLA41.

1. Update the local arrays NWØRDS and NGPTS. NWØRDS(I) is the number of words read from the ECPTNL data block for the I^{th} element type, and NGPTS(I) is the number of grid points associated with the I^{th} element type.

2. When appending the components of the displacement vector to the ECPTNL element entry, either the three translation components of displacement at each grid point or all six components of displacement at each grid point can be appended. The default value is three. If six are to be appended, then expand the logical IF statement:

```
IF (ELTYPE. EQ. 34) NWDS = 6
```

located between statement numbers 20 and 30.

6.8.3.13.2 Phase 2 Changes

Make the following changes to Block Data subprogram PLA4BD and subroutine PLA42.

1. Change the /PLA42C/ variables IØVRLY, NWØRDS, and possibly NLINKS in PLA4BD. The explanations in Section 6.8.3.5.1 of the variables of the same names in /SMA1CL/ apply here as well.

2. In PLA42, update the local array NWDSP2, which defines the number of words per element entry to be written on the ECPTNL output data block.

3. Change the computed-go-to statement in PLA42 which performs a branch on element-type identification number, and insert a call to the new element routine, PKNEWL, following this computed-go-to statement.

6.8.3.13.3 Coding the PKNEWL Subroutine

When coding PKNEWL, follow this checklist:

1. Document the element's appended ECPTNL entry at the beginning of the routine via comments.

2. Same as No. 2 in Section 6.8.3.5.2.

3. PKNEWL common block interfaces are:

   a. /PLA42C/. The first word, NPVT, is the pivot point. The next two words are the same as GAMMA and GAMMAS in /PLA32C/ (see Section 6.8.3.12.2, paragraph 3(c)).

   b. /PLA42E/. Contains the element's appended ECPTNL entry.

   c. /PLA42D/. Scratch block for variables local to PLA4 element routines.

   d. /MATIN/ and /MATØUT. Input and output blocks for MAT.

4. Same as No. 4 in Section 6.8.3.5.2.

5. Same as No. 5 in Section 6.8.3.5.2.

6. Same as No. 6 in Section 6.8.3.5.2.

7. Subroutine PLA4B performs the insertions (see Section 4.55.8.3). Insert only those six-by-six partitions corresponding to the pivot point.

8. After completion of the computations and prior to returning to PLA42, update, in the cells assigned to them in /PLA42E/, the new updated stress information. These updated data are used the next time PLA4 is executed.

9. Some of the code in PKNEWL might be taken from subroutine KNEWEL of SMA1 and subroutines SNEWL1 and SNEWL2 of SDR2.

6.8.4 Updating the NASTRAN Manuals

Concurrent with coding and check out, update the NASTRAN manuals. Updating will apply to the three principal manuals, Theoretical, User's and Programmer's. If demonstration problems are formally devised, updates to the Report on the Demonstration Problems may be desired. However, only the interfaces with the three principal manuals will be discussed here.

The NASTRAN manuals have been designed to accommodate future additions and modifications. Each major section (e.g., Section 6 of the Programmer's Manual) stands alone with its own page numbers, equation numbers, figure numbers and table numbers, so that new sections can be added without significant disruption. In the following paragraphs, each major section of each of the three manuals will be examined to determine whether or not an update will be necessary.

6.8.4.1 The Theoretical Manual

The major sections in the NASTRAN Theoretical Manual are numbered up to 16. However, some of the sections have been reserved for future development. Although the structural analyst and not the programmer will probably update the Theoretical Manual, the following paragraphs, preceded by major section numbers, identify material that might be updated in that section.

2. No updates. The matrix operations discussed in this section are the system matrix operations routines and not the in-core matrix subroutines used by element routines.

3. Only Section 3.8.4, Element Algorithms for Piecewise Linear Analysis, is an update candidate. The new element may or may not (the membrane elements currently incorporated in NASTRAN are not admissible to piecewise linear analysis) be analyzed in the piecewise linear analysis rigid format.

5. This section is the primary candidate for updating. For existing elements, the discussion in this section falls short of a complete presentation of all the equations implemented in the program. Section 4.87 of the Programmer's Manual contains the complete

equations for each element. Note that neither differential stiffness nor piecewise linear analysis element-dependent material is presented in this section; the former is discussed in Section 7, and the latter in Section 3.8.

7. If the new element contributes to the differential stiffness matrix, a new major subsection must be written.

14. The new element may involve special modeling techniques. If this is the case and the analyst decides it is worthy of note, a new major subsection might be added to Section 14 rather than incorporating the special technique in Section 3.8, 5, or 7.

15. Significant error analyses performed during program development might be incorporated here.

6.8.4.2 The User's Manual

The NASTRAN User's Manual contains seven major sections. The following paragraphs, preceded by major section numbers, identifies material that might be updated in that section.

1. For each element in NASTRAN, Section 1.3 gives the mnemonics for the connection and (if defined) the property card; defines the basic structural and inertia properties of the element; describes the element coordinate system; lists the stresses and forces in the element; and gives diagrams for the element coordinate system and direction of element forces and/or stresses. Update this section.

2. Section 2.4.2 documents each NASTRAN bulk data card with a one-page description. The connection card and, if defined, the property card must be documented. The design of these cards should be one of the initial tasks that the analyst and programmer perform.

3. Section 3 has 13 subsections. Section 3.1 is an introduction, and Sections 3.2 through 3.13 document each of the NASTRAN rigid formats. Section 3.1 does not have to be updated. Subsections 3.i.1 and 3.i.2 (i = 2,3, ..., 13) do not have to be updated. Update subsections 3.i.3 (i = 2, 3, ..., 13) to document the "Bit Positions for the Card Name Restart Table" for the connection and property bulk data cards associated with the new element. If the new element has both lumped and coupled mass matrix options in module SMA2, then update the explanation for the CØUPMASS parameter in Sections 3.i.4 (i = 2, 3, 7, 9, 10) and 3.j.5 (j = 4, 5, 6, 8, 11, 12, 13).

4. If the new element can be plotted, then update the list of element types that can be specified on a SET definition card in the Structural Plotter request packet to reflect the new element's name. This list is in Section 4.2.2.1. Additionally, update the list of labels for element types that are for element-type identification. This list is in Section 4.2.2.3. Update the tables of element-stress item codes and element-force item codes which are keys to what can be plotted with the XYPLØT module. These tables are at the end of Section 4.3.3.

6. If the programmer and analyst find that a general user message related to elements, such as message number 2026 in Section 6.2.3, does not fulfill their needs, they may choose to add a new message to subroutine MSGWRT or USRMSG. If this is the case, Section 6.2.3 must be updated.

7. Assume the new element has the mnemonic NEWEL. Then add the following entries to the NASTRAN Dictionary:

CNEWEL	IB	New element connection definition card
NEWEL	IC	Requests structure plot for all NEWEL elements
PNEWEL	IB	New element property definition card

6.8.4.3 The Programmer's Manual

The NASTRAN Programmer's Manual contains seven major sections. The following paragraphs, preceded by major section numbers, identify material that might be updated in that section.

2. Make the following changes to Section 2:

a. Add the data on the new element connection card, CNEWEL, to the data block description for GEØM2, Section 2.3.2.2.

b. Add the data on the new element property card, PNEWEL, to the data block description for ECT, Section 2.3.2.5.

c. Update the data block description for EST, Section 2.3.8.1.

d. If the new element is defined for piecewise linear analysis, update the data block description for ESTNL, Section 2.3.34.3.

e. If the new element is defined for piecewise linear analysis, update the data block description for ECPTNL, Section 2.3.34.4.

f. Update the element stress and force output data descriptions in Sections 2.3.51 and 2.3.52 respectively.

3. If the material property options currently implemented in subroutine PREMAT, Section 3.4.36, are inadequate for the new element and PREMAT is consequently modified, then update this section.

4. Section 4 contains numerous subsections that must be updated, some extensively. They are:

a. Update the index in Section 4.1.3 to include all the new entry points for element routines coded for SMA1, SMA2, SSG1, SDR2, DSMG1, PLA3 and PLA4.

b. Update Tables 1 and 2 at the end of Section 4.5.

c. Add a subroutine description for the new stiffness matrix element routine, e.g., KNEWEL, to Section 4.27.8.

d. Add a subroutine description for the new mass matrix element routine, e.g., MNEWEL, to Section 4.28.8. (Of course add two descriptions if both a lumped mass matrix and a coupled mass matrix routine are added.)

e. For some elements (e.g., a triangular ring), SSG1 incorporates thermal loading in an element subroutine; for others, entry point TEMPL of subroutine EDTL is used. If a new element routine is coded, add a subroutine description to Section 4.41.11.

f. Add two subroutine descriptions for the new phase 1 and phase 2 stress data recovery element routines, e.g., SNEWL1 and SNEWL2, to Section 4.46.8.

g. For module DSMG1 (Section 4.49):

(1) Update the first paragraph of Section 4.49.7.

(2) If necessary, update indented paragraph 6 in Section 4.49.7.

(3) Add a subroutine description for the new differential stiffness matrix element routine, e.g., DNEWEL, to Section 4.49.8.

h. For module PLA3 (Section 4.54):

(1) If necessary, update the second paragraph of Section 4.54.7.

(2) Add a subroutine description for the new piecewise linear analysis stress data recovery element routine, e.g., PSNEWEL, to Section 4.54.8.

j. For module PLA4 (Section 4.55):

(1) If necessary, update the second paragraph of Section 4.55.7.

(2) Add a description for the new nonlinear stiffness matrix generation element routine, e.g., PKNEWL, to Section 4.55.8.

k. In Section 4.87, Structural Element Descriptions:

(1) Update Table 1.

(2) Add a new subsection, 4.87.15, to describe the equations used in the element routines for all structural modules. This section's introduction stated that it was assumed that a structural analyst has written mathematical specifications for the structural element. The analyst should write these specifications in a format similar to those in Section 4.87, that is, list the ECPT/EST input data; list coordinate system data obtainable from the CSTM data block; define the material property assumptions and data; list the equations common to all element routines; list the equations specific to stiffness and mass matrix generation, thermal and enforced deformation loading, stress and force data recovery, differential stiffness matrix generation, and stress data recovery and stiffness matrix generation for piecewise linear analysis.

5. Update the overlay diagrams in Section 5.2 as follows:

a. Change link 3 to reflect the new element routines in SMA1 and SMA2.

b. Change link 5 if a new subroutine was added to SSG1.

c. Change link 13 to reflect the new element routines added to SDR2, DSMG1, PLA3 and PLA4.

6.8.5 Dummy User Elements (DUM1 thru DUM9)

A capability exists within NASTRAN which permits a user to enter his own element subroutines for purposes of generating stiffness and mass matrix contributions, thermal load contributions and for computation of various stress, force, etc. outputs. Through the use of ADUMi, CDUMi, and PDUMi bulk data cards (i = 1 to 9), he may enter geometry, property and connection data as is done for any other NASTRAN structural element. The difference being that this input data is of a dynamic nature based on the parameters he enters via the ADUMi card.

Thus a user who may have a structural element formulation not found within NASTRAN may through the dummy element capability implement it into NASTRAN with a lot less difficulty than would be the case of adding an entirely new element.

The procedure for utilizing a dummy element is:

1. Create an element stiffness routine KDUMi modeled after an existing routine (e.g., subroutine KRØD) which will compute and output via insertion routines one 6x6 matrix for each connecting grid point with respect to the connected pivot point. (Each connected grid point becomes the pivot point independently, see Section 1.8).

2. If desired, generate a similar routine MDUMi to compute the MASS matrix based on an existing routine (e.g., subroutine MRØD).

3. If desired, generate a routine DUMi similar to an existing routine (e.g., RØD) to compute a thermal load or element deformation load. At present, the user must update subroutine EDTL by adding a call to SSGETD; this may change the parameters in the call to DUMi.

4. If stress and/or force outputs are desired, generate two routines SDUMi1 and SDUMi2 similar to SRØD1 and SRØD2 to compute the stress and/or force outputs.

5. For any of the above routines prepared (KDUMi, MDUMi, DUMi, SDUMi1, and SDUMi2), a "Linkedit" run will be necessary to load these into the NASTRAN executable.

In the design of these element routines the "user programmer" needs to understand the format of the EST table (see Sections 2.3.8.1 and 2.3.8.3).

Note also common block table /GPTA1/. (See Section 2.5.2).

Note also the above sections (see Section 6.8.1 through 6.8.12).

All module code for the basic dummy elements has been provided in modules SMA1, SMA2, DS1, SSG1, and SDR2.

As element routines do not use NASTRAN executive functions, the user programmer should, before attempting a linkedit of his element routines into the NASTRAN executable, do the following:

1. Prepare a "load and go" environment which, e.g., simulates SMA1. This environment would contain a driver routine which would set up interface common blocks to the element routine KDUMi. KDUMi would call a dummy SMA1B insertion routine which might only print the matrices.

2. Prepare similar environments for the thermal and stress data recovery functions.

When the user-programmer feels he has element routines which are modeled correctly with respect to NASTRAN, a linkedit might be performed. Linkedits are in general non-trivial systems-programmer's tasks with large overlay programs, and thus all work possible should be accomplished before this is attempted.

Dummy output formats and headings are provided within NASTRAN. These encompass both real and complex (see Section 2.3.52).

Refer to subroutine descriptions in Section 3 for the following subroutines:

1. GMMATD
2. GMMATS
3. INVERD
4. INVERS
5. PREMAT
6. PRETRS

6.9 PRINTED OUTPUT

The majority of the NASTRAN data scheduled for output are input to the Output File Processor (ØFP) module. This module performs the actual formatting and outputting of the data.

To implement additional output capability in the ØFP, the following ground rules should be observed in designing a data block intended to be input to ØFP for output to the system printer or punch unit.

1. The data block's name, for consistency, should begin with an "Ø".

2. There should be one or more repeating record pairs, where the record pair is of the following form:

WORD	MODE	DESCRIPTION
1	Available for Data	
2	I	Major ID
3	I	Minor ID
4	I	Subcase ID
5		
.	Available for Data	
.		
.		
9		
10	I	Number of words per entry
11		
.	Available for Data	
.		
.		
50		
51	BCD	
.	.	32 Words Title
.	.	32 Words Subtitle
.	.	32 Words Label
146	BCD	

Identification Record

(An odd-numbered Record)

Repeating data entries of the length specified in the preceding record. This record may be null but should exist.

Data Record (An even-numbered Record)

3. The Major ID is formulated depending on the data type as follows.

   a. For a new data type an integer should be selected which equals I, where I is a value one greater than the current number of accepted data types within ØFP.

   b. The Major ID then depends on the data classification

$$\text{Major ID} \begin{cases} \text{I = SØRT1 - Real} \\ \text{1000 + I = SØRT1 - Complex} \\ \text{2000 + I = SØRT2 - Real} \\ \text{3000 + I = SØRT2 - Complex} \end{cases}$$

4. The Minor ID is optional to distinguish subclasses of the Major ID.

With the data block format outlined above, the NASTRAN systems programmer may implement the new data formats within the current ØFP procedure by modeling from any current data type now handled by ØFP. The current ØFP has dynamic formatting for the outputting of entries of the Data Record. However, if the programmer is not familiar with the five level pointer procedure used for the dynamic formatting, it is recommended that he implement logic to explicitly output the Data Record.

ØFP will, without modification, output new data blocks via the table print routine, TABPT.

6.10 PLOTTER OUTPUT

Plotted output in NASTRAN is restricted to three modules: 1) the Structural Plotter (PLØT - see section 4.24); 2) the XY Plotter (XYPLØT - see section 4.69); and 3) the Matrix Plotter (SEEMAT - see section 4.74). Each of these modules uses the NASTRAN plotter software package of utility routines, each of which is individually documented in section 3.4.

6.10.1 Changes to the Plotter Software

In order to add a new plotter to the NASTRAN plotter software, the following must be done: 1) up to four (4) new subroutines (AXISi, LINEi, TYPEi, WPLTi) must be written, where "i" is the internal index of the new plotter (see section 3.1 for the current values of i); and, 2) changes and/or additions must be made to ten (10) existing subroutines (AXIS, FNDPLT, LINE, PLØTBD, SELCAM, SKPFRM, SYMBØL, TIPE, TYPFLT, TYPINT).

Initially, it should be decided which of the four possible new subroutines will be needed for the new plotter. For the most part, three will be the minimum: LINEi, TYPEi, WPLTi. If the new plotter has no typing capability, an existing subroutine, DRWCHR, will be used in place of TYPEi. It is strongly recommended that the calling sequences of any new subroutines be the same as those of their existing counterparts. None of the four possible new subroutines should present much difficulty to the programmer if he uses their existing counterparts as models.

Subroutine AXISi need only be written if the following two conditions are true on the new plotter: 1) lines must be drawn generally as a series of short lines; and 2) there does exist a special plotter instruction permitting the drawing of a horizontal or vertical line without representing it as a series of short lines. Both of these conditions do exist for plotter 3 and may exist for plotter 10. If either one of these two conditions is not true for the new plotter, then LINE should be used in place of AXISi.

Subroutine LINEi is always required. If the new plotter must be put into the line drawing mode before any lines can be drawn, LINE1, LINE2, LINE9 and LINE10 should be used as models. If the new plotter is an incremental plotter, LINE4 should be used as the model. Otherwise, use LINE3 as the model. In addition, LINE1, LINE2 and LINE3 represent lines as series of short lines; LINE9 and LINE10 use only one plot command to draw a line of any length.

Subroutine TYPEi should be written if there is a typing capability on the new plotter. If the new plotter must be put into the typing mode before any lines can be drawn, TYPE1, TYPE2, TYPE9 and TYPE10 should be used as models. Otherwise, use TYPE3 as the model. All characters should be vertically oriented and miniature in size. Each of the model subroutines has three important symbols initialized in a DATA statement: LSTCHR, NCHR and CHAR. LSTCHR is the index of the last legitimate character in the CHAR94 table (see section 2.5) available on the new plotter. NCHR is the number of characters for which the character code on the new plotter differs from the corresponding character code in the CHAR94 table. CHAR is a list of NCHR pairs of indices into the CHAR94 table: $CHAR_{1,j}$ is the index value of the character code which will produce the wrong typed character on the plotter, and $CHAR_{2,j}$ is the index value of the character code which will produce the correct typed character. One further note: some plotters have both a "typewriter" and "single-character typing" mode. The existing TYPEi subroutines use only the "single-character typing" mode. It is strongly recommended that this policy be continued for all new plotters.

Subroutine WPLTi is almost entirely dependent upon the structure of the plot commands for the new plotter. The existing WPLTi subroutines will help the programmer only insofar as the overall logic is concerned. Once the plot command is constructed, it is written using subroutine SWRITE. Some plotters also require special information at the beginning and/or end of each record on the plot tape. If this is the case with the new plotter, WPLT3, WPLT4, WPLT9 and WPLT10 contain the logic necessary to recognize the beginning and/or end of a plot tape record. In addition, all the existing WPLTi subroutines, except for WPLT4, generate fixed-length plot commands. This results in a simpler subroutine and also adapts easier to the computer-independent characteristic of NASTRAN. It is therefore recommended that this policy be continued, if at all possible, for all new plotters.

Of the ten (10) subroutines to which changes and/or additions must be made, changes in six of the ten subroutines are dependent upon a) the internal index of the new plotter; and b) which of the four possible new subroutines have been written. These six (6) subroutines are: AXIS, LINE, SYMBØL, TIPE, TYPFLT and TYPINT. In each there are one or two computed-go-to statements based upon the internal index of the new plotter which will have to be enlarged. Then corresponding statements calling the new subroutines (AXISi, LINEi, or TYPEi) will have to be added. If an AXISi subroutine was not written for the new plotter, subroutine LINE should be called

from subroutine AXIS instead of calling AXISi. If a TYPEi subroutine was not written for the new plotter, then subroutine DRWCHR should be called from subroutines SYMBØL, TIPE, TYPFLT and TYPINT instead of calling TYPEi.

Subroutine FNDPLT relates the external plotter and model names with its internal plotter and model indices. There is a table within this subroutine which reflects this relationship. The programmer need only append the external name of the new plotter and/or an additional model name to an existing plotter, together with the corresponding internal plotter and model indices. In addition, the value of the variable NPLTRS will have to be incremented by one whenever a new external plotter name is added.

Subroutine PLØTBD is a Block Data subprogram. Both the PLTDAT and SYMBLS tables (see section 2.5) must be expanded to reflect the addition of the new plotter. A new 20-word section must be appended to the PLTDAT table reflecting the physical characteristics of the new plotter. The values in this new section must correspond on a one-to-one basis with the values defined for the existing plotters. In addition, the buffer size defined for the new plotter must be a multiple of 60 characters if computer independency is to be preserved. A new 20-word section must be appended to the SYMBLS table. The first "NSYM" values in this new section are indices into the CHAR94 or CHRDRW tables (see section 2.5). These indices represent the special symbols used by the SYMBØL subroutine for the new plotter.

A new section must be added to subroutine SELCAM. The function of the new section varies depending upon the requirements of the new plotter. If the new plotter is a table plotter, a plot command should be generated to stop the plotter so that the operator can prepare for the next plot. If the new plotter is a microfilm plotter, the requested camera must be selected. Some plotters require a special "header" record at the beginning of each plot. If so, it must be generated in this subroutine. Again, the function of this subroutine varies depending upon the requirements of the new plotter, and as a result, the added section is very likely to be entirely plotter-dependent. In addition, there are two computed-go-to statements (based upon the internal index of the new plotter) which must be enlarged to reflect the new plotter.

The last subroutine to which changes and/or additions must be made is SKPFRM. Its function is to skip a variable number of frames on a microfilm plotter, or to skip over the current plot on a drum plotter. If the new plotter is neither a microfilm nor a drum plotter, no new section

is needed. In either case, there is a computed-go-to statement (based upon the internal index of the new plotter) which must be enlarged to reflect the new plotter. If the new plotter is a microfilm plotter, the commands necessary to skip the frame(s) must be added to the subroutine (e.g., plotters 3 and 9). If the new plotter is a drum plotter, then the commands necessary to skip over the current plot must be added to the subroutine (e.g., plotter 4). As with subroutine SELCAM, any added section is very likely going to be plotter-dependent.

Finally, an important word of caution to the programmer must be stated: if the computer and installation independence of the NASTRAN plotter software package is to be maintained, no existing software provided for his computer or installation ought to be used to accomplish the task of adding a new plotter to the NASTRAN plotter software package. This restriction prevents the direct usage of on-line plotters. NASTRAN does provide however for the indirect usage of on-line plotters as described in section 6.10.6.

6.10.2 Changes to the PLØT Module, the Structural Plotter

In order to add a new plotter to the NASTRAN structural plotter module, PLØT, only one subroutine need be altered: PLTØPR. This subroutine generates messages to the plotter operator. Probably the only message which should be added is one to identify the plotter for which the structural plots are being generated. There is a repertoire of other messages in this subroutine which should be general enough to apply to any plotter type. If additional messages are needed, the programmer must remember that the plotter operator is not normally a "programmer type". Hence he will be more apt to respond to messages written in his language than to messages written in programming terminology. In addition, there are several computed-go-to statements based upon the internal index of the new plotter. These will have to be enlarged to reflect the new plotter.

6.10.3 Changes to the XYPLØT Module, the XY Plotter

No changes are required within the XYPLØT module when adding a new plotter. However, a minor change is required in subroutine IFP1XY of the IFP module if and only if the new plotter uses the NASTRAN BCD plot tape, PLT1. If this is the case, the new internal plotter number which is generated by subroutine FNDPLT of the NASTRAN plotter software should be added to the FØRTRAN logical IF statement directly after the following comment in subroutine IFP1XY:

```
C
C  IF MØRE BCD PLØTTERS ARE ADDED EXPAND THE FØLLØWING TEST
C
```

6.10.4 Changes to the SEEMAT Module, the Matrix Plotter

No changes to the SEEMAT module are necessary when a new plotter is to be added since the plotter and model names are communicated to the module through the DMAP calling sequence (see section 4.74).

6.10.5 Use of the NASTRAN Plotter Software in a New Module

There exists in NASTRAN a self-contained computer-independent environment for creating plots on a large number of plotters. Currently three modules use this environment: 1) PLØT, the Structural Plotter; 2) XYPLØT, the XY Plotter; and 3) SEEMAT, the Matrix Plotter. In order for another module to generate plots in this same environment, it is essential that the module writer understand this environment.

The NASTRAN plotting environment can be understood most easily if viewed as being composed of five parts: 1) parameter definitions; 2) parameter initialization; 3) plot initiation; 4) plot creation; and 5) plot termination.

There is one DMAP parameter (passed through blank common) and two named common blocks in the parameter definition section of the NASTRAN plotting environment. The DMAP parameter is PLTNUM, the plot number of the last plot created, and is both an input and output integer value. The two named common blocks, with their symbolic contents, are as follows:

```
CØMMØN/XXPARM/PBFSIZ,MEDIUM,BFRAMS,SKIP(4),XPAPSZ,YPAPSZ
```

where:

PBFSIZ = size of the plot tape buffer (integer)

MEDIUM = medium output request (integer, default value = 2)

$$= \begin{cases} 1 = \text{film only} \\ 2 = \text{paper only} \\ 3 = \text{both} \end{cases}$$

BFRAMS = number of blank frames (on film only) between plots (integer, default value = 1)

XPAPSZ = width of the paper (inches, for table plotters only) to be used (real, default value = 8.5 inches)

YPAPSZ = height of the paper (inches, for table plotters only) to be used (real, default value = 11.0 inches)

```
CØMMØN/PLTDAT/MØDEL,PLØTER,REGIØN(4),AXMAX,AYMAX,XEDGE,YEDGE,SKIP(10),PCNTIN,CNTCHX,CNTCHY,
      SKIP(4),PLTYPE,PLTAPE,SKIP(2),FCNTIN
```

where:

MØDEL = model index of the plotter to be used (integer, default value = 1)

PLØTER = plotter index of the plotter to be used (integer, default value = 3 - the SC 4020 microfilm plotter)

REGIØN = the region of the plotting surface (x_{min}, y_{min}, x_{max}, y_{max}) in which a plot is being created (real)

AXMAX = width of the plotting surface less any borders (real)

AYMAX = height of the plotting surface less any borders (real)

XEDGE = width of the border on the left and right side of the plotting surface (real)

YEDGE = height of the border on the top and bottom of the plotting surface (real)

PCNTIN = number of counts (plotter units) per inch of paper (real)

CNTCHX = the width (includes horizontal spacing between characters) of each printed or drawn character (real)

CNTCHY = the height (includes vertical spacing between characters) of each printed or drawn character (real)

PLTYPE = plotter type (integer)

$$= \begin{cases} \pm 1 = \text{microfilm plotter} \\ \pm 2 = \text{table plotter} \\ \pm 3 = \text{drum plotter} \end{cases}$$

$$= \begin{cases} <0 \text{ if no typing capability exists on the plotter.} \\ >0 \text{ if typing capability does exist on the plotter.} \end{cases}$$

PLTAPE = GINØ file name of the plot tape (BCD)

$$= \begin{cases} \text{PLT1 for an even parity plot tape} \\ \text{PLT2 for an odd parity plot tape} \end{cases}$$

FCNTIN = number of counts (plotter units) per inch of film (real, FCNTIN = PCNTIN if the plotter is not a microfilm plotter)

The usage and initialization of each of the variables listed above are detailed in the following descriptions of the four remaining sections of the NASTRAN plotting environment (see section 2.5 for a more detailed description of /XXPARM/ and /PLTDAT/).

The parameter initialization section of the NASTRAN plotting environment involves initializing all the variables listed above for the /XXPARM/ and /PLTDAT/ named common blocks, with the exception of MEDIUM and BFRAMS. First, the plotter and model indices (PLØTER, MØDEL) of the plotter to be used must be set by using subroutine FNDPLT:

CALL FNDPLT (PLTTER,MØDELN,PLTID,MØDID)

where:

PLTTER = plotter index of the plotter specified in PLTID and MØDID (integer, output)

MØDELN = model index of the plotter specified in PLTID and MØDID (integer, output)

PLTID(2) = 8 character name (4 characters per word, left-adjusted, with all remaining characters blank) of the plotter of interest (BCD, input).

MØDID(2) = model identification of the plotter of interest. $MØDID_i$ may either be numeric or BCD, depending upon the way in which various models are identified for the plotter of interest. If $MØDID_i$ is BCD, it must be 4 characters, left-adjusted, with all remaining characters blank. (Integer and/or BCD, input and output).

See section 3.1 for a list of current plotter and model names.

Subroutine FNDPLT will attempt to match PLTID with an internal list of plotters available in the NASTRAN plotting environment. If no match is found, FNDPLT sets both PLTTER and MØDELN = 0 and immediately returns. Otherwise, FNDPLT will attempt to match MØDID with an internal list of models for the plotter of interest. If no match is found, a default model for the plotter is stored in MØDID. Then the corresponding plotter and model indices are stored in PLTTER and MØDELN. Generally, PLTID and MØDID will be provided by the NASTRAN user. It is suggested that the module writer set MØDID(1) and MØDID(2) equal to zero before inserting the user supplied values for MØDID. This provides the user with the capability of defaulting to a standard default model for his specified plotter by supplying no values for MØDID or by supplying a value only for MØDID(1).

Having called subroutine FNDPLT to determine the plotter and model indices, the module writer should then set PLØTER and MØDEL equal to PLTTER and MØDELN, respectively:

PLØTER = PLTTER

MODEL = MØDELN

Next, the remainder of the /PLTDAT/ named common block must be initialized. Subroutine PLTSET must be used to do this. PLTSET sets all the variables in /PLTDAT/, except MØDEL and PLØTER, to values dependent upon the plotter index (PLØTER). In addition, if the plotter is a table plotter, AXMAX and AYMAX are also functions of the paper size (XPAPSZ, YPAPSZ). For this reason, if the current or default paper size is to be changed, it must be done before calling PLTSET. Finally REGIØN is initialized in PLTSET as follows:

```
REGIØN(1) = 0.
REGIØN(2) = 0.
REGIØN(3) = AXMAX
REGIØN(4) = AYMAX
```

and the plot tape buffer size (PBFSIZ) in the /XXPARM/ named common block is initialized.

This completes the parameter initialization section of the NASTRAN plotting environment. The next step is plot initiation. Once this step is initiated, none of the parameters in either the /XXPARM/ or /PLTDAT/ named common blocks may be changed, except for MEDIUM, BFRAMS and REGIØN, without repeating the parameter initialization step.

In the plot initiation step, the module writer must first ensure that the plot tape (PLTAPE) is indeed a physical tape. This can be done by using logical function TAPBIT. If the function result is .FALSE., the plot tape is not a physical tape and hence no plotting should be attempted by the module:

```
IF (.NØT.TAPBIT(PLTAPE)) "no physical tape setup"
```

Having verified the existence of a physical plot tape, an array of PBFSIZ words must be provided for the NASTRAN plotting software as follows:

```
CALL SØPEN ($n,PLTAPE,BUFFER,PBFSIZ)
```

where:

n = FØRTRAN statement number to which SØPEN is to return if PLTAPE has not been correctly initialized.

BUFFER = an array of PBFSIZ full words.

Next, the plotter must be started. However, before doing this, the plot number (PLTNUM) should be incremented by one. In addition, this is the module writer's last opportunity to change the medium request (MEDIUM) and the number of blank frames between plots (BFRAMS). To start the plotter, the module writer must call subroutine STPLØT:

CALL STPLØT (PLTNUM)

Subroutine STPLØT will select the proper medium (if appropriate), generate an identification plot (if necessary), and insert the specified number of blank frames (on film only).

Having initiated a plot, the module writer must then create the plot. In the plot creation section of the NASTRAN plotting environment, there are seven (7) subroutines provided for various tasks: AXIS, LINE, PRINT, SYMBØL, TIPE, TYPFLT, TYPINT. An explanation of the calling sequence and purpose of each of these subroutines exists in section 3. It is essential that the module writer familiarize himself with the calling sequences and purposes of these subroutines. In addition, it is just as essential that he also understand a certain amount of the philosophy which exists in these subroutines as a class. What follows is an attempt to explain this philosophy, together with pertinent suggestions.

There are three operating modes defined in these seven subroutines: 1) axis mode; 2) straight line mode; and 3) typing mode. These three modes are totally independent of each other and are mutually self-exclusive. What this actually implies is that only one mode can be active at any one point in time. Subroutine AXIS operates in the axis mode; subroutine LINE operates in the straight line mode; and subroutines PRINT, SYMBØL, TIPE, TYPFLT and TYPINT all operate in the typing mode.

Each of these subroutines has a common argument, which is always the last argument in each of the calling sequences. This argument (ØPT) is used to initiate a mode (ØPT=-1), operate within a mode (ØPT=0), or terminate a logical subset of plot commands within a mode (ØPT=+1). Only while operating within a mode (ØPT=0) do any of the other arguments in a calling sequence have any meaning. For this reason, it is usually a good practice to use zeros for the other arguments when initiating a mode or when terminating a logical subset of plot commands.

It is strongly recommended that the set of all commands used to create a plot be grouped into logical subsets of commands, with each subset operating in only one of the three possible modes.

This does not mean that all axes or all lines or all typing be included in one subset of commands. In many cases it is more logical to create several subsets of axis commands or straight line commands. The module writer must call one of the subroutines which operates within the same mode, with ØPT=-1, so that the mode will be properly initiated. It is then recommended that, following such a subset of commands, the module writer again call one of the subroutines which operates within the same mode, with ØPT=+1, to terminate the subset of plot commands. An example of these recommendations is as follows:

```
CALL TIPE (0,0,0,0,0,-1)

CALL PRINT (.....,0)
    :

CALL TIPE (.....,0)
    :

CALL SYMBØL (.....,0)
    :

CALL TYPFLT (.....,0)
    :

CALL TYPINT (.....,0)
    :

CALL TIPE (0,0,0,0,0,+1)
```

Generally, the module writer should avoid constantly changing plot modes. This is suggested for two reasons. First, some plotters operate very inefficiently in a mode switching environment. Second, should an error exist in either the software or hardware, it might be necessary to dump the generated plot tape. Interpreting this dump would generally be no easy task. However, if the idea of creating subsets of commands was used in generating the plot tape, the task of locating the command(s) causing the problem(s) would be eased considerably in most cases.

All the subroutines used in creating a plot require that at least one of the arguments be the location of a point on the plotting surface. In each case, the point(s) must be specified as real

numbers already scaled to the plotter units. There is no general recommendation as to when this scaling should take place. In some cases, it would be more logical to perform all the scaling at once. In other cases, it would be more logical to perform the scaling on each subset of plot commands. While in other cases, it would be more logical to perform scaling only on an as-needed basis. The choice is left entirely to the discretion of the module writer. Since AXMAX and AYMAX in the /PLTDAT/ named common block define the width and height of the plotting surface in plotter units, and since the plotter origin can always be assumed to be in the lower left corner of the plotting surface, the required scaling ought to be a relatively easy task.

The lower left corner of the plotting surface is always at (0.,0.), while the upper right corner of the plotting surface is always at (AXMAX,AYMAX). These are also the default values of REGIØN (see the /PLTDAT/ named common block) as set by the PLTSET subroutine. The purpose of the REGIØN parameters is to define a rectangular plotting area, outside of which no plotting is to be attempted. For this reason, each of the seven subroutines used in creating a plot always compares the point(s) specified in the calling sequence with the REGIØN values. No portion of any line or axis will be drawn outside the corresponding rectangular plotting area. Nor will any typing be attempted outside this same area. The usage of these REGIØN parameters is left to the discretion of the module writer and the requirements of the module design. In most cases, the default values of REGIØN will not be altered by the module. One situation in which the REGIØN parameters will be altered is when the user has the capability of specifying that a plot is to be drawn only within a specific portion of the total plotting surface and that any part of the plot which appears outside this area is not to be drawn. In any case, if the REGIØN parameters are altered within the module, this can be done at any time on an as-necessary basis.

Having created the desired plot in the plot creation step, the only remaining task for the module writer is terminating the plot. This is a very simple task, accomplished by calling STPLØT:

```
CALL STPLØT (-1)
```

This subroutine, which was also used to initiate the plot, upon sensing a negative argument, will terminate the current subset of plot commands, skip to a new frame (if appropriate), and write an end-of-file mark on the plot tape (if necessary).

If additional plots are to be created within the same module, the entire process just described must be repeated, starting with step 3 (plot initiation). If, however, a new plotter is specified for the succeeding plots, step 2 (parameter initialization) must also be repeated. If a new paper size is specified, subroutine PLTSET must be re-executed prior to repeating step 3.

This concludes the description of the NASTRAN plotting environment. There are two other sections in the NASTRAN Programmer's Manual which deal with this environment. It is suggested that the module writer read these sections also so that he may acquire more of an understanding of the NASTRAN plotting environment than this section affords him. These other sections are: Changes to the Plotter Software, section 6.10.1, and NASTRAN General Purpose Plotter, section 6.10.6.

6.10.6 NASTRAN General Purpose Plotter

One feature which the NASTRAN plotting software lacks is the capability of direct usage of the plotting equipment attached on-line to a computer. This is due not to special purpose programming, but rather to one of the basic characteristics of NASTRAN: computer independence. To access on-line plotters would not only make NASTRAN computer-dependent, but probably installation-dependent also. This installation dependency would result from the necessity of using special subroutines provided by the computer installation to access the on-line plotter, with no guarantee that subroutines having the same name and calling sequences would be available at any other computer installation. Even so, there would almost certainly occur a subroutine naming conflict, due to the great number of subroutines in NASTRAN.

An effort is made in NASTRAN to partially overcome this deficiency. In general, NASTRAN will produce a plot tape which can be used directly by any one of several off-line plotters. In addition, NASTRAN can be directed by the user to produce a so-called "General Purpose Plotter" tape. Another program, completely external to NASTRAN, would then have to exist, its function being to translate this "plot" tape for the on-line plotter so that it will produce the plots intended by NASTRAN. This implies that in order to produce a NASTRAN plot, two programs must be run: first, NASTRAN itself; and then the external translator program.

The purpose of this section is to explain the characteristics and construction of the "NASTRAN General Purpose Plotter" tape, so that a programmer will be able to write a program to translate this "plot" tape for the on-line plotter. Understanding the overall logic used by the NASTRAN plotter software package in producing a plot tape will simplify the task of writing this translator program. It is therefore recommended that the programmer familiarize himself not only with this section of the Programmer's Manual, but also with sections 6.10.1 and 6.10.5, which describe the technique of adding a new plotter to the NASTRAN plotting software package.

The "NASTRAN General Purpose Plotter" tape is composed of a simple set of elementary plot operations, which can easily be deciphered by a FØRTRAN program on any digital computer. As each operation is deciphered, the translator program should direct the on-line plotter to appropriate action. This would normally be done by using the installation software to interface between the translate program and the on-line plotter. With the existence of this external translator program, NASTRAN would then have the capability of indirectly referencing the corresponding on-line

plotter. A by-product of this environment is the implied capability of indirectly accessing any plotter, whether on-line or off-line, assuming the appropriate external translator programs are written.

The "NASTRAN General Purpose Plotter" tape is a seven-track, odd parity, fixed-length record tape. An end-of-file mark follows the last plot only. Each record is composed of 300 six-bit unsigned integers (75 words on an IBM S/360, 50 words on an IBM 7094 or Univac 1108, 30 words on a CDC 6600) and is composed of 10 plot commands, each being composed of 30 six-bit unsigned integers (15 half-words on an IBM S/360, 5 words on an IBM 7094 or Univac 1108, 3 words on a CDC 6600). Not all plot commands will have useful information in all 30 six-bit integers. Some commands use only two of the 30 six-bit integers, while others use 22. The general format of each command is as follows:

$$PCR_4R_3R_2R_1R_0S_4S_3S_2S_1S_0T_4T_3T_2T_1T_0U_4U_3U_2U_1U_0 00000000 \ ,$$

where:

P = plot command,

C = control index,

R_i = decimal digit of an integer called R,

S_i = decimal digit of an integer called S,

T_i = decimal digit of an integer called T,

U_i = decimal digit of an integer called U,

0 = zero.

The plot command is a six-bit integer, any one of seven (7) possible plot commands, as follows:

0 = no operation,

1 = start new plot,

2 = select camera,

3 = skip to a new frame,

4 = type a character (may also = 14),

5 = draw a line (may also = 15),

6 = draw an axis (may also = 16).

The control index is also a six-bit integer. It may be a pen number, a line density, a camera number, or a pointer into a list of characters and symbols. The four integer values (R,S,T,U) specified in a command must be reconstructed by the external translator program. Each integer value is represented in the command as follows:

$$d_4 d_3 d_2 d_1 d_0 \ ,$$

where the original integer value is given by:

$$d_4 10^4 + d_3 10^3 + d_2 10^2 + d_1 10^1 + d_0 10^0 \ .$$

The significance of each of the four integer values (R,S,T,U) may vary from one plot command to another.

The no-operation (0) command is simply a padding for plot records which may otherwise have been less than 300 characters long. All 30 characters of this command will be zero.

The start-new-plot (1) command will always be the first command introducing each new plot. The first integer (R) will be the plot number. The second and third integers (S and T) are the maximum x and y values specified in any other command for this plot. The minimum x and y values are always zero and are therefore not specified in the start new plot command. If necessary, the translator program can use these maximum x and y values to scale subsequent integer values so that the plot will not exceed the limits of the plotting surface. The plot number is included because some plotters require the plot number as part of the first command for each new plot. In addition, if the receiving plotter is a table plotter, the translator program should issue a command to the plotter which will stop it so that the plotter operator can change the paper. If the plotter is a drum plotter, the translator program must skip a sufficient amount of paper to insure that the previous plot will not be over-plotted. And if the receiving plotter is a microfilm plotter, nothing else need be done.

The select-camera (2) command uses only the control index (C). The remaining 28 characters are always zeros. This command is meaningful only on a microfilm plotter having both film and hardcopy output. The control index is the camera or medium request number: 1 = film only; 2 = hardcopy (paper) only; and 3 = both. Upon receiving this command, the translator program should issue a command to the receiving plotter selecting the requested camera or output medium,

then this command should be ignored.

The skip-to-a-new-frame (3) command also uses only the control index. The remaining 28 characters are always zeros. This command is meaningful only on a microfilm plotter. The control index is the camera or output medium request number: 1 = film only; 2 = hardcopy (paper) only; and 3 = both. The appropriate camera will have already been selected in a previous select-camera command. The only reason the camera number is included in this command is because some microfilm plotters require the camera or output medium to be specified in both a select camera and skip frame command. Upon receiving this command, the translator program should issue a command to the receiving plotter to skip to a new frame. If the receiving plotter is not a microfilm plotter, then this command should be ignored. Note: at least one skip-to-a-new-frame command will appear after each start-new-plot command and before the next start-new-plot command.

The type-character (4), draw-line (5), and draw-axis (6) commands will always occur in sets, i.e., a set of type-character commands, a set of draw-line commands, a set of draw-axis commands. There may be more than one set of each type of command, but within a set the commands will all be of an identical type. This is done because on some plotters it is very inefficient to frequently change modes (e.g., typing mode, line drawing mode) of operation. The plot command of the first command in a set will always = 10 + the basic plot command value, i.e., type-character = 14; draw-line = 15; and draw-axis = 16. In all subsequent plot commands in the set, the plot command value will always equal the basic plot command value.

For a type-character command, the control index is a pointer into a specific list of characters and special symbols. The list of characters to which the pointer applies is Section I of the CHAR94 table (see section 2.5), with the following exceptions: 48 = dot, 49 = circle, 50 = square, 51 = diamond, 52 = triangle (point up). The first two integer values (R and S) in the plot command represent the x and y coordinates of the point on the plotting surface at which the center of the character or symbol should be typed. The remaining 18 characters of the command are always zeros. Upon receipt of a type-character command, the translator program should issue a command to the receiving plotter to type the requested character or special symbol at the specified point. Of course, there is no guarantee that all the possible characters and special symbols can be typed by the receiving plotter. If any character or special symbol cannot be typed by the receiving plotter, the translator program will then have to make a substitution or not type the character at all.

For a draw-line command, the control index is either a pen number (for table and drum plotters) or a line density (for microfilm plotters). If the receiving plotter is a microfilm plotter, it is recommended that the translator program simply draw the line as many times as is indicated by the line density value, rather than using any special density settings available on the plotter hardware. The first two integer values (R and S) represent the x and y coordinates of the starting point of the line. The next two integer values (T and U) represent the x and y coordinates of the ending point of the line. The last 8 characters of the command are always zeros. Upon receipt of this command, the translator program should issue a command to the receiving plotter to draw the line. Note: some plotters require that a line be broken into a series of short lines. If this is the case on the receiving plotter, the translator program will have to accomplish this task unless the installation software makes provision for this automatically.

The draw-axis command is identical to the draw-line command. The only difference is in the orientation of the drawn line. The line drawn by a draw-axis command will always be either horizontal or vertical. For most plotters, the translator program will handle this command just like a draw-line command. However, some plotters which would ordinarily require that lines be broken into a series of short lines, may have a special command available to draw a horizontal or vertical line of any length. For these few plotters only will this command have any special significance in the translator program. If such is the situation, the translator program, upon receipt of this command, should issue a command to the receiving plotter to draw the axis. Otherwise, the translator program should simply issue a command to the receiving plotter to draw a line representing the axis.

6.11 ADDITION OF A NEW LINK

Links can be added to the NASTRAN system with little effort if the total number of links does not exceed fifteen (15). There are at present thirteen (13) links. Links are numbered consecutively, and this should be maintained. If the total number of links must exceed 15, Executive System changes to increase the link limit will be required. These Executive System changes are described in section 6.11.5.

It is assumed that the reader is familiar with the other alternatives for adding new material to the system (section 6.2 through 6.10), and that a new link is normally needed only if the addition of new modules to a present link makes that link non-executable because of an excess of overlay structure or decks. In this case, the programmer generates a new link through the following steps (assuming the link limit is not exceeded):

1. Decide what modules to include in the new link.
2. Add any new modules to the MPL Executive table (see section 2.4.2.2) in deck XMPLBD.
3. Generate a new Link Specification Table and a new link driver.
4. Subsys (create an absolute element of) the new link.

6.11.1 Modules to Include

The following entry points of Executive modules must be included in each new link: XCHK, XCEI, XSAVE, XPURGE, XEQUIV, XSFA and QPARAM. The following non-root segment subroutines must be included in each new link: MSGWRT, USRMSG, BTSTRP, ENDSYS and XEØT. The following DMAP output modules should be included in each new link: TABPT, MATPRN and PRTPARM. Diagrams for the IBM 7094/7040(44) DCS overlay structures for all these routines can be found in section 5.2.9. The addition or use of any other module is at the discretion of the NASTRAN systems programmer. Any existing NASTRAN module can be included in the new link if it is so desired.

6.11.2 Addition of New Modules

All new modules must be added to the MPL Executive table (see section 2.4.2.2). Once this is done, the new MPL needs to be added to the present NASTRAN system before proceeding to generate a new Link Specification Table and a new link driver. The new modules need not be present in the system, but their entry points in the MPL must be in the system.

6.11.3 Generation of a New Link Specification Table and a New Link Driver

The addition of a new link requires that: a) the Link Specification Table, LNKSPC, (see section 2.4.2.7) be updated; and b) a new XSEMi deck (see section 3.3.7), which will be the main program for the new link, be generated.

The FØRTRAN code, in punched card form, necessary to accomplish both of the above tasks can be produced automatically in a NASTRAN run using a LNKSPC update deck as indicated below.

6.11.3.1 Link Specification Table Update

To update the Link Specification Table the user must insert a LNKSPC update deck after the Bulk Data Deck in a NASTRAN run. The processing of a LNKSPC update deck is initiated by logical "sense switches" on a DIAG card in the Executive Control Deck (see explanation below); hence no special header card is required in the LNKSPC update deck. The format of each card of the LNKSPC update deck is as follows:

$$\alpha \quad \beta \quad L_1, \ldots, L_n$$

where

α = Module DMAP name (1 to 8 characters)

β = { Entry point name (1 to 6 characters)
"(NØNE)" (6 characters) if there is no entry point name

$L_1, \ldots, L_n$ = zero or more integers, specifying all links the module resides in.

The α, β and L_i fields must be separated by at least one blank or one comma. An example of a card in a LNKSPC update deck is

```
CHKPNT      XCHK      1,2,3,4,5,6,7,8,9,10,11,12,13,14
```

At present the Executive module CHKPNT with entry point XCHK is in links 1 to 13; the above card will add it to a new link 14. Be sure to include all the other Executive modules in any new link. Cards in this format are repeated until all the modules in the new link have been named. The end of the LNKSPC update is specified by the following card:

```
ENDDATA
```

The following logical sense switches, set by a DIAG card in the Executive Control Deck, must be used to process the LNKSPC update deck:

1. Logical sense switch 29 allows the LNKSPC update deck to be processed.
2. Logical sense switch 28 causes the new Link Specification Table to be punched.*
3. Logical sense switch 31 causes the new Link Specification Table to be printed.

The following DIAG card within the Executive Control Deck

```
DIAG 28,29,31
```

accomplishes this result.

*This code is for the Block Data subprogram XBSBD, and may be compiled under that name as punched, or altered into the present deck to retain the comments presently in that deck. The latter procedure is recommended.

6.11.3.2 Generating New Link Driver Decks

The FØRTRAN code necessary to make a new link driver deck can be produced by setting logical sense switch 30 and the logical sense switches corresponding to the desired link(s). For example the Executive Control Deck card:

```
DIAG 30,2,14
```

will punch the code for XSEM2 and XSEM14. The FØRTRAN code produced, when altered into the deck "XSEMXX" (see section 3.3.8), will produce the desired XSEMi routine. XSEMXX is the model for the link drivers.

This driver code may be produced in the same run as the code for the Link Specification Table, or this coce may be produced by adding the new XBSBD deck to the user's system and then setting the appropriate sense switches on a subsequent run.

If logical sense switch 30 is set, the program will automatically terminate after satisfying all sense switch requests to punch XSEMi's. In essence, the structural problem submitted is only a dummy needed to start NASTRAN. The user is cautioned to check his DIAG card(s) carefully when logical sense switch 30 is set to be sure only the sense switches corresponding to the desired links are set.

6.11.4 Subsys the New Link

The subsys deck necessary to add a new link will vary with the computing machine (see section 5). The safest way for the NASTRAN systems programmer to develop the subsys deck for the new link is to copy the overlay structure of the necessary routines, which are listed in section 6.11.1, and then add the new functional module(s) to this base. The mechanisms for switching from one link to another already exists in NASTRAN up to 15 links, so that, once the subsys of the new link has been accomplished, NASTRAN will be able to assimilate it.

6.11.5 Increasing the Link Limit

To increase the link limit beyond 15, the following Executive System changes must be made.

1. Increase the size of the NAME array in the /SEM/ common block to the desired link limit. Add the additional link names (e.g., NS16, NS17, etc.) to the NAME array via the DATA statement. The /SEM/ common block is defined in the System Block Data subprogram, SEMDBD.

2. Items MAXLNK, DRVRNM, and LNKEDT, defined in subroutine XGPIBS of Executive Preface module XGPI (see section 4.7), must be updated. Increase the value for MAXLNK in the /XLINK/ common block to the desired link limit. Add the additional XSEMi names (e.g., XSEM16, XSEM17, etc.) to the local DRVRNM array via the DATA statement. Add the additional link numbers (e.g., 16, 17, etc.) to the local LNKEDT array via the DATA statement.

6.12 WRITING A NEW MODULE

The purpose of this section is to draw together material presented throughout the manual from the point of view of the NASTRAN applications programmer (i.e., the programmer assigned to add a new capability to NASTRAN). This section is provided as a guide for the general module writer, and will conclude with a specific example of a simple module.

6.12.1 Summary of NASTRAN Coding Conventions and Terminology

The new NASTRAN applications programmer is typically overwhelmed by the vastness of the system into which he will inject his modifications and additions. In this section, a review of commonly used terminology and coding conventions will be given in an attempt to assist the new programmer and provide a review for the programmer who infrequently works with the system.

A module in NASTRAN is a collection of subprograms which performs a logical set of data processing tasks. A module is executed by the user by writing and executing a DMAP instruction. Modules communicate with other modules and with the NASTRAN Executive System (EXEC) only through:

1. Data Blocks (Tables or Matrices existing as collections of data on a physical storage device)
   a. Input Data Blocks are referenced by the GINØ file reference numbers 101,102,..., corresponding to the position of the data block in the DMAP call statement.
   b. Output Data Blocks are referenced by the GINØ file reference numbers 201,202,..., corresponding to the position of the data block in the DMAP call statement.
   c. Scratch Data Blocks are referenced by the GINØ file reference numbers 301,302,..., corresponding to any arbitrary order the module writer desires.
   d. Note that there are no data blocks which are used for both input and output except the scratch data blocks which exist only internally within the module. An exception is present when a output data block is APPENDed.
2. Parameters (single values)
   a. Parameters may be input, output or both as desired by the module programmer.
   b. Each parameter defined for the module has a type and a corresponding number of computer words as follows:

	Type	Example	No. Words
(1)	Integer	-3	1
(2)	Real	2.9	1
(3)	BCD	BX2	2
(4)	Double Precision	-3.2D0	2
(5)	Complex	(1.3, -4.9)	2
(6)	Complex Double Precision	(6.2D0,0.0D0)	4

c. Parameters are stored in blank common (/ /) in the order defined by the DMAP call statement.

3. Executive System Common Blocks

Several System Common Blocks are accessible to the module programmer. These include parametric values used by various utility routines, FØRTRAN unit definitions, the GINØ buffer length value, and numerous communication areas for various utility routines such as the matrix packing routines. A description of these common blocks may be found in Section 2.

4. Executive System Utility and Matrix Operation Routines

A large number of routines are directly callable by the module programmer. These vary from elementary bit manipulation routines to extremely involved matrix operation routines. Routines which are usable by module programmers are described in Section 3.

The characteristics or properties of all modules are prescribed by the Module Properties List (MPL), a table used by the DMAP compiler XGPI and defined by the Block Data program XMPLBD. The number of input data blocks, output data blocks, scratch data blocks, as well as the number and type of the parameters is defined by the MPL and must be adhered to by both the user when using the module and by the module writer. The properties of a module can be changed only by recompiling XMPLBD.

The subprograms of a module may consist of SUBRØUTINE subprograms, FUNCTIØN subprograms and/or unnamed BLØCK DATA subprograms as desired by the programmer. The main subprogram for the module, however, must be a SUBRØUTINE subprogram without arguments. The name of this subprogram is prescribed by the Link Specification Table which is defined by the BLØCK DATA program XBSBD.

Labeled common blocks may be defined for the module as desired for intra-module communication so long as unique names are chosen. Similarly, the names of all new subprograms must be unique. It is extremely important to remember to close all open GINØ files before executing a RETURN to the Executive System.

The basic GINØ file element is the logical record, which contains an arbitrary number of words of data. A most important non-FØRTRAN feature in NASTRAN is the ability to read and write part of a logical record. An interesting and useful application is the "blast read/write" illustrated below. Let NW be the number of words of working core (open core less GINØ buffers and any other pre-assigned areas) available to the module starting at X(K). If we wish to copy the contents of GINØ file F1 onto GINØ file F2, the following represents the most efficient way since the data is handled in as large as pieces as possible. Assume that both files are open and rewound.

```
10   CALL READ($30,$20,F1,X(K),NW,0,M)
     CALL WRITE(F2,X(K),NW,0)
     GØ TØ 10
20   CALL WRITE(F2,X(K),M,1)
     GØ TØ 10
30   CALL CLØSE(F2,1)
     CALL CLØSE(F1,1)
```

The DMAP name of a data block is not known a priori to the programmer since it is defined at execution time by the user in his DMAP sequence. If the programmer desires to obtain the name of the data block he is processing, he may do so via

```
CALL FNAME(F,NAM)
```

where F is the GINØ file reference identification number (101,203, etc.), and NAM is a two word array into which the name will be stored.

6.12.2 Module Design

Before a module can be written, it must be designed. While the general process of design cannot be formalized, certain NASTRAN rules and conventions can be discussed and illustrated.

A module can obtain input data in three ways: 1) through any of a fixed number of input data blocks, 2) via parameters maintained by the EXEC, and 3) from system common blocks. Thus, the first items to determine are the input data blocks required, their number, and the parameters. A module can only create printed output, output data blocks, or parameters. It may not update system tables. The second item to determine is the number of output data blocks. Only one matrix can be written per output data block, and the format is prescribed. Table data blocks, on the other hand, may be formatted as the module designer pleases. A module may require temporary storage (other than central memory), and hence require scratch files. (These are often required by NASTRAN utility subroutines, such as MPYAD, etc.)

A module can be completely described by the number of inputs, the number of outputs, the number of scratch files, and an ordered list of parameters and their types (integer, real, BCD, double precision, complex single precision or complex double precision). The total number of files required should be less than 26. To be used, a module must be scheduled into a DMAP sequence along with other modules. A primary module design consideration must be the DMAP sequence in which it will function. Items to be considered include: 1) Are all input data blocks available prior to the running of this module? 2) Are the parameter types consistent? 3) Do the formats of the output data blocks agree with the input formats for the modules which will process them?

While the flow of data within a module can be as desired, a few guidelines are given below:

1. Try to use existing utility routines. In other words, try to express operations to be performed as tasks which can be solved by existing subroutines. For this purpose the utility routines of Section 3 can be classified as follows:

Processing Tables

READ	ØPEN
WRITE	CLØSE
FWDREC	FNAME
BCKREC	SØRT
REWIND	BISRCH
EØF	GØPEN
RDTRL	FREAD
WRTTRL	

Printing Output

CØNMSG	MATDUM
SSWTCH	TABPRT
PEXIT	DMPFIL
PAGE	BUG
MESAGE	EJECT

In-Core Matrix Operations

GMMATD	INVERS
GMMATS	PRETRD
INVERD	PRETRS

Processing Data Cards

PRELØC	XRCARD
PRETAB	PREMAT

Processing Matrices (General)

ØPEN	GØPEN
CLØSE	FREAD
FWDREC	BLDPK
RDTRL	PACK
WRTTRL	INTPK
FNAME	UNPACK

Processing Matrices (Operations)

SSG2A	SSG3A
SDR1B	SØLVER
UPART	FACTØR
SSG2B	TRANP1
SSG2C	

Plotting

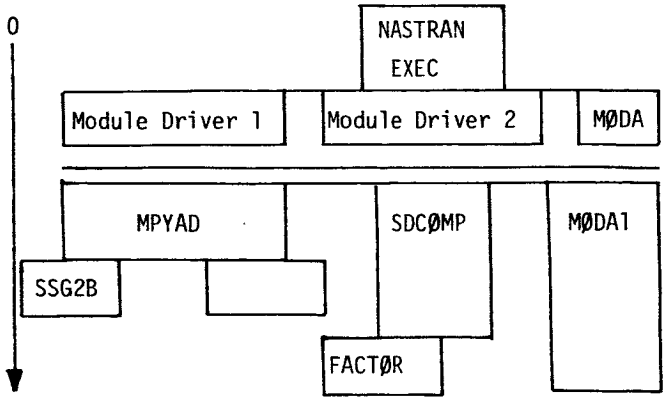
AXIS	STPLØT
SKPFRM	SYMBØL
SELCAM	TIPE
IDPLØT	TYPFLT
LINE	DRWCHR
PRINT	PLTSET
SØPEN	FNDPLT
SCLØSE	

2. Try to limit material held in the central memory to as few items as possible. Thus, matrices should be processed a column at a time, if possible, and tables handled by logical records.

3. Stay within the existing overlay structure. In NASTRAN, certain types of subroutines are grouped together. The existing groupings can be determined by examining the overlay maps in Section 5. In particular, each major matrix operation is grouped by itself. This leads to the concept of a module driver and several subroutines which each call only one major matrix routine. For example, assume a module called MØDA wishes to read data cards, assemble a matrix, multiply this matrix by an input matrix, and decompose the result. It should be organized as follows:

```
Matrix Driver:
     SUBRØUTINE MØDA
     CALL MØDA1(      )   ---    Outputs new matrix.
     CALL SSG2B(      )   ---    Multiplies by input matrix.
     CALL FACTØR(     )   ---    Decomposes matrix.
     RETURN               ---    Back to EXEC.
     END
```

The overlay environment might be as follows:



Note that all matrix routines and all major areas of code are placed in core after all module drivers; therefore, each module driver should be as short as possible. Note that no data can be left in central memory between each part of the module; i.e., all data must be transferred to scratch files, thus freeing a maximum of central memory for each major matrix operation. Note also that the names of each user-generated subroutine should be related to the module name, as indicated in the example.

6.12.3 Implementing the New Module

Actual implementation of the new module can be done in two ways. The simplest way is to pick an existing dummy module (as documented in Section 5 of the User's Manual) which contains at least as many inputs, outputs, scratches, and parameters as needed for the new module. Failing this, the procedures described in Sections 6.11.2 and 6.11.3 must be followed. The new decks must be added to the existing overlay structure through the overlay control language of each particular machine.

The NASTRAN EXEC will (at the proper moment) call the specified entry point to the module. Note that no arguments are allowed. Thus, the new module must start as SUBRØUTINE MØDA, if MØDA is its entry point. The module must conclude with a RETURN statement. Parameters will be placed in BLANK CØMMØN in the order specified in the DMAP calling sequence. Assume the module has three parameters, a BCD value, an integer, and a complex single precision number. They could be referenced as

```
CØMMØN // BCD(2),INTGR,CØMPLX(2)
```

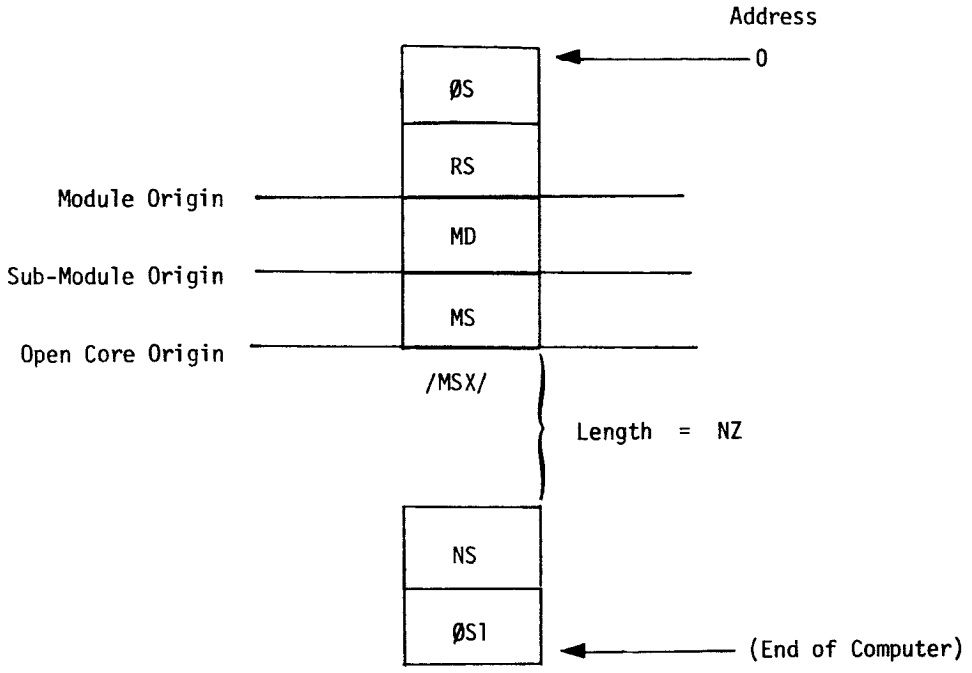
The parameter values may be changed by the module at will, and BLANK common used as the module writer pleases. (Note that BLANK CØMMØN is usually in the root segment, and should be held to 300 words or less.)

6.12.4 Coding a Module Subroutine

The remaining tasks should now be broken into coding individual module subroutines. (It may be possible to code a module which only calls existing subroutines. SCE1 is such a module.) Module subroutines are normal FØRTRAN subprograms written in NASTRAN's limited FØRTRAN subset. Note that bit operations have been added to NASTRAN FØRTRAN via RSHIFT, LSHIFT, ANDF, ØRF, etc. Two major differences are noted by experienced FØRTRAN programmers, open core and I/Ø management. These are treated in subsequent sections.

6.12.4.1 Open Core Coding

A module subroutine can, of course, have normal FØRTRAN arrays and CØMMØN blocks as it pleases, but many items in NASTRAN, such as the size of a matrix or the length of a table, are open ended or variable from run to run. These items must be held in a variable length storage space. Many FØRTRAN programs simply DIMENSIØN an array as large as possible and work within this array. NASTRAN chooses to view this array as starting in a particular CØMMØN BLØCK, the name of which is assigned by each module. This CØMMØN BLØCK is positioned at the first available location within the existing overlay (usually immediately after the particular module subroutine). The module subroutine obtains the length of the array in this CØMMØN BLØCK by calling upon a NASTRAN EXECUTIVE function CØRSZ. The module writer may organize this array as he pleases, as long as he stays within its specified length. Consider the following diagram, which shows a picture of the main memory of a hypothetical computer.

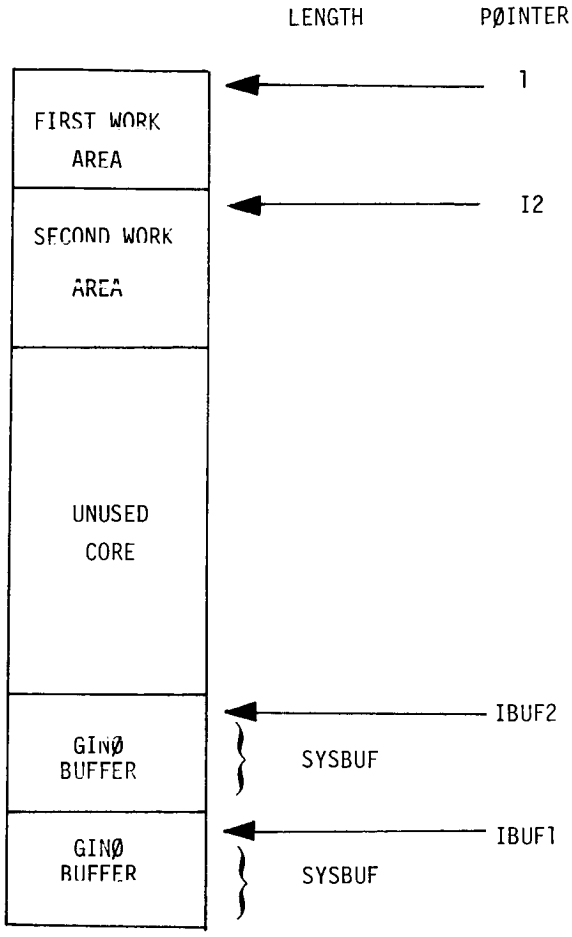


ØS represents the area reserved for the resident Operating System, RS represents the area reserved for the Root Segment of NASTRAN, MD represents the area reserved for the Module Driver, and MS represents the area reserved for the Module Subroutine which is currently executing. /MSX/ is the LABELED CØMMØN BLØCK used by MS to delimit the beginning of the variable array (open core). NS represents the area reserved for the NASTRAN EXEC, and ØS1 represents the remainder of the machine controlled by the operating system. The words of core from /MSX/ to the beginning of NS can be used by module subroutine MS. There are NZ of them.

A typical module subroutine determines the length of open core as follows:

```
INTEGER CØRSZ
CØMMØN  /MSX/IZ(1)
NZ  =  CØRSZ(IZ,IZ)
```

This subroutine might organize the open core as shown below:



Such diagrams are indispensable to module programmers. The programmer would locate items such as the first GINØ buffer by IZ(IBUF1). Such locations can be computed by

```
IBUF1  =  NZ - SYSBUF + 1
IBUF2  =  IBUF1 - SYSBUF
```

The proper length of open core should be checked before any use is made by a statement such as

```
IF(2*NRØW+2*SYSBUF .LT. NZ) CALL MESAGE (-8, 0, NAME)
```

6.12.4.2 I/Ø Management

Data blocks are selected via their GINØ file names. The input data blocks have positional numbers beginning with 101. Thus, data for the fourth input data block can be obtained by referencing GINØ file number 104. Outputs have positional numbers beginning with 201; scratches with 301. A module must close all of its open files before returning to EXEC.

The module writer must supply a buffer to GINØ for each file as he uses it. Supplying this buffer is referred to as opening the file. This buffer should exist in the module's open core. During the time the file is open, this area belongs to GINØ. Do not store in this area. The area may be reused after the GINØ file is closed. The length of this area is given by the value of the first word in the /SYSTEM/ common block.

A typical module subroutine might proceed as follows:

```
SUBRØUTINE MØDA1(INPUT)
INTEGER SYSBUF,CØRSZ
CØMMØN / SYSTEM/SYSBUF,NØUT
CØMMØN / MSX/IZ(1)
NZ = CØRSZ(IZ,IZ)
IBUF1 = NZ - SYSBUF+1
IF(NZ .LT. SYSBUF)  CALL MESAGE(-8 . . .)
CALL GØPEN(INPUT,IZ(IBUF1),0)
  .
  .
  .
Process file
  .
  .
WRITE(NØUT,   )   -----
  .
  .
CALL CLØSE(INPUT,1)
RETURN
END
```

Printed output should be written onto the FØRTRAN unit given by the value of the second word of /SYSTEM/.

All NASTRAN data blocks have a header record, which can be supplied by GØPEN or FNAME, and a trailer, which can be supplied by RDTRL or WRTTRL. Nonzero trailers must be written for all output data blocks and should be written on all scratch data blocks. These trailers are particularly important when processing matrices.

6.12.5 Sample Module Coding

This section will contain the entire FØRTRAN code for a new NASTRAN module. The module is to normalize a matrix to a maximum magnitude of 1.0 in each column. The module will also output the number of rows and columns of the matrix as output parameters.

```
MØDULE NAME = NØRM
Entry Point:  NØRMM
Inputs:        1
Outputs:       1
Scratches:     0
Parameters:    2 - integer - output
DMAP Calling Sequence:
      NØRM   ANYMAT / NØRMMAT / V,N,NCØL / V,N,NRØW $
      SAVE   NCØL,NRØW $
```

The module will be written as a single subroutine (rather than as a module driver/subroutine combination). Note the handling of multiple precision and complex values in open core and the liberal use of comments.

```
      SUBROUTINE NORMM
C
C     THIS IS THE DMAP MODULE NORM WHOSE CALL INSTRUCTION IS
C
C     NORM IN / OUT / V,N,NCOL / V,N,NROW $
C
C     NUMBER OF INPUT DATA BLOCKS        1
C     NUMBER OF OUTPUT DATA BLOCKS       1
C     NUMBER OF SCRATCH DATA BLOCKS      0
C     NUMBER OF INPUT PARAMETERS         0
C     NUMBER OF OUTPUT PARAMETERS        2--INTEGER
C
C     NORM WILL NORMALIZE EACH COLUMN OF AN INPUT MATRIX
C
      INTEGER CORSZ,SYSBUF,MCB(7),NAME(2)
      REAL Z(1)
      DOUBLE PRECISION DZ(1),DMAX,CDZ(2,1),CDMAX
      COMPLEX CZ(1)
      DIMENSION NW(4)
      COMMON /NORMX / IZ(4)
      COMMON /      / NCOL,NROW
      COMMON /SYSTEM/ SYSBUF,NOUT
      COMMON /UNPAKX/ ITC,II,JJ,INCR
      COMMON /PACKX / ITA,ITB,III,JJJ,INCR1
      EQUIVALENCE (IZ(1),Z(1),DZ(1),CZ(1),CDZ(1,1))
      EXTERNAL READ,WRITE
      DATA INPUT/101/,IOUT/201/,NAME/4HNORM,4HM
      DATA NW/1,2,2,4/
C
C     NORM WILL USE OPEN CORE AT IZ
C
C
```

```
C     DETERMINE IF INPUT MATRIX IS PRESENT
C
      MCB(1) = INPUT
      CALL RDTRL(MCB)
      IF(MCB(1).LE.0) GO TO 500
C
C     OUTPUT PARAMETERS
C
      NCOL = MCB(2)
      NROW = MCB(3)
      WRITE(NOUT,10)NCOL,NROW
   10 FORMAT(36H0*** USER INFORMATION MESSAGE ****, ,7HNCOL = ,I10,2H, ,
     *       7HNROW = ,I10)
C
C     ALLOCATE OPEN CORE
C
      NZ = CORSZ(IZ,IZ)
      IBUF1= NZ-SYSBUF+1
      IBUF2= IBUF1-SYSBUF
C
C     CHECK FOR SUFFICIENT CORE TO HOLD AN UNPACKED
C     COLUMN OF THE INPUT MATRIX AND TWO GINO BUFFERS
C
      KW = MCB(5)
      IF(NROW*NW(KW)*2*SYSBUF.GT.NZ)CALL MESAGE(-8,0,NAME)
C
C     OPEN INPUT AND OUTPUT MATRICES
C
      CALL GOPEN(INPUT,IZ(IBUF1),0)
      CALL GOPEN(IOUT,IZ(IBUF2),1)
C
C     INITIALIZE MATRIX TRAILER
```

```
C
      MCB(1) = IOUT
      MCB(2) = 0
      MCB(6) = 0
      MCB(7) = 0
C
C     SET UP FOR MATRIX PACK/UNPACK
C
      ITC = Kw
      INCR = 1
      ITA = ITC
      ITB = ITC
      INCR1 = 1
C
C     LOOP ON EACH COLUMN
C
      DO 100 I = 1,NCOL
C
C     ONLY BRING IN BAND TERMS
C
      II = 0
      CALL UNPACK(INPUT,IZ,READ),RETURNS(80)
C
C     GET READY TO OUTPUT
C
      III = II
      JJI = JJ
      NTERM = JJ-II+1
      GO TO (20,30,40,50),Kw
C
C     FIND MAX -- REAL SINGLE PRECISION
C
```

```
   20 XMAX = 0.0
      DO 22 J = 1,NTERM
      XMAX = AMAX1(ABS(Z(J)),XMAX)
   22 CONTINUE
      IF(XMAX.LE.0.0) GO TO 80
C
C     NORMALIZE
C
      DO 25 J = 1,NTERM
      Z(J) = Z(J)/XMAX
   25 CONTINUE
      GO TO 90
C
C     FIND MAX -- REAL DOUBLE PRECISION
C
   30 DMAX = 0.0D0
      DO 32 J = 1,NTERM
      DMAX = DMAX1(DABS(DZ(J)),DMAX)
   32 CONTINUE
      IF(DMAX.LE.0.0D0) GO TO 80
C
C     NORMALIZE
C
      DO 35 J = 1,NTERM
      DZ(J) = DZ(J)/DMAX
   35 CONTINUE
      GO TO 90
C
C     FIND MAX -- COMPLEX SINGLE PRECISION
C
   40 CMAX = 0.0
      DO 42 J = 1,NTERM
```

```
      CMAX = AMAX1(CABS(CZ(J)),CMAX)
   42 CONTINUE
      IF(CMAX.LE.0.0) GO TO 80
C
C     NORMALIZE
C
      DO 45 J = 1,NTERM
      CZ(J) = CZ(J)/CMAX
   45 CONTINUE
      GO TO 90
C
C     FIND MAX -- COMPLEX DOUBLE PRECISION
C
   50 CDMAX = 0.0D0
      DO 52 J = 1,NTERM
      CDMAX = DMAX1(DSQRT(CDZ(1,J)**2+CDZ(2,J)**2),CDMAX)
   52 CONTINUE
      IF(CDMAX.LE.0.0D0) GO TO 80
C
C     NORMALIZE
C
      DO 55 J = 1,NTERM
      CDZ(1,J) = CDZ(1,J)/CDMAX
      CDZ(2,J) = CDZ(2,J)/CDMAX
   55 CONTINUE
      GO TO 90
C
C     NULL COLUMN --
C
   80 III=1
      JJ1=1
      DO 85 J=1,4
```

```
   85 IZ(J)=0
C
C      OUTPUT NEW COLUMN
C
   90 CALL PACK(IZ,IOUT,WRITE,MCB)
  100 CONTINUE
C
C      CLOSE OPEN FILES
C
      CALL CLOSE(IOUT,1)
      CALL CLOSE(INPUT,1)
C
C      CREATE TRAILER FOR THE OUTPUT DATA BLOCK
C
      CALL WRTTRL(MCB)
      GO TO 900
C
C      HANDLE CASE WHERE INPUT DATA BLOCK IS PURGED BY SETTING OUTPUT
C      PARAMETERS TO ZERO.  OUTPUT DATA BLOCK WILL BE AUTOMATICALLY
C      PURGED BY THE EXECUTIVE SYSTEM SINCE NO TRAILER IS WRITTEN.
C
  500 NCOL = 0
      NROW = 0
C
C      RETURN TO THE EXECUTIVE SYSTEM
C
  900 RETURN
C
      END
```

7.1 INTRODUCTION

In section 3 of this manual, we described NASTRAN subroutines not an integral part of a module. These subroutines were partitioned into three classes: Executive, matrix, and utility. An Executive subroutine is one which is clearly part of the NASTRAN Executive System, i.e., no functional module uses it; a matrix subroutine is one which is clearly dedicated to NASTRAN matrix (data block) operations; all other subroutines are termed utility subroutines.

There exists another class of subroutines, better still, programs that while not actually part of NASTRAN per se, are all important for the smooth functioning of NASTRAN. The programs in this class are called support programs. NASTRAN together with its associated support programs comprise the NASTRAN System of Computer Programs.

Clearly the most important of the support programs is the CDC 6400/6600 Linkage Editor. The development of this Linkage Editor was necessary to insure that there be just one version of NASTRAN. The policy decision that there be just one version of NASTRAN was derived from the criterion that NASTRAN be a day-to-day production tool. This criterion immediately implies a one version, maintainable program. Section 5.6 of this manual describes the usage of the Linkage Editor; section 7.2 describes the programming details of the Linkage Editor.

During the early stages of NASTRAN development, the design team chose a subset of FORTRAN IV to be the "language" of the overwhelming majority of NASTRAN code (less than 1% of the NASTRAN System is in assembly language). Section 6.2 describes this subset. However, the FORTRAN RUN compiler at Langley Research Center and other CDC 6600 series compilers have two major differences in FORTRAN language specifications from the "NASTRAN FORTRAN language." First, NASTRAN FORTRAN allows arguments on the ENTRY statement; CDC FORTRAN does not. Additionally, nonstandard returns in NASTRAN FORTRAN have different formats from that in CDC FORTRAN. Table 1 illustrates this major difference.

To overcome these language differences, the Source Conversion Program (SCP) was developed. The SCP accepts a UNIVAC 1108 NASTRAN source tape and generates a CDC 6600 NASTRAN source tape which, after compilation and link editing, produces an executable NASTRAN system tape that is equivalent to its UNIVAC 1108 (and IBM S/360) counterpart(s). Section 7.3 describes the SCP.

Table 1. Nonstandard return differences.

NASTRAN FORTRAN	CDC FORTRAN
A. MAIN PROGRAM	A. MAIN PROGRAM
.	.
.	.
.	.
CALL SUB1($100,$200,A)	CALL SUB1(A)RETURNS(100,200)
B=A+C	B=A+C
GO TO 300	GO TO 300
.	.
.	.
.	.
100 B=A+D	100 B=A+D
GO TO 300	GO TO 300
.	.
.	.
.	.
200 B=A+E	200 B=A+E
300 .	300 .
.	.
.	.
B. SUBROUTINE SUB1	B. SUBROUTINE SUB1
SUBROUTINE SUB1(*,*,A)	SUBROUTINE SUB1(A)RETURNS(RETURN1,RETURN2)
IF(A-3.5) 10,20,30	IF(A-3.5) 10,20,30
10 RETURN1	10 RETURN RETURN1
20 RETURN2	20 RETURN RETURN2
30 RETURN	30 RETURN
END	END

7.2 DESIGN OF THE CDC 6400/6600 LINKAGE EDITOR

This section describes the design of the CDC 6400/6600 Linkage Editor that was developed to insure that the CDC 6000 version of NASTRAN would be essentially the same as the IBM 360 and UNIVAC 1108 versions. It is assumed that the reader has already read, and is familiar with, section 5.6, which discusses the linkage editor from a user's point of view.

The term "linkage editor" is not used unequivocally in the following pages. In a global sense, the linkage editor system consists of three programs: the linkage editor program which combines and links object decks into a (large) program in which all external references are resolved; the segment loader which loads program links into core as needed (execution-time loader); and the bootstrap program which is loaded by the CDC loader at the beginning of program execution and then transfers to the principal entry point of the program link-edited by the linkage editor. In most instances, we do not differentiate the system from the program, but usually which one is under discussion is clear from the context. The linkage editor discussed in section 5.6 is the program and not the system.

Section 7.2 is divided into 11 subsections. Section 7.2.1 is an introduction describing the purpose of the linkage editor, its relationship to SCOPE, major divisions of the linkage editor, and linkage editor files and organization. Section 7.2.2 describes the major divisions of the linkage editor: the linkage editor tables are discussed; a sample problem is introduced; linkage editor processing is described with regard to the sequence of operations performed (initial processing, control statement processing, object deck processing, address assignment processing; relocation processing, and final processing); then the bootstrap program and the segment loader are discussed. Flowcharts comprise section 7.2.3. Descriptions for linkage editor subroutines are given in section 7.2.4 Section 7.2.5 describes the formats of SCOPE object decks, providing the interface between SCOPE and the linkage editor via the tables in each object deck. Section 7.2.6 describes in tabular form the principal linkage editor variables. Section 7.2.7 shows linkage editor output, describes diagnostic messages and gives a list of programs in LINKLIB. In section 7.2.8, improvements to the Level 2.0 Version (the current Version) of the linkage editor are recommended. Finally, section 7.2.9 gives a glossary of terms unique to the CDC 6400/6600 Linkage Editor.

7.2.1 Introduction

7.2.1.1 Purpose of the Linkage Editor

The linkage editor is a service program designed to be used in association with the RUN compiler to prepare an executable program from symbolic language programs written in FØRTRAN and CØMPASS. Linkage editor processing is a necessary step between source program compilation and object program execution.

Linkage editor processing allows the programmer to divide his program into several parts, each containing one or more control sections. Each part may then be coded in the programming language best suited to it and may then be separately assembled or compiled.

The primary purpose of the linkage editor is to combine and link object decks (the output of the RUN compiler) into a program in which all cross references between control sections are resolved as if they had been assembled or compiled as one program. The program produced by the linkage editor consits of executable machine language code in a format that can be loaded into main storage by the bootstrap program (see section 7.2.1.4.7) and segment loader (see section 7.2.1.4.8).

The main design objective of the linkage editor/loader is to efficiently process and execute unusually large programs that require extensive segmentation (a feature entirely lacking in the existing CDC loader).

In addition to combining and linkage object decks, the linkage editor performs the following functions:

1. Library Call Processing. If unresolved external references remain after the linkage editor processes all input to it, an automatic library call feature retrieves subprograms required to resolve the references.

2. Program Modification. Control sections can be rearranged during linkage editor processing as directed by linkage editor control statements. Common control sections are collected. References to entry points can be altered by control statements.

3. Overlay Processing. The linkage editor prepares programs for overlay by inserting tables (SEGTAB$, ENTAB$, see section 7.2.2.7) to be used by the segment loader during execution.

7.2.1.2 Relationship to the SCØPE Operating System

The linkage editor is not an integral part of the SCØPE operating system. As a result, it is executed as a normal "user" program, i.e., using the facilities of the CDC loader.

The object decks that comprise the linkage editor exist as a card, tape, or disk file and the linkage editor is executed as a normal job step.

The executable program produced by the linkage editor may be in the form of a sequential file on tape or disk or an indexed (random) file on disk. In either case, the initial records of the file contain object decks that comprise the bootstrap program loads the initial portion (Link 0) of the executable program into main storage and optionally writes the remaining links of the executable program. Thereafter, all loading of additional segments of the executable program is controlled by the segment loader which was included in Link 0 by the linkage editor.

In the Level 2.0 version of the linkage editor (the current version), processing is limited to object decks produced by the RUN compiler because of linkage conventions established by that compiler. Reasonably extensive modification of the linkage editor/loader and LINKLIB (see below) is required to process object decks produced by the FTN compiler.

Associated with SCØPE and the RUN Compiler are a number of subprograms which accomplish the primary interface between the user and the resident monitor. These subprograms are a principal input to the linkage editor and reside on a file named LINKLIB. Since the linkage editor is not an integral part of SCØPE, modification of the LINKLIB subprograms is not automatically accomplished with SCØPE updates and remains a maintenance task at each installation.

Linkage editor processing and subsequent execution time loading is dependent on the file concepts and operations as defined and supported in SCØPE 3.1. In particular, changes to the subfields of the File Environment Table (FET) or changes to the object deck format are likely to require modification to the linkage editor and segment loader code.

7.2.1.3 General Description

Input to the linkage editor consists of: a) one or more sequential files (libraries) containing subprograms in relocatable format (object decks) as produced by the RUN compiler, and

b) linkage editor control statements contained in INPUT, the standard input file. The primary function of the linkage editor is to combine these subprograms, in accordance with the requirements stated on the control statements, into a machine-language program suitable for loading into main storage and executing. External references that are undefined after processing all subprograms cause the automatic call mechanism to search for subprograms that will resolve the references. When these subprograms are found, they become part of the executable program.

To produce an executable program, the linkage editor:

1. Assigns relative main storage addresses to the control sections to be included in the program.

2. Resolves references between control sections (translates symbolic references to relative main storage addresses)

3. Collects common sections and assigns a single relative machine address to all sections of the same name. The length of the common section is taken to be the longest length of any individual section.

Figure 1 illustrates an example of linkage editor processing. The executable program produced by the linkage editor contains three portions:

1. A sequence of object decks suitable for loading by the CDC loader. The main program in this sequence, named XBØØT (see section 7.2.2.9), reads the remainder of the program and writes it on the disk as an indexed file (unless the program is already an indexed file). XBØØT reads Link 0 in main storage and passes control to the entry point which initiates execution of the problem program.

2. A sequence of three records which defines Link 0 - a directory record, a symbol dictionary record, and the executable machine language code.

3. A sequence of records for each of the additional links - one directory record per link plus one record containing executable machine language code for each segment in the link.

Link 0 remains in main storage at all times during program execution. Link 0 contains no overlay segments. The linkage editor supplies the segment loader (named XLØADER, see section 7.2.2.10) when Link 0 is constructed. XLØADER accomplishes the loading of segments and links

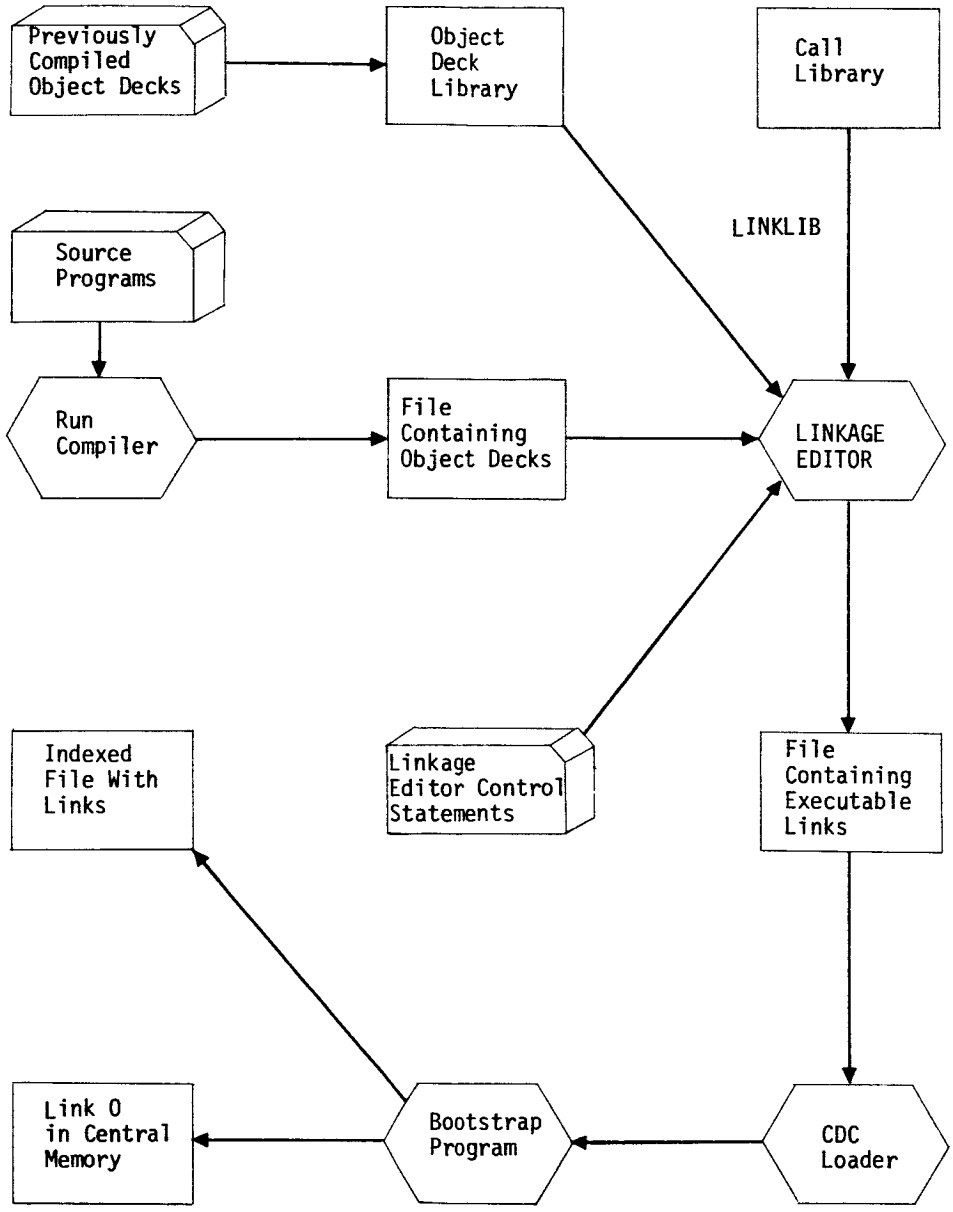


Figure 1. Linkage editor processing.

when requested. Segment load requests are supplied automatically by the linkage editor through tables called ENTAB$ (see Figure 29) which are written as a part of the text (instructions and data) for each segment which may require additional segment loading. An additional table, SEGTAB$ (see Figure 28) which is constructed by the linkage editor as a part of the root segment of every link is used by XLØADER to facilitate segment loading.

Major divisions of a program are links. Each link consists of self-contained overlay structure and might be thought of as a complete program in itself. All routines in a link communicate freely with Link 0 routines. Consequently, Link 0 may be thought of as logically belonging to every link.

7.2.1.4 Major Divisions of the Linkage Editor

7.2.1.4.1 Initial Processing

Initial processing begins when the linkage editor receives control from the CDC loader. After control is received, the following functions are performed:

1. The LINKEDIT card is read, echoed, and converted. Parameters are set based on options selected.
2. Initial allocation of working storage and buffers is made.
3. If the program from a previous linkage editor run is present as a sequential file (INFILE), it is read and written as an indexed file.
4. Each file named on the LIBRARY card is read. Each deck is written on a local disk file named SYSUT2 (indexed file). Subprogram names are saved in a main storage table. For the file named LINKLIB, each of the entry point names is saved in main storage.

7.2.1.4.2 Control Statement Processing

For a link, cards from LINK through END are read and converted. Two passes are made. On the first pass, each card is checked for proper format, content, and order (if important). Various counts are accumulated such as the number of segments, number of regions, number of RENAME cards, etc. The control statements are echoed on ØUTPUT unless this option is suppressed. At the end of the first pass, allocation of working storage is completed. If the currently processed link is not Link 0, the dictionary defining entry point and common block names and address

for Link 0 is read, and entries are made in the General Table (see section 7.2.2.1.9) for each Link 0 name and address.

On the second pass of the control statements, each statement (having been saved in main storage during the first pass) is again converted, and entries are made in various tables depending on the control statement and its contents.

Following the second pass of the control statements, control is passed to LKED025 (see Figure 35, section 7.2.3) to read each of the object decks named on INCLUDE statements plus those subprograms required to satisfy undefined external references.

7.2.1.4.3 Object Deck Processing

The list of subprogram names in each of the named libraries is scanned. For each subprogram which is marked for inclusion, the following processing occurs:

1. The deck is read from SYSUT2.
2. Subprogram (or common block) length is entered in the General Table (GT).
3. Each common block referenced by the subprogram is entered into the GT (if not already present), and the length field is updated. If text (data) for the common block exists, a reference to the defining subprogram is noted.
4. An entry in the GT is created for each entry point of the subprogram. The relative address of the entry point is saved. The number of arguments associated with each entry point is found by searching the TEXT tables (see section 7.2.5) for the conventional identification word. If not found, less than seven arguments is assumed.
5. The LINK table is processed. For each external reference by the subprogram, the GT is checked for an existing entry. If present, a path analysis is made. If the call is not in the path, a call chain entry is created in the GT. If the entry is not present, an entry in the GT is created and a call chain entry is created.

When all object decks have been processed, the automatic call logic is invoked. For each undefined external reference, the list of entry points to LINKLIB is searched. If found, the corresponding subprogram from LINKLIB is included. If not found, an error message is issued.

When all object decks from LINKLIB have been processed, a pass through each of the entries in the GT is made and various checks are made. Call chains are checked, and entries now resolved (in the path) are removed. Remaining entries in the call chains will require facilities of the segment loader, and these entries will form the ENTAB$ tables.

At this point, all information is available to perform assignment of final addresses for the program. Control is passed to LKED050 (see Figure 36, section 7.2.3) for this task.

7.2.1.4.4 Address Assignment Processing

The program computes final storage addresses for all subprograms, entry points, and common blocks in the program by executing the following steps:

1. Lengths for each segment are computed by summing the lengths of each entry (subprogram or common block) in the segment. This information is stored in the Segment Definition Table (see section 7.2.2.1.7).

2. The lengths for each region are computed by finding the longest path in the region and summing the length of all segments in that path.

3. Region lengths are converted to region addresses by summing the region lengths. This information is stored in the Region Definition Table (see section 7.2.2.1.5).

4. Segment addresses are computed by following the paths in each region and summing the previous segment lengths.

5. Finally, addresses for each entry in each segment are computed by tracing the order of each entry in the segment and summing lengths of previous entries.

7.2.1.4.5 Relocation Processing

The final phase for each link consists of building the executable machine language code, performing all necessary relocation of relative addresses.

This is accomplished by executing the following steps:

1. If the current link is Link 0, object decks defining the bootstrap program are copied from LINKLIB to the executable program file (either SYSUT1 or ØUTFILE). A directory record containing link number, number of entries in the Link 0 dictionary, and total length of the

link is written followed by the Link 0 dictionary defining each of the entry points and common blocks and their addresses in the link.

2. If the current link is not Link 0, a directory record containing link number, number of segments, and total length of the link is written as in 1. above.

3. The first entry in the root segment of each link is a table (LINK0$ for Link 0 and SEGTAB$ for any other link). This table is built and written.

4. Executable machine language code is built and written one logical record per segment. Each entry (subprogram or common block) in each segment is examined. If text (for a subprogram) or data (for a common block) is defined for the entry, the object deck containing the text is read from SYSUT2. Address relocation defined in TEXT, FILL, LINK, and REPL tables (see section 7.2.5) is performed, and the relocated text for the entry is written. If no text is defined for the entry, zero words are written.

5. As the relocation of text is being performed, the storage map is printed on ØUTPUT unless NØMAP was selected.

6. Finally, if an ENTAB$ table is defined for the segment, the text for this table is assembled and written as the last entry for the segment.

7. When all segments for the link are complete, the XREF option on the LINKEDIT card (see section 5.6.4.2) is tested. If selected, LKED077 (Figure 37, section 7.2.3) is called to produce a listing of all cross references in the link.

7.2.1.4.6 Final Processing

When processing for all links is complete (the ENDLINKS card has been read from INPUT), the status of ØUTFILE is tested. If ØUTFILE = name(C) was coded, no further processing is required. Otherwise, the executable program exists as a local indexed file (SYSUT1) and it is necessary to write it as a sequential file on the user-requested file. This is accomplished by LKED080 (Figure 38, section 7.2.3). When the link has been copied to ØUTFILE, a message is written on ØUTPUT indicating the event.

7.2.1.4.7 The Bootstrap Program

The bootstrap program is a computer program made up of relocatable routines which are appended by the linkage editor to the beginning of the absolute output of the linkage editor. These routines consist of: a) a dummy Block Data subprogram containing one labeled common block of a length sufficient to hold Link 0; b) the bootstrap program driving routine, XBØØT; c) an input/output utility routine XIØRTNS; and d) MAPFNS, a routine containing miscellaneous utility routines for bit manipulation, field length determination, etc.

The bootstrap program is employed to permit the execution of the absolute output of the linkage editor in a way that requires no special handling of the job and allows the job to appear as any other batch job. It is a small program, loaded by the CDC loader which if necessary reads and outputs to the disk the sequential linkage editor output in a direct access (random) format. The bootstrap program also reads into the locations 77_8+1 through 77_8+N Link 0 (N being its length). This core space is available because the CDC loader has placed the dummy Block Data subprogram there.

Having completed its function, the bootstrap program calls CØMPASS routine XJUMP in, MAPFNS which directs the central processor to jump to location 101_8 in the jobs core, which is in Supermain, and execution then continues from there. Figure 2 illustrates core through the bootstrap process. It should be noted that for the completion of this particular job step, execution of the bootstrap program is no longer required, nor is it available.

7.2.1.4.8 The Segment Loader

The bootstrap program is actually the initial loader of absolute object code as produced by the linkage editor. It does in fact load "Supermain," Link 0. After the bootstrap program directs the central processor to branch into Supermain, and execution proceeds from there, any calls for the loading of a link's root segment, results in an automatic transfer into the segment loader to the entry point LINK. Similarly, any calls to a segment lower in a tree or in another region results in an automatic call into the segment loader to the entry point LØADER.. This type of "downward" call is forced through an entry table ENTAB$ (see section 7.2.2.7) before reaching the segment loader at entry point LØADER..

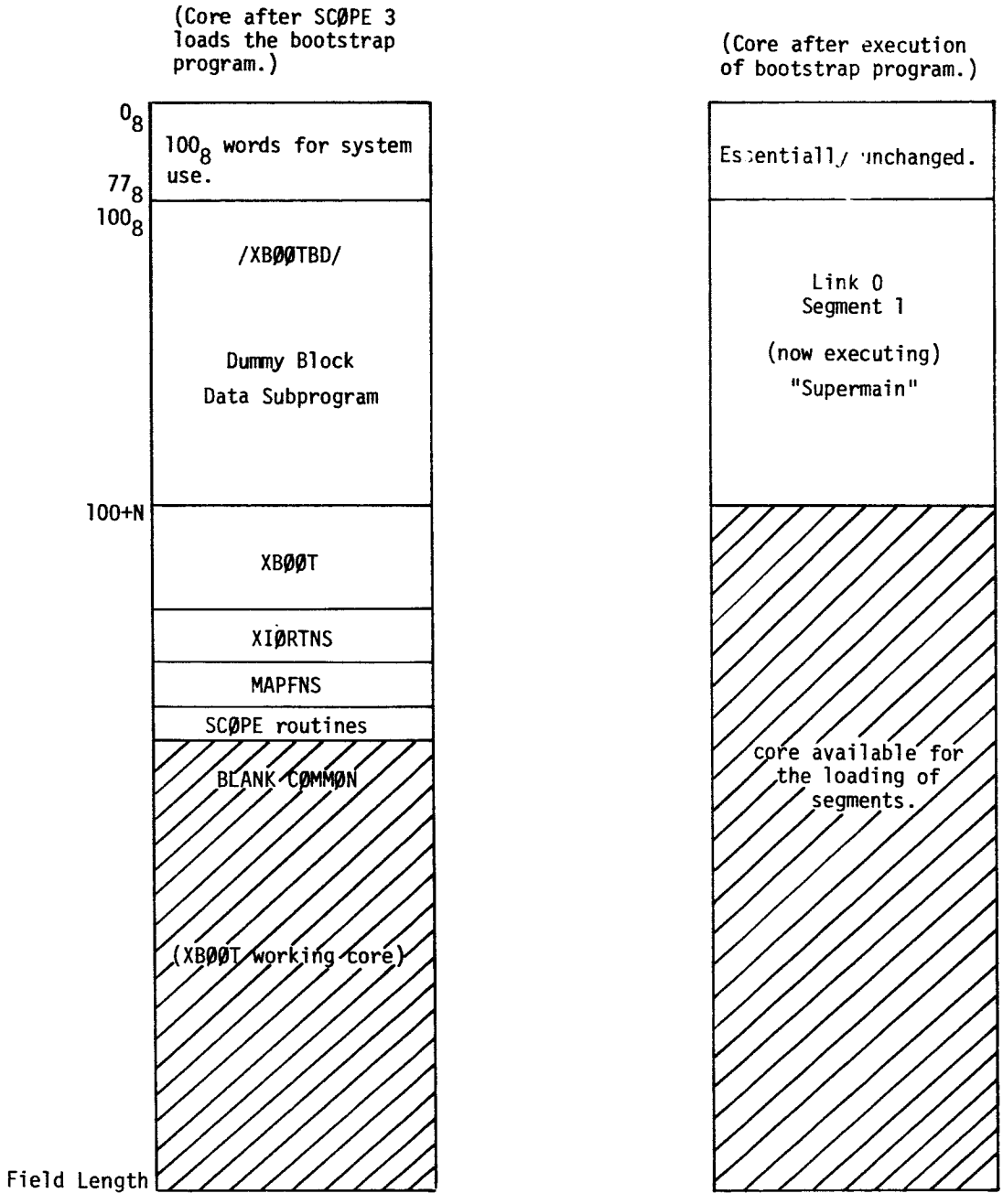


Figure 2. Core before and after execution of the bootstrap program.

Calls made to LINK from any segment, anywhere in core, result in the segment loader first checking the link number for legitimacy. The indexes of relative disk addresses for the segments of the link desired is then read from the disk. A link directory is then read from the disk and further legitimacy checks are made along with a check to insure that sufficient core is available for the loading of the lowest segment of the link.

After successfully completing these tasks, the root segment of the new link is read into core, and a branch is made to its entry point and execution of the program continues.

Downward calls reaching the entry point LØADER. via an ENTAB$ table result in a series of conditional events by the segment loader. The loader first checks to see if the segment to which the call is directed is in core. If the segment is not in core, it is loaded along with any segments above and in its path as required. Once the segment is determined to be in core, any argument addresses over six (which are assigned to B registers B1 through B6 by the RUN compiler generated code) are moved from the ENTAB$ entry and placed in the actual subroutine being called along with the actual branch return. A jump is then made to the desired entry point to complete the automatic loading process. Returns from any called control section are always made directly to the point from which the call was made.

7.2.1.5 Linkage Editor Files

7.2.1.5.1 Input Files

There are three types of files that may be input to the linkage editor. They are:

1. Libraries. All object decks that are to be processed by the linkage editor are contained in libraries. A library is defined to be a sequential file (which may reside on tape or disk) consisting of one or more logical records with one object deck per logical record. The names of the library files are defined on the LIBRARY control statement (see section 5.6.4.2). A file named LINKLIB must always exist for linkage editor processing. LINKLIB contains object decks for automatic library call plus object decks which are required in constructing the initial load portion (bootstrap program) of the executable program. There is no theoretical limit to the number of libraries which may be defined for linkage editor processing. Subprograms of the same name may appear in more than one library or even in the same library. In the latter case, the first such subprogram is included.

2. Control statements. Statements which direct and control processing by the linkage editor are contained as a single logical record on the file named INPUT. INPUT must be positioned to the logical record containing the control statements prior to executing the linkage editor. For a complete description of the linkage editor control statements, see section 5.6.4.

3. Previously link-edited links. This input source is optional and is required only if the user desires to modify an existing link (other than Link 0) or add a new link to the program. The name and status of this file is defined by the INFILE keyword on the LINKEDIT control statement (see section 5.6.4.2). It may be a sequential file on tape or disk or an indexed file on disk.

7.2.1.5.2 Local Files

These may be one, two or three local files generated by the linkage editor during processing. A file named SYSUT2 is always generated. It is an indexed file and contains all object decks from all defined libraries (including LINKLIB). When the file is being generated, a directory of subprogram names as well as a list of all entry points in LINKLIB is extracted and maintained in working storage. If either INFILE or ØUTFILE is declared as a common (indexed) file, then a second local file does not exist (note that if both INFILE and ØUTFILE are declared common files, they must be the same file). Otherwise, a local file named SYSUT1 is generated as an indexed file to contain each of the links as they are constructed. If the XREF option is selected on the LINKEDIT control statement (see section 5.6.4.2), a sequential file named SYSUT3 is written by LKED075 and read by LKED077 (see Figure 37, section 7.2.3). This file contains information regarding calls made by each subprogram and is used by LKED077 to produce a cross reference listing.

7.2.1.5.3 Output Files

There are two files output by the linkage editor. One is a file named ØUTPUT which contains a listing of control statements, messages, a storage map, and a cross reference dictionary. Most items scheduled for ØUTPUT are selectable (or suppressed) by options on the LINKEDIT control statement. The second output file contains the executable program. It may be a sequential file on tape or disk, or an indexed file on disk. Its name and status are defined by the ØUTFILE keyword on the LINKEDIT control statement.

7.2.1.5.4 Input/Output Flow

The flow of information between the files of the linkage editor and the linkage editor phases is illustrated in Figure 3. The general case is shown where both INFILE and ØUTFILE are sequential files. Data flow through SYSUT3 is not illustrated (XREF case only).

7.2.1.6 Organization of the Linkage Editor

7.2.1.6.1 Major Routines

The relationship of the six principal phases (major divisions) of the linkage editor discussed in section 7.2.1.5 is illustrated in Figure 4. If symbol (e.g., a rectangular box) of the flowchart is identified by a symbolic name above and near the left-hand edge of the box, the box represents a subroutine call and the symbolic name is the subroutine name. This convention is also followed in section 7.2.3. Section 7.2.3 gives detailed flow within each of the principal phases of the linkage editor. This processing is executed in FØRTRAN routines whose names are of the form LKEDxxx where $000 \leq xxx \leq 099$. The "main" (in the FØRTRAN sense) program of the linkage editor is LKED. Buffers for FØRTRAN files INPUT and ØUTPUT are located within this program. LKED000 has two functions: a) provide the major flow of control; and b) process the control statements. Communication between routines occurs through named common blocks (see section 7.2.1.6.3) and tables in working storage (see section 7.2.1.6.4).

7.2.1.6.2 Subroutines

Subroutines of the linkage editor are classified in four categories:

1. Major subroutines. These are coded in FØRTRAN and are named LKEDxxx where $100 \leq xxx \leq 299$. In general, these subroutines perform various operations on the tables in working storage. Detailed subroutine descriptions for major subroutines are given in section 7.2.4.1.

2. Linkage editor utilities. These routines are CØMPASS routines whose names are related to the function they perform. They are all entry points in subprograms whose names are of the form LKEDxxx where $300 \leq xxx \leq 399$. Most of these routines perform tasks directly related to the linkage editor such as manipulating the various fields of a table entry. Detailed subroutine descriptions for linkage editor utilities are given in section 7.2.4.2.

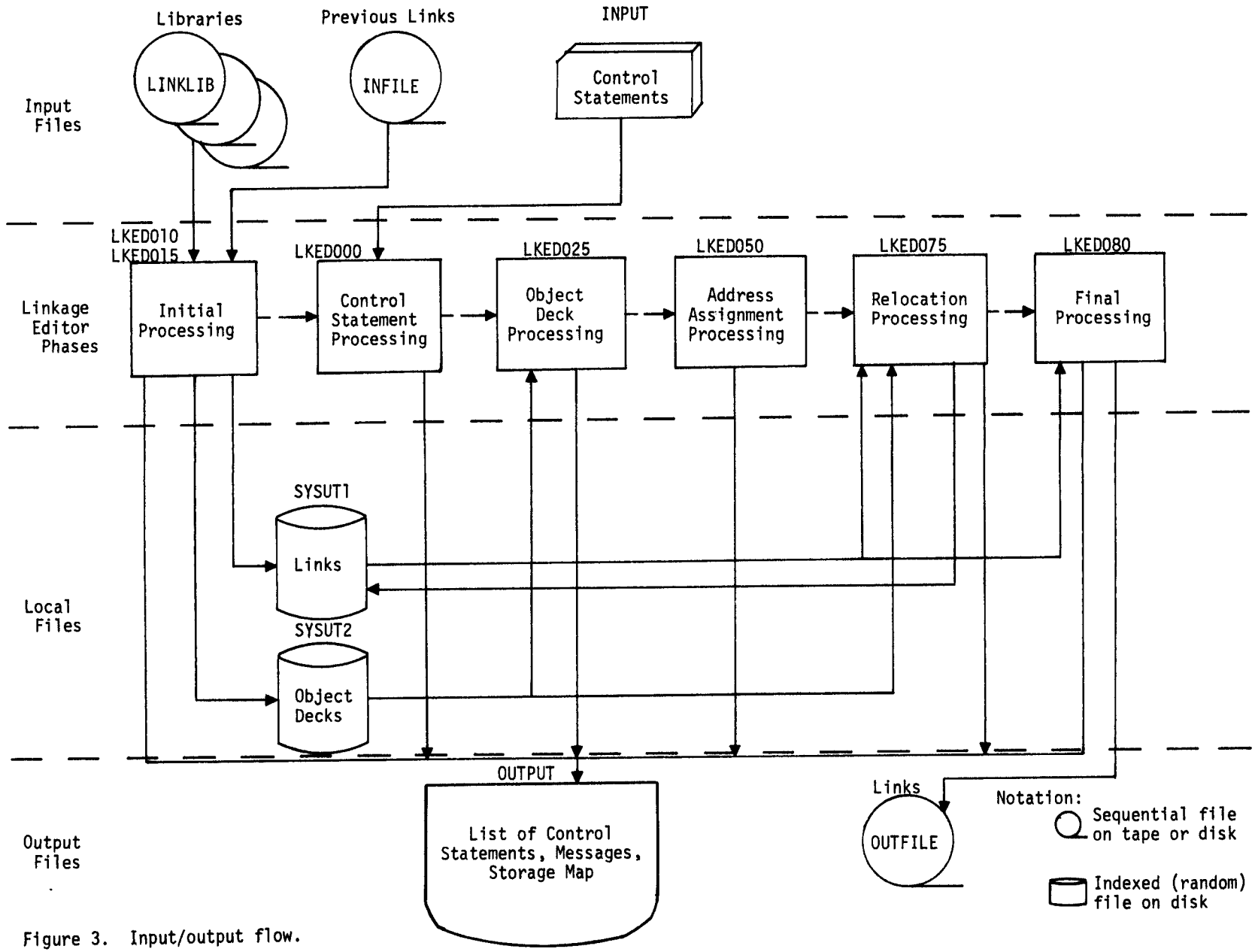


Figure 3. Input/output flow.

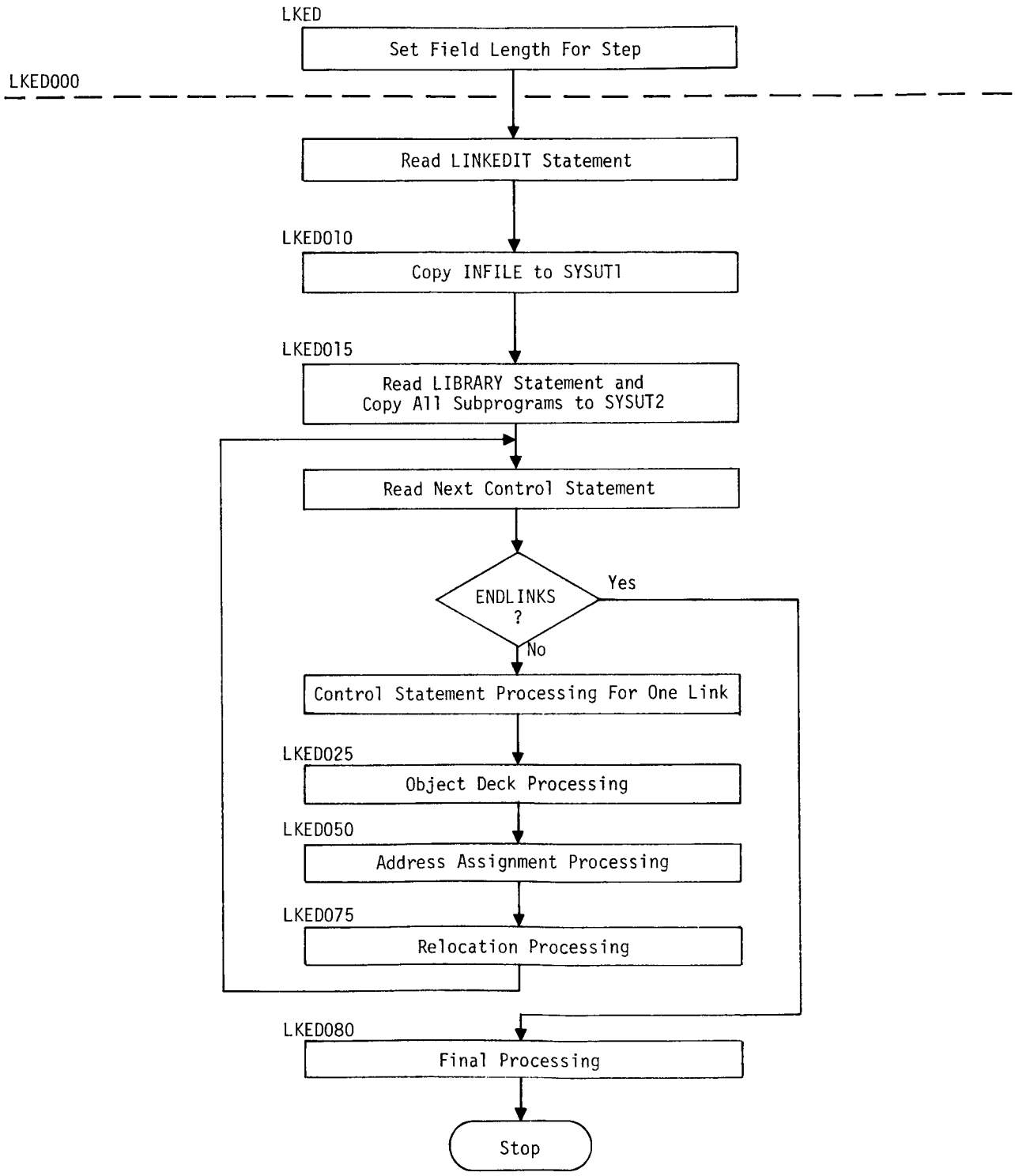


Figure 4. General flow of the linkage editor.

3. General utilities. These routines are CØMPASS and FØRTRAN routines whose primary functions are general in nature and not limited to linkage editor applications. Several of these routines are also common with the NASTRAN program (e.g., XRCARD). No naming convention exists. General utilities are described in section 7.2.4.3.

4. Miscellaneous. These are subroutines written primarily in FØRTRAN which perform auxiliary tasks for the linkage editor. The naming convention is LKEDxxx, where $900 \leq xxx \leq 999$. An example is LKED990, a routine which abnormally terminates the linkage editor in the event of a error in the logic (i.e., an "unplanned" event). Subroutine descriptions for miscellaneous routines are given in section 7.2.4.4.

7.2.1.6.3 Named Common Blocks

There are seven named common blocks in the linkage editor which provide for communication of parameters and fixed length tables between the various subprograms of the linkage editor. A brief description of these common blocks follows:

1. LKEDC01. Defines pointers to tables and parameters defining table sizes in open-ended working storage (blank common).

2. LKEDC02. Defines fixed-size working storage areas.

3. LKEDC03. Defines linkage editor control parameters.

4. LKEDC04. Defines names, characters, masks, and miscellaneous data.

5. LKEDC05. Defines data for generating instructions, programs, etc.

6. LKEDC06. A scratch area for sharing storage of local variables between independent programs in the linkage editor.

7. LKEDC07. Defines the names of subprograms on LINKLIB which comprise the bootstrap program.

Section 7.2.6 gives definitions of the principal variables in these common blocks.

7.2.1.6.4 Working Storage

All open-ended (variable length) tables are stored in blank common. Since the CDC loader loads blank common last, the dimension of blank common is, effectively, its origin to the field length. Section 7.2.2.1 provides a complete description of the linkage editor tables.

7.2.2 Discussion of the Major Divisions of the Linkage Editor/Loader

7.2.2.1 Linkage Editor Tables

7.2.2.1.1 Introduction to the Tables

All open-ended working storage tables for the linkage editor are held in blank common. Since the CDC loader loads blank common last, storage from the beginning of blank common to the field length is available. The user may choose a field length for the link-edited step as a function of the requirements of the problem. (For an estimate of storage requirements for the linkage editor, see section 5.6.6). Figure 5 illustrates the arrangement of the tables in blank common. (Table pointers are discussed later in this section).

The technique by which symbolic entries (e.g., entries in the Rename Table and General Table) are located in a table involves "hashing." The hash number of a symbol is defined as the modulus (remainder upon division) of the numerical value of the symbol of and (by) the number of entries available in the table. For example, assume that there are 128 entries in a table. Then the hash number of the symbol KREDNER is 122_8 (note that KREDNER=13220504160522_8) at the entry to which 122_8 points is stored a pointer to the beginning of a chain of entries with the hash number of 122_8. That chain might contain only the entry corresponding to KREDNER, or there might be several entries in the chain. To determine if an entry for KREDNER is already in the table, each entry in the chain which begins at the entry to which 122_8 points is checked.

Entries in the General Table are chained in many ways. Entries with identical hash numbers is one example of chains. Another includes all entries belonging to the same segment. In this case, a forward as well as backward chain is kept. A forward chain pointer points to the next entry in the chain. A backward chain pointer points to the previous entry in the chain. By convention, any pointer which has the value of zero indicates the beginning or end of a chain as the case may be.

This paragraph defines the word "pointer." As previously mentioned, all working storage tables are stored in blank common; the array name universally used in the linkage editor for blank common is Z. The first word in the Segment Definition Table is Z (ISEGDEF). A pointer, P, to the 5th segment would have the value 5. Thus the reference would be Z(ISEGDEF+P-1). Pointers always have the range $1 \leq P \leq$ LASTENT, where LASTENT, a pointer, points to the last entry in the

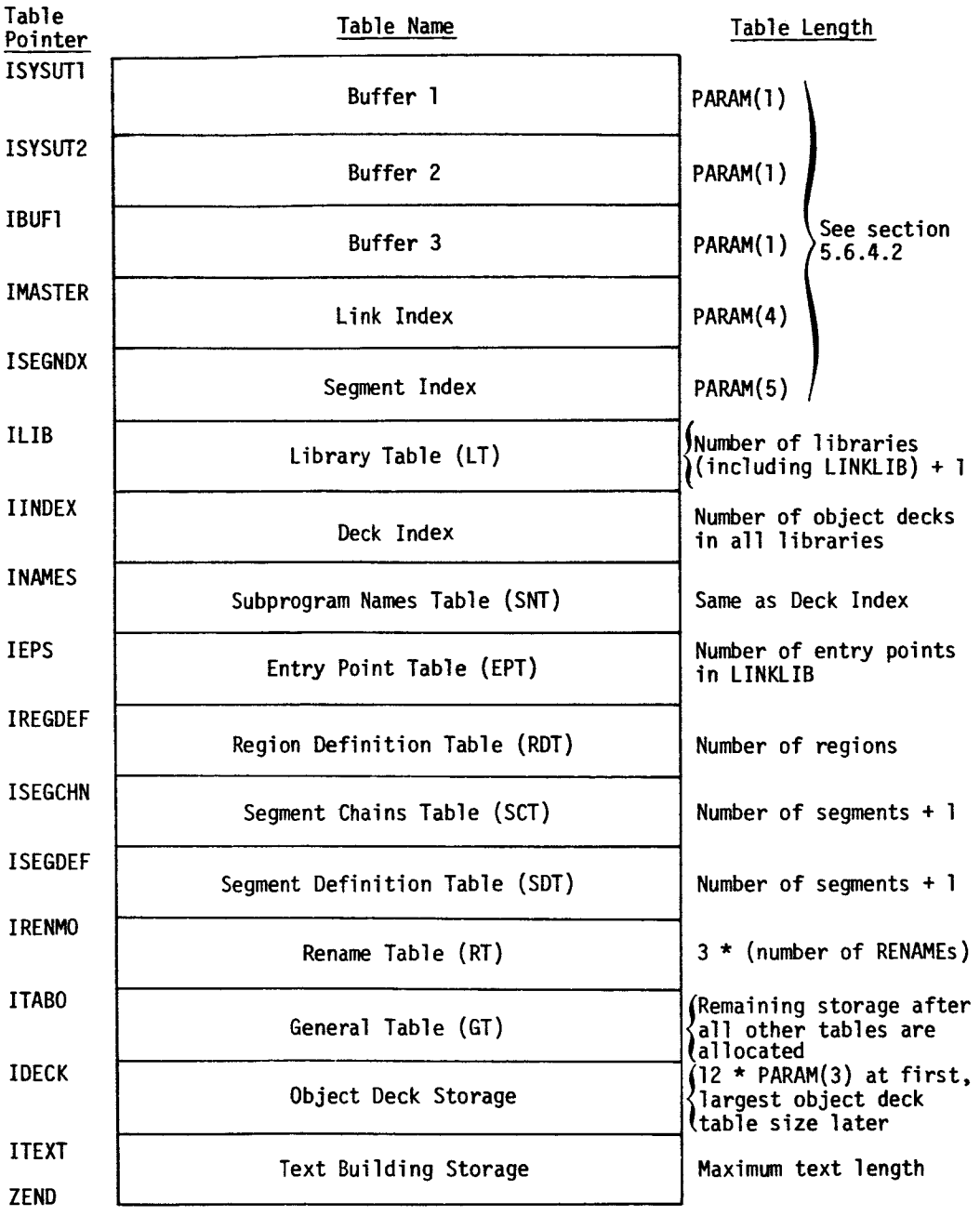


Figure 5. Arrangement of linkage editor tables in working storage (blank common).

table. If the number of words per entry is n, then P-1 is always divisable by n. Most tables are referenced by the "zero" word in the table, e.g., the entries in the Segment Definition Table are referenced relative to ISEG0 = ISEGDEF -1.

7.2.2.1.2 Library Table (LT)

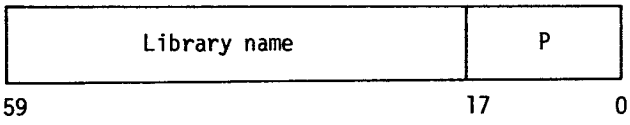
no. of words per entry: 1

no. of entries: one entry for each file named on LIBRARY control statements plus one.

first constructed by: LKED015

description: each entry contains the file name of the library and a pointer to the entry in the Subprogram Names Table which corresponds to the first subprogram in the library. LINKLIB is always the first entry in the table. The additional entry in the table is so that any two adjacent entries in the table will delimit a library.

format:



P = pointer to the entry in Subprogram Names Table for the first subprogram in this library.

7.2.2.1.3 Subprogram Names Table (SNT)

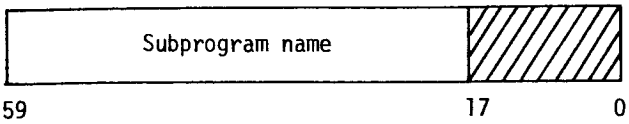
no. of words per entry: 1

no. of entries: one entry for each subprogram in each library named on the LIBRARY control statement plus one entry for each subprogram in LINKLIB.

first constructed by: LKED015

description: each entry contains a subprogram name

format:



7.2.2.1.4 Entry Point Table (EPT)

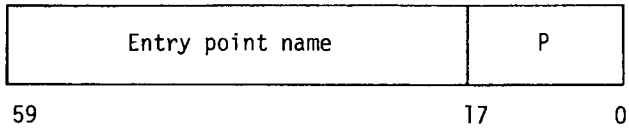
no. of words per entry: 1

no. of entries: one entry for each entry point in LINKLIB

first constructed by: LKED015

description: each entry contains the name of an entry point and a pointer to the entry in the Subprogram Names Table which defines the subprogram in which the entry point is defined.

format:



P = pointer in Subprogram Names Table

7.2.2.1.5 Region Definition Table (RDT)

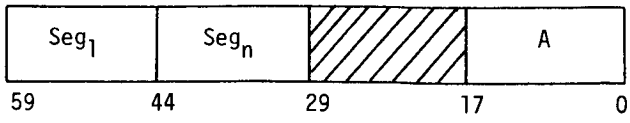
no. of words per entry: 1

no. of entries: one entry for each region in the Link

first constructed by: LKED000

description: each entry contains the first and last segment numbers in the region and, after LKED050 is executed, the initial address in the region.

format:



Seg_1 = first segment number in region

Seg_n = last segment number in region

A = initial address in region

7.2.2.1.6 Segment Chains Table (SCT)

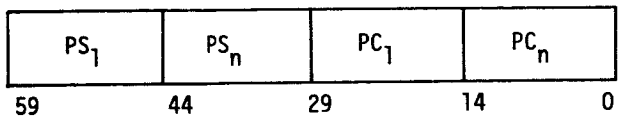
no. of words per entry: 1

no. of entries: one entry for each segment in the Link plus one

first constructed by: LKED000

description: each entry contains two pairs of pointers to entries in the General Table. The first pair of pointers points to the first and last entries in the chain which defines all symbolic entries in the segment. The second pair points to the first and last entries in a chain of calls which are not in the path. This latter chain will eventually become the ENTAB$ table for the segment. The last entry in the Segment Chains Table is the "undefined" segment. The undefined segment is a chain of entries which is generated by external references to symbols not yet defined in the General Table. When a symbol in the undefined chain becomes defined, it is removed from the undefined chain and linked to its appropriate segment chain, consequently, when all decks have been processed, any symbols remaining in the undefined chain, if they are to be defined, must be defined in LINKLIB. The automatic call logic attempts to define all such undefined symbols from LINKLIB.

format:



PS_1 = pointer to first entry in segment chain

PS_n = pointer to last entry in segment chain

PC_1 = pointer to first entry in call chain

PC_n = pointer to last entry in call chain

7.2.2.1.7 Segment Definition Table (SDT)

no. of words per entry: 1

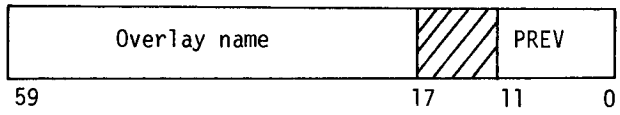
no. of entries: one entry for each segment in the Link plus one

first constructed by: LKED000

description: initially, the Segment Definition Table contains the name of the overlay segment as recorded on the ØVERLAY control statement (see section 5.6.4.7) and the segment number of the previous segment in the path, i.e., the "parent" of the current segment. After address assignment processing in LKED050, each entry contains the initial address in the segment, the length of the segment, the region number of the segment, and the segment number of the parent of the segment. The Segment Definition Table in its second format becomes the principal part of the SEGTAB$ table at execution time.

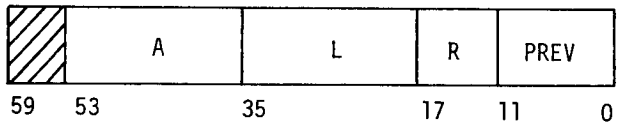
format:

Before address assignment processing:



PREV = segment number of previous segment in path (i.e., parent of segment)

After address assignment processing:



A = initial address in the segment

L = length of the segment

R = region number of the segment

PREV = segment number of the parent of the segment

7.2.2.1.8 Rename Table (RT)

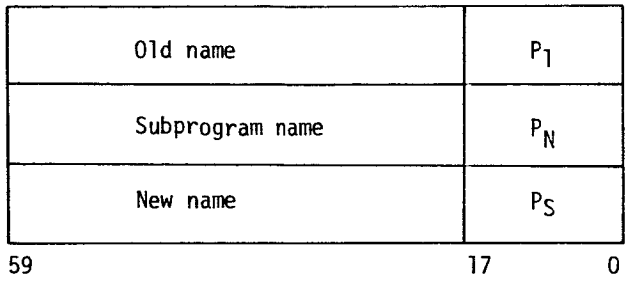
no. of words per entry: 3

no. of entries: one entry for each RENAME control statement (see section 5.6.4.9) in the current link.

first constructed by: LKED000

description: each entry contains a description of the information coded on a RENAME control statement plus information to chain the entries together. During processing, each external reference appearing in a LINK Table (see section 7.2.5) is checked for possible rename in this table.

format:



P_I = pointer to first entry in table with hash number of this entry

P_N = pointer to next entry in hash chain

P_S = pointer to next entry with same old name.

7.2.2.1.9 General Table (GT)

no of words per entry: 3

no. of entries: one entry for each subprogram, alternate entry point and common block in the Link plus, if not Link 0, one entry for each entry point and common block in Link 0, plus one entry for each "tentative" call in the path (calls which, at the time encountered, are either not in the path or are undefined). The number of "tentative" calls not in the path usually exceeds the actual number of calls not in the path.

first constructed by: LKED000

description: the General Table is the table central to all linkage editor processing. There are two kinds of entries in the General Table: a) a symbol entry which includes subprogram names, alternate entry points and common blocks and which describes various characteristics such as length, number of arguments, segment number, chain pointers, etc., and b) a call entry which describes characteristics about a call to a symbol. These characteristics include the

the segment from which the call comes, chain pointers, etc. Symbol entries are generated in the following ways:

1. Subprogram names defined on INCLUDE control statements (see section 5.6.4.5)

2. Alternate entry points defined in the ENTR Table (see section 7.2.5) of included subprograms.

3. Common block names mentioned on INSERT control statements or defined in the LCT of a PIDL Table (see section 7.2.5) of an included subprogram.

4. External references defined in LINK Tables (see section 7.2.5) of included subprograms.

5. Entry point or common block name in Link 0 when processing a link $\neq 0$.

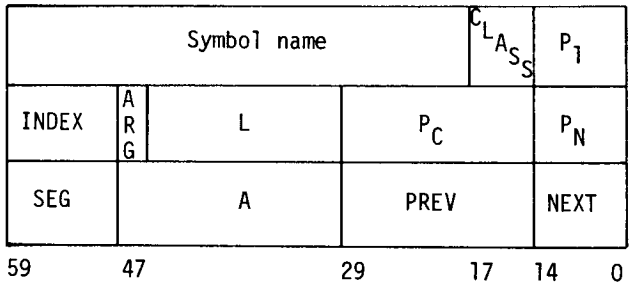
A call entry is generated in one of two ways:

(1) When the symbol called is not in the path

(2) When the symbol called is undefined.

format:

Symbol Entry



Symbol name = name of subprogram or entry point or common block

CLASS = code defining entry

0 = Link 0 symbol when Link $\neq 0$

1 = Subprogram name (primary entry point)

2 = Common block

3 = Alternate (secondary) entry point

4 = Subprogram marked for inclusion on INCLUDE card

5 = Block data program marked for inclusion

6 = Call entry (see below for format)

7 = undefined entry

P_1 = pointer to first entry with hash number of this entry

INDEX = Record number (index) of subprogram containing text (data) for this entry.

ARG = Bit which defines P_C entry (before execution of LKED050)

1: P_C = number of arguments for primary or alternate entry point

0: P_C = pointer to first entry in call chain.

ARG = bit defining address assignment status (during and after execution of LKED050) for CLASS = 1 entries only

1: final address has been assigned

0: final address not yet assigned

L = depends on CLASS

CLASS = 1, 2: L = Length

CLASS = 3: L = pointer to CLASS = 1 entry

CLASS = 4, 5: L = pointer to library name in Library Table

P_C = depends on ARG

ARG = 1: P_C = number of arguments

ARG = 0: P_C = pointer to first entry in call chain

P_N = pointer to next entry in hash chain

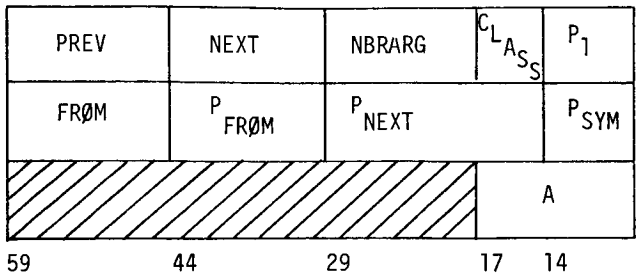
SEG = number of segment to which this entry belongs

A = relative and then final address of this entry

PREV = pointer to previous entry in this segment

NEXT = pointer to next entry in this segment

Call Entry:



PREV = pointer to previous entry in call chain

NEXT = pointer to next entry in call chain

NBRARG = number of arguments passed to symbol called

CLASS = 6

P_1 = pointer to first entry in hash chain

FRØM = segment number of subprogram making call

$P_{FRØM}$ = pointer to previous entry in 'FRØM' segment chain

P_{NEXT} = pointer to next entry in 'FRØM' segment chain

P_{SYM} = pointer to entry defining symbol called

A = relative/final address of ENTAB$ entry (see section 7.2.2.7).

7.2.2.1.10 XREF Table

no. of words per entry: 3 or 6 depending on CLASS

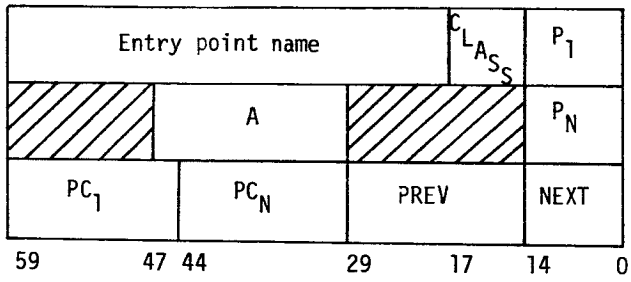
no. of entries: one 3-word entry for each entry point in the link plus one 6-word entry for each eleven calls from a given subprogram to a given entry point.

first constructed by: LKED077

description: this table is generated only if the XREF option is selected on the LINKEDIT control statement (see section 5.6.4.2). The origin of the table is the same as the Region Definition Table (see section 7.2.2.1.5) and the table extends to the end of working storage (ZEND). There are two types of entries in the table: (1) entry point entry which defines

an entry point and its address and pointers to the chains emanating from the entry and, (2) a call entry which defines up to eleven calls from a subprogram to the entry point. A call entry is a subservient entry to a entry point entry (i.e., each entry point entry has a chain of call entries linked to it). Information to generate the entries is created from the ENTR and LINK Tables (see section 7.2.5) of each of the subprograms to be included during processing in LKED075. The information is passed to LKED077 on a scratch file.

format:



CLASS = class of entry = 1

P_1 = pointer to first entry in hash chain

A = address of entry point

P_N = pointer to next entry in hash chain

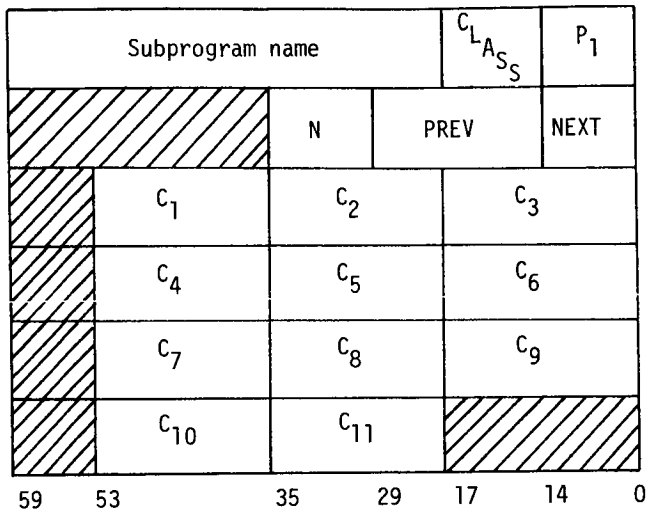
PC_1 = pointer to first entry in call chain

PC_N = pointer to last entry in call chain

PREV = pointer to previous entry in list chain (i.e., chain of entry points)

NEXT = pointer to next entry in list chain

XREF Entry



CLASS = class of entry = 2

P_1 = pointer to first entry in hash chain

N = number of C_i in this entry ($1 \leq N \leq 11$)

PREV = pointer to previous entry in this call chain

NEXT = pointer to next entry in this call chain

C_i = relative location within subprogram named in this entry of a call to the entry point to which this entry is chained.

7.2.2.2 Sample Problem for Discussion

To facilitate discussion of the major divisions of linkage editor processing, a sample problem has been chosen. The particular problem illustrates most of the features of linkage editor processing and was actually the principal test problem during initial checkout of the linkage editor.

Figures 6 through 17 show listings of the main program and the subprograms.

```
      PRØGRAM MAIN(ØUTPUT,TAPE6=ØUTPUT)
      CØMMØN/CØM0/J0
      CØMMØN/CØM3/J3
      LENGTH = 0
      CALL FIELDLN( LENGTH )
      CALL ZAP
      F = 28,4
      PRINT 20,F,F
   20 FØRMAT(*1*,E20,6,F20,6)
      PRINT 123
      CALL LINK( 1 )
      PRINT 123
  123 FØRMAT(*0CALLING LINK 1 *)
      STØP
      END
```

Figure 6. Sample main program.

```
BLØCK DATA PRT
CØMMØN/CØM1/I1
CØMMØN/CØM2/I2
CØMMØN/CØM4/I4
CØMMØN/CØM5/I5,KEITH(4)
CØMMØN/CØM6/I6
DATA I1,I2,   I4,I5,I6/71,72,74,75,76/
DATA KEITH/-1,-2,-3,-4/
END
```

Figure 7. Block data subprogram PRT.

```
      SUBRØUTINE PRTO
      CØMMØN/CØMO/JO
      CØMMØN/CØM3/J3
      I = 1
      I = I + 1
      PRINT 100, I,JO
  100 FØRMAT(*OPRTO CALLED *,2Ø24)
      CALL PRT1( I )
      I1 = 1001
      I2 = 1002
      I3 = 1003
      I4 = 1004
      I5 = 1005
      I6 = 1006
      I7 = 1007
      I8 = 1008
      I9 = 1009
      I10 = 1010
      I11 = 1011
      CALL PRT8(I,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11)
      PRINT 222, I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11
  222 FØRMAT(15I6)
      CALL PRT2( I )
      I = I + 1
      PRINT 100, I,J3
      CALL XDUMP( 0B, 100000B, 0 )
      IF( JO ,NE, 0 ) CALL LINK( 2 )
      JO = 7
      CALL LINK( 7)
      STØP
      END
```

Figure 8. Subroutine PRTO.

```
      SUBRØUTINE PRT1(I)
      CØMMØN/CØM1/J1
      I = I + 1
      PRINT 100, I,J1
      J1 = 101
  100 FØRMAT(*OPRT1 CALLED *,2Ø24)
      CALL PRT7( I )
      RETURN
      END
```

Figure 9. Subroutine PRT1.

```
      SUBRØUTINE PRT2(I)
      CØMMØN/CØM2/J2
      I = I + 1
      PRINT 100, I,J2
      J2 = 102
  100 FØRMAT(*OPRT2 CALLED *,2Ø24)
      CALL PRT3( I )
      CALL PRT5( I )
      CALL PRT4( I )
      RETURN
      END
```

Figure 10. Subroutine PRT2.

```
      SUBRØUTINE PRT3(I)
      CØMMØN/CØM3/J3
      I = I + 1
      PRINT 100, I,J3
      J3 = 103
  100 FØRMAT(*OPRT3 CALLED *,2Ø24)
      CALL PRT4(I)
      RETURN
      END
```

Figure 11. Subroutine PRT3.

```
      SUBRØUTINE PRT4(I)
      CØMMØN/CØM4/J4
      I = I + 1
      PRINT 100, I,J4
      J4 = 104
  100 FØRMAT(*OPRT4 CALLED *,2Ø24)
      CALL PRT7(I)
      RETURN
      END
```

Figure 12. Subroutine PRT4.

```
      SUBRØUTINE PRT5(I)
      CØMMØN/CØM5/J5
      I = I + 1
      PRINT 100, I,J5
      J5 = 105
  100 FØRMAT(*OPRT5 CALLED *,2Ø24)
      RETURN
      END
```

Figure 13. Subroutine PRT5.

```
      SUBRØUTINE PRT6(I)
      CØMMØN/CØM6/J6
      I = I + 1
      PRINT 100, I,J6
      J6 = 106
  100 FØRMAT(*OPRT6 CALLED *,2Ø24)
      RETURN
      END
```

Figure 14. Subroutine PRT6.

```
      SUBRØUTINE PRT7(I)
      CØMMØN/CØM3/J3
      CØMMØN/CØM7/J7
      I = I + 1
      PRINT 100, I,J7
      I = I + 1
      PRINT 100, I,J3
      J7 = 107
  100 FØRMAT(*OPRT7 CALLED *,2Ø24)
      RETURN
      END
```

Figure 15. Subroutine PRT7.

```
      SUBRØUTINE PRT8(I,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11)
      CØMMØN/CØM6/J6
      CØMMØN/CØM8/J8
      PRINT 222, I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11
  222 FØRMAT(15I6)
      I1 = 2001
      I2 = 2002
      I3 = 2003
      I4 = 2004
      I5 = 2005
      I6 = 2006
      I7 = 2007
      I8 = 2008
      I9 = 2009
      I10 = 2010
      I11 = 2011
      I = I + 1
      PRINT 100, I,J8
  100 FØRMAT(*OPRT8 CALLED *,2Ø24)
      CALL PRT9( I )
      CALL PRT6(I)
      I = I + 1
      PRINT 100, I,J6
      RETURN
      END
```

Figure 16. Subroutine PRT8.

```
      SUBRØUTINE PRT9(I)
      CØMMØN/CØM9/J9
      I = I + 1
      PRINT 100, I,J9
      J9 = 109
  100 FØRMAT(*0PRT9 CALLED *,2Ø24)
      RETURN
      END
```

Figure 17. Subroutine PRT9.

Figure 18 illustrates the overlay tree for the example problem.

Each of the object decks for the sample problem is assumed to reside in a file named ØBJ. The linkage editor control statements to build an executable program corresponding to overlay tree in Figure 17 are given in Table 1.

Table 1(a). Linkage Editor Control Statements for Sample Problem.

```
LINKEDIT        LET,ØUTFILE=ABS(T),XREF,PARAM(7)=3
LIBRARY         ØBJ
LINK            0
RENAME          XDUMP=XTRACE
RENAME          SYSTEM=SYSTEM
INCLUDE         ØBJ(MAIN)
INSERT          CØM0
INSERT          CØM3
ENTRY           MAIN
END
LINK            1
RENAME          XDUMP=XTRACE
INCLUDE         ØBJ(PRT0)
INCLUDE         ØBJ(BLKDATA(CØM1)
ØVERLAY         A00000A
INCLUDE         ØBJ(PRT1)
INSERT          CØM1
ØVERLAY         A00000A
INCLUDE         ØBJ(PRT2)
INSERT          CØM2
ØVERLAY         B00000B
INCLUDE         ØBJ(PRT3)
INCLUDE         ØBJ(PRT4
INSERT          CØM4
ØVERLAY         B0000B
INCLUDE         ØBJ(PRT5)
INSERT          CØM5
REGIØN
ØVERLAY         C00000C
INSERT          CØM6
```

Table 1(a). Linkage Editor Control Statements for Sample Problem.

```
INCLUDE          PRT6
ØVERLAY          DOOOOOD
INCLUDE          ØBJ(PRT7)
INSERT           CØM7
ØVERLAY          DOOOOOD
INCLUDE          ØBJ(PRT8)
INSERT           CØM8
INCLUDE          ØBJ(PRT9)
INSERT           CØM9
ENTRY            PRTO
END
ENDLINKS
```

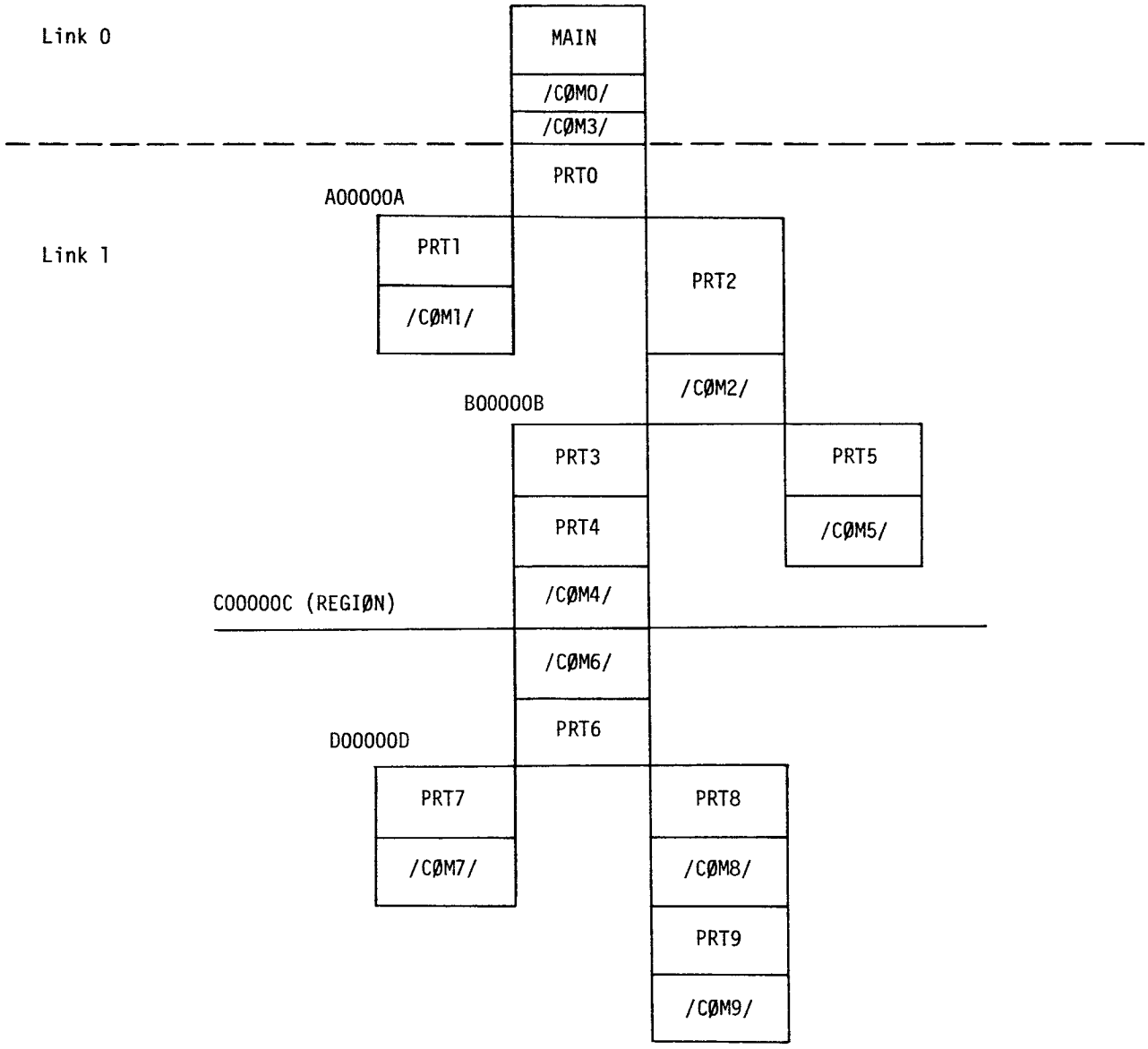


Figure 18. Overlay tree for sample problem.

7.2.2.3 Initial Processing

The flow of the initial processing phase of the linkage editor is shown in Figure 31.

Not shown in Figure 31 is the program which receives initial control when the linkage editor is executed. The functions of this program, LKED, are to establish buffers for INPUT and ØUTPUT (through SCØPE routine Q8ENTRY), set the field length for execution in words 63_8 and 76_8 (through routine FIELDLN), and call LKED000. If the linkage editor has itself been link edited, then the call to LKED000 is renamed to LINK and LKED000 becomes the entry point in Link 1.

INPUT is assumed to be positioned at the beginning of a logical record which contains the linkage editor control statements. A card is read from INPUT (via FØRTRAN formatted read routines) and converted by XRCARD. If this card is not the LINKEDIT control statement, or if the control statement contains an error, execution of the linkage editor is terminated.

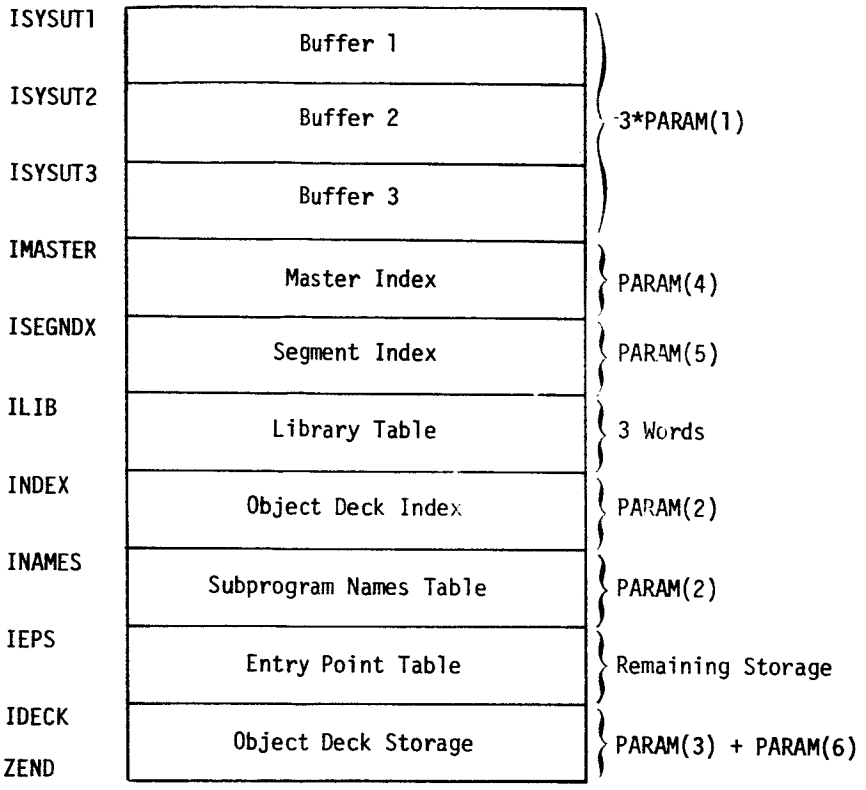
In the sample problem Table 1, section 7.2.2.2, the variable LET is set to .TRUE., the name ABS is stored in the variable ØUTFILE, T is stored in the variable ØUTSTAT, the variable XREF is set to .TRUE., and the 7th word of the array PARAM is set to 3. Since INFILE is not defined, LKED010 is bypassed and LKED015 is called to process the object deck libraries.

Following conversion of the LIBRARY statement, the Library Table (LT), section 7.2.2.1.2, appears as follows:

LINKLIB	1
ØBJ	0
0	0

59 17 0

The object deck index, Subprogram Names Table (SNT) (section 7.2.2.1.3), Entry Point Table (EPT) (section 7.2.2.1.4) and object deck storage table are allocated in working storage based on: PARAM(2) for the object deck index and SNT; PARAM(3)+PARAM(6) for object deck storage table; and all remaining storage for the EPT (see 5.6.4.2 for a discussion of the PARAM array). Working storage at this point is as follows:

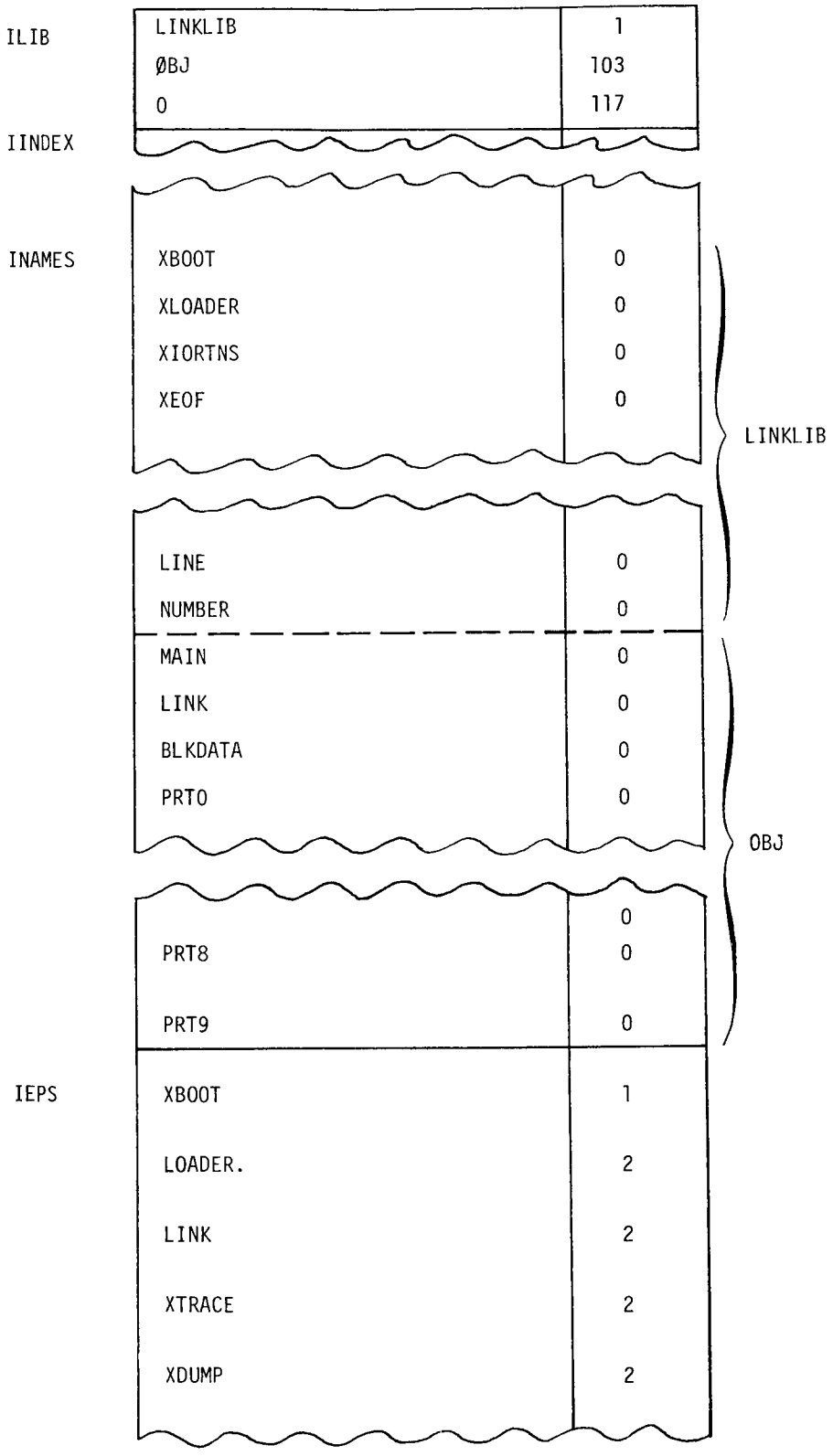


LINKLIB is opened to read. For each object deck in LINKLIB:

1. the PIDL Table is located (see section 7.2.5)
2. the subprogram name is extracted and stored in the SNT
3. the ENTR Table is located (see section 7.2.5)
4. each entry point name is extracted and stored in the EPT with a pointer to the subprogram name in the SNT.

When an end-of-file is encountered, LINKLIB is closed. ØBJ is opened and processing similar to LINKLIB occurs except that no entries are made in the EPT.

When ØBJ has been processed, the tables will appear as follows:

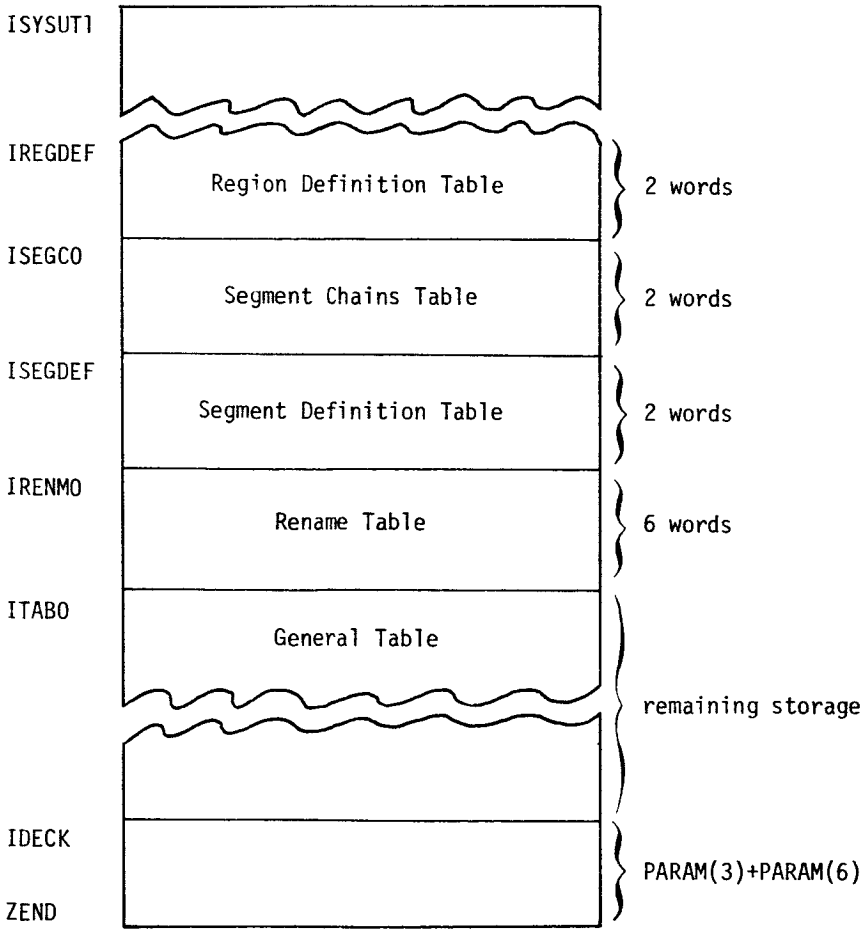

ILIB
LINKLIB 1
ØBJ 103
0 117
IINDEX
INAMES
XBOOT 0
XLOADER 0
XIORTNS 0
XEOF 0
LINKLIB
LINE 0
NUMBER 0
MAIN 0
LINK 0
BLKDATA 0
PRTO 0
OBJ
0
PRT8 0
PRT9 0
IEPS
XBOOT 1
LOADER. 2
LINK 2
XTRACE 2
XDUMP 2

Prior to returning control to LKED000, LKED015 compresses the SNT and EPT based on actual sizes.

7.2.2.4 Control Statement Processing

For a given link, two passes are made through the control statements. On the first pass, the format of each statement is checked and counts of the various types of statements are accumulated. The card images are stored in working storage from the end (starting at ZEND-7) and working toward the beginning using 8 words per card. At the end of the first pass, all remaining tables are allocated in working storage.

In the sample problem, the important counts indicate one region, one segment, and two RENAME statements. Working storage would appear as in the following diagram. Note that ISEGCO, IRENMO, and ITABO are zero pointers (e.g., ISEGCO=ISEGCHN-1, where ISEGCHN is the pointer to the beginning of Segment Chains Table--see Figure 5.



The first entry in the GT is an entry for LINKO$. On the second pass through the control statements for Link 0, each of the tables is updated depending on the type of control statement. The tables as they appear at the conclusion of the second pass are shown in Figure 19.

When the control statements for Link 1 are processed (after all processing is complete for Link 0), the tables are far more dense. Note that there are two regions, eight segments and one RENAME statement in Link 1. In addition, at the conclusion of the first pass through the control statements for Link 1, the Link 0 entries are read from the Link 0 dictionary or SYSUT1 and entered into the GT so all references from Link 1 to Link 0 may be completed. The tables as they appear at the conclusion of the second pass through the control statements for Link 1 are shown in Figure 20.

Inspection of Figure 20 indicates that the entries for Link 0 are not chained. These entires always begin with the second entry in the GT and form consecutive entries until the CLASS (see section 7.2.2.1.9) of an entry is not zero.

The SDT is made clear by studying it in connection with the overlay tree shown in Figure 18.

7.2.2.5 Object Deck Processing

The following procedure is used to include object decks which were named on INCLUDE control statements:

1. A subprogram name is taken from the SNT (proceeding sequentially from the first to the last entry)

2. An entry corresponding to the subprogram name is located in the GT (if not located, of course, the subprogram is not included).

3. If the CLASS of the entry is 4 or 5 and the A field (section 7.2.2.1.9) points to the library to which the subprogram belongs, it is included. Otherwise, it is not.

4. The position of the subprogram in the SNT is its logical record number in SYSUT2. The subprogram is read from SYSUT2 to working storage.

Referring to the picture of the SNT in section 7.2.2.3, the first subprogram to be included in Link 0 is MAIN (the 103rd entry in the SNT).

DUMP OF LINKAGE EDITOR TABLES AFTER LKED000

---LIBRARY TABLE---

LIBNAME	LIBCNT
LINKLIB	1
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	1	000000

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	10	0	0
2	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS,	LENGTH	PARENT
1		000000	000000	0

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		4	XTRACE
4	SYSTEM	0		0	SYSTEM,

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	LINK0$	2	0	0	001273	0	0	1	000000	0	4
4	MAIN	4	0	0	000000	0	0	1	000002	1	7
7	COM0	7	0	0	000000	0	0	1	000006	4	10
10	COM3	7	0	0	000000	0	0	1	000000	7	0

Figure 19. Linkage editor tables after control statement processing for Link 0.

DUMP OF LINKAGE EDITOR TABLES AFTER LKED000

---LIBRARY TABLE---

LIBNAME	LIBCNT
	0
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	5	000000
2	6	8	000000

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	289	0	0
2	295	292	0	0
3	298	301	0	0
4	304	310	0	0
5	313	316	0	0
6	319	322	0	0
7	325	328	0	0
8	331	340	0	0
9	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS	LENGTH	PARENT
1		000000	000000	0
2	A00000A	333333	333301	1
3	A00000A	333333	333301	1
4	B00000B	333333	333302	3
5	B00000B	333333	333302	3
6	C00000C	333333	333303	0
7	D00000D	333333	333304	6
8	D00000D	333333	333304	6

Figure 20(a). Linkage editor tables after control statement processing for Link 1.

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		0	XTRACE

---LINK 0 DICTIONARY---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
4	LINK0$	0	0	0	000000	0	0	0	000101	0	0
7	MAIN	0	0	0	000000	0	0	0	001376	0	0
10	COM0	0	0	0	000000	0	0	0	002504	0	0
13	COM3	0	0	0	000000	0	0	0	002506	0	0
16	SYSTEM.	0	0	0	000000	0	0	0	002710	0	0
19	MAPFNS	0	0	0	000000	0	0	0	003571	0	0
22	OUTPTC	0	0	0	000000	0	0	0	004034	0	0
25	XLOADER	0	0	0	000000	0	0	0	004120	0	0
28	LOADER.	0	0	0	000000	0	0	0	004235	0	0
31	LINK	0	0	0	000000	0	0	0	004127	0	0
34	XTRACE	0	0	0	000000	0	0	0	004364	0	0
37	XDUMP	0	0	0	000000	0	0	0	004341	0	0
40	COMPARE	0	0	0	000000	0	0	0	004360	0	0
43	ABSENT.	0	0	0	000000	0	0	0	004444	0	0
46	XIORTNS	0	0	0	000000	0	0	0	004450	0	0
49	LINKERR	0	0	0	000000	0	0	0	004763	0	0
52	CORDUMP	0	0	0	000000	0	0	0	005161	0	0
55	CPC	0	0	0	000000	0	0	0	005701	0	0
58	XOPEN	0	0	0	000000	0	64	0	004460	0	0
61	XCLOSE	0	0	0	000000	0	0	0	004515	0	0
64	XEVICT	0	0	0	000000	0	0	0	004524	0	0
67	REINDX	0	0	0	000000	0	271	0	004531	0	0
70	XWRITE	0	0	0	000000	0	0	0	004537	0	0
73	XREAD	0	0	0	000000	0	0	0	004560	0	0
76	XREWIND	0	0	0	000000	0	0	0	004607	0	0
79	XBKREC	0	0	0	000000	0	0	0	004616	0	0
82	XFRDREC	0	0	0	000000	0	0	0	004635	0	0
85	XBKPREC	0	0	0	000000	0	0	0	004627	0	0
88	XREQST	0	0	0	000000	0	0	0	004636	0	0
91	WRITEX	0	0	0	000000	0	0	0	004652	0	0
94	READX	0	0	0	000000	0	0	0	004713	0	0
97	IORANDM	0	313	0	000000	0	0	0	006076	0	0
100	IO	0	0	0	000000	0	0	0	006302	0	0
103	ANDF	0	0	0	000000	0	0	0	003603	0	0
106	ORF	0	0	0	000000	0	0	0	003601	0	0

Figure 20(b). Linkage editor tables after control statement processing for Link 1.

109	COMPLF	0	0	0	000000	0	0	0	003613	0	0
112	XORF	0	0	0	000000	0	0	0	003572	0	0
115	RSHIFT	0	0	0	000000	0	0	0	003630	0	0
118	LSHIFT	0	0	0	000000	0	0	0	003616	0	0
121	CORSZ	0	0	0	000000	0	0	0	003576	0	0
124	CORWDS	0	0	0	000000	0	0	0	003665	0	0
127	XSTORE	0	0	0	000000	0	0	0	003642	0	0
130	XFETCH	0	0	0	000000	0	0	0	003647	0	0
133	LWORDS	0	0	0	000000	0	0	0	003661	0	0
136	XJUMP	0	0	0	000000	0	334	0	003672	0	0
139	ZAP	0	0	0	000000	0	0	0	003675	0	0
142	LOCF	0	0	0	000000	0	0	0	003704	0	0
145	FIELDLN	0	0	0	000000	0	0	0	003707	0	0
148	FLUSH	0	0	0	000000	0	0	0	003723	0	0
151	RECOVRY	0	0	0	000000	0	0	0	003726	0	0
154	TDATE	0	0	0	000000	0	0	0	003746	0	0
157	DAYTIME	0	0	0	000000	0	0	0	003766	0	0
160	KLOCK	0	0	0	000000	0	0	0	004004	0	0
163	LINK20.	0	0	0	000000	0	0	0	004026	0	0
166	XCOMMON	0	0	0	000000	0	0	0	004016	0	0
169	Q8NTRY	0	0	0	000000	0	0	0	002515	0	0
172	SYSTEMC	0	0	0	000000	0	0	0	002662	0	0
175	SYSTEMP	0	0	0	000000	0	0	0	002711	0	0
178	END	0	0	0	000000	0	0	0	002605	0	0
181	STOP	0	0	0	000000	0	0	0	002635	0	0
184	EXIT	0	0	0	000000	0	0	0	002627	0	0
187	ABNORML	0	0	0	000000	0	0	0	002645	0	0
190	SIO%	0	0	0	000000	0	0	0	006516	0	0
193	CIO1.	0	0	0	000000	0	0	0	007553	0	0
196	RCL1.	0	0	0	000000	0	0	0	007564	0	0
199	DAT.	0	0	0	000000	0	0	0	006520	0	0
202	SIO.CTL	0	0	0	000000	0	0	0	006746	0	0
205	INITL.	0	0	0	000000	0	0	0	006766	0	0
208	SIO.	0	0	0	000000	0	0	0	007032	0	0
211	SIO.END	0	0	0	000000	0	0	0	007527	0	0
214	OPEN.	0	0	0	000000	0	0	0	007572	0	0
217	RDPRU.	0	0	0	000000	0	0	0	007633	0	0
220	BKSPRU.	0	0	0	000000	0	0	0	007650	0	0
223	ADVIN.	0	0	0	000000	0	0	0	007655	0	0
226	POSFI.	0	0	0	000000	0	0	0	007702	0	0
229	MVWDS.	0	0	0	000000	0	0	0	010022	0	0
232	GETBA	0	0	0	000000	0	0	0	010037	0	0
235	KODER	0	0	0	000000	0	0	0	010057	0	0
238	IOREAD	0	0	0	000000	0	0	0	006342	0	0
241	IOWRITE	0	0	0	000000	0	0	0	006350	0	0
244	IOREWRT	0	0	0	000000	0	0	0	006345	0	0

Figure 20(c). Linkage editor tables after control statement processing for Link 1.

247	IOIO	0	0	0	000000	0	0	0	006353	0	0
250	IOSAV	0	0	0	000000	0	0	0	006313	0	0
253	IOZZ	0	0	0	000000	0	0	0	006506	0	0
256	IOZW	0	0	0	000000	0	0	0	006512	0	0
259	D.BCDRD	0	0	0	000000	0	0	0	006332	0	0
262	D.BCDWR	0	0	0	000000	0	0	0	006336	0	0
265	IORR	0	0	0	000000	0	0	0	006076	0	0
268	IORW	0	0	0	000000	0	0	0	006111	0	0
271	IORRW	0	0	0	000000	0	0	0	006136	0	0
274	CPC02	0	0	0	000000	0	0	0	005764	0	0
277	CPC03	0	0	0	000000	0	0	0	005634	0	0
280	CPC04	0	0	0	000000	0	0	0	005652	0	0
283	CPC999	0	0	0	000000	0	0	0	006065	0	0
286	ACGOER	0	0	0	000000	0	0	0	011270	0	0

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	SEGTAB$	2	0	0	000012	0	0	1	000000	0	289
289	PRT0	4	0	0	000000	0	0	1	000002	1	0

---SYMBOL CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
295	PRT1	4	0	0	000000	0	0	2	000002	0	292
292	COM1	5	0	0	000000	0	0	2	000002	295	0

---SYMBOL CHAIN FOR SEGMENT 3---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
298	PRT2	4	0	0	000000	0	0	3	000002	0	301
301	COM2	7	0	0	000000	0	0	3	000000	298	0

---SYMBOL CHAIN FOR SEGMENT 4---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
304	PRT3	4	0	0	000000	0	0	4	000002	0	307
307	PRT4	4	0	0	000000	0	0	4	000002	304	310
310	COM4	7	0	0	000000	0	0	4	000000	307	0

---SYMBOL CHAIN FOR SEGMENT 5---

Figure 20(d). Linkage editor tables after control statement processing for Link 1.

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
313	PRT5	4	0	0	000000	0	0	5	000002	0	316
316	COM5	7	0	0	000000	0	0	5	000000	313	0

---SYMBOL CHAIN FOR SEGMENT 6---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
319	COM6	7	0	0	000000	0	0	6	000000	0	322
322	PRT6	4	0	0	000000	0	0	6	000004	319	0

---SYMBOL CHAIN FOR SEGMENT 7---

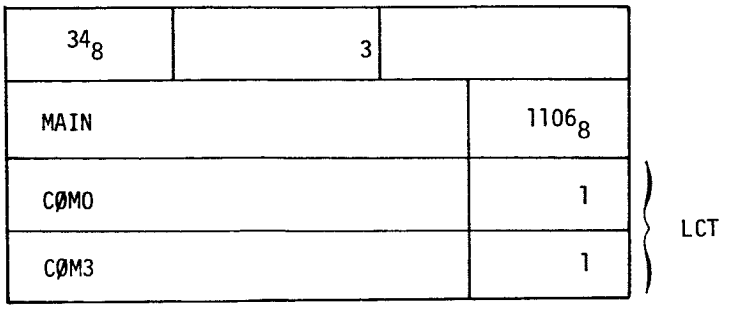
ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
325	PRT7	4	0	0	000000	0	0	7	000002	0	328
328	COM7	7	0	0	000000	0	0	7	000006	325	0

---SYMBOL CHAIN FOR SEGMENT 8---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
331	PRT8	4	0	0	000000	0	0	8	000002	0	334
334	COM8	7	0	0	000000	0	0	8	000006	331	337
337	PRT9	4	0	0	000000	0	0	8	000004	334	340
340	COM9	7	0	0	000000	0	0	8	000000	337	0

Figure 20(e). Linkage editor tables after control statement processing for Link 1.

The object deck for MAIN is read into working storage and the PIDL Table (section 7.2.5) is located. The PIDL Table for MAIN is as follows:



At the entry corresponding to the MAIN, the following fields can be completed:

L = 1106_8

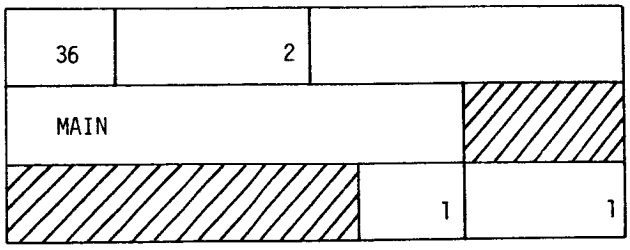
CLASS = 1

INDEX = 103

Since the LCT (section 7.2.5) is not empty, each TEXT Table (section 7.2.5) of the subprogram is searched to determine if any of the tables point to one of the common blocks. In this case, none do. However, in processing the BLKDATA subprogram in Link 1, data is defined for each of the common blocks. This condition isnoted in the LCT by setting the high order bit of length field of the entry.

An attempt is made to locate each of the common blocks (CØMO and CØM3) in the GT. Neither is present so entries of CLASS=2 are created and the L field is set in each entry. The entries are chained to the segment 1 chain and the pointers in the SCT are updated.

The ENTR Table (section 7.2.5) is located next. For the subprogram MAIN this table will appear as follows:



An attempt is made to locate the entry point name in the GT. In this case, MAIN is located with a CLASS=1. The relative entry address is stored in the A field of the entry. For segments other than one, the TEXT Tables (see section 7.2.5) are searched to locate the ID word corresponding to the entry point and thus extract the number of arguments defined for the entry.

Next, the LINK Table is located. For MAIN, this table is as follows:

44		16_8			
Q8ENTRY					0
5	1	2	FIELD		
LN		0	5	1	5
ZAP					0
5	1	6	ØUTPUT		
C		0	5	1	12_8
5	1	14_8	5	1	16_8
5	1	17_8	5	1	22_8
5	1	23_8	5	1	30_8
5	1	31_8	LINK		
		0	5	1	25_8
STØP					0
5	1	33_8	END		
		0	5	1	35_8

An attempt is made to locate each of the external references in the LINK Table (section 7.3.5) (after first checking for possible rename via the RT). In this case, none of the entries exists in the GT. Therefore, for each external reference, the following occurs:

1. A new entry is created with CLASS=7 (the "undefined" class)

2. The entry is linked to the "undefined" segment chain (segment 2 for Link 0)

3. Since it is possible that the names may be defined subsequently in a segment not in the path (it is true that in Link 0 this is not possible, however, this case is not tested and so for this processing, Link 0 is treated as any other Link) a call entry (CLASS=6) is created for each of the symbol entries. The call entries form an ENTAB$ (see section 7.2.2.7) chain for the segment and each is chained to the symbol entry of the call.

Since there were seven external references by MAIN, seven symbol entries in the undefined segment chain are created and seven call entries in the segment one ENTAB$ chain are created. The contents of the tables at this point are shown in Figure 21.

Processing for MAIN is now complete. Since no other subprograms were marked for inclusion in Link 0, the automatic call logic is now invoked. This works as follows:

1. For each entry in the undefined segment chain, the EPT is searched.

2. If a match is found, an entry of CLASS=4 is created in the GT (unless it already exists) for the subprogram to which the entry point belongs.

3. The main logic is repeated with a logical variable SYSLIB set to .TRUE..

Note the possible cascading effect of automatic library calls. This happens when a LINKLIB routine makes external references to other LINKLIB routines. This case is handled as follows:

1. When the LINK Table is processed and it is the SYSLIB pass (i.e., SYSLIB=.TRUE.), each external reference which is not in the GT is looked up in the EPT.

2. If the external name is found in the EPT and the corresponding subprogram has not already been marked for inclusion, an entry in the GT is created of CLASS=4.

3. If necessary, the current pointer in the SNT is reset to the entry corresponding to the new subprogram to insure that is included.

DUMP OF LINKAGE EDITOR TABLES AFTER 1 DECK IN 025

---LIBRARY TABLE---

LIBNAME	LIBCNT
LINKLIB	1
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	1	000000

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	10	16	52
2	13	49	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS	LENGTH	PARENT
1		000000	000000	0

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		4	XTRACE
4	SYSTEM	0		0	SYSTEM.

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN		HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	LINK0$	2	0	0	001273	0		0	1	000000	0	4
4	MAIN	1	0	103	001106	0	*	0	1	000001	1	7
7	COM0	2	0	0	000001	0		0	1	000000	4	10
10	COM3	2	0	0	000001	0		0	1	000000	7	0

Figure 21(a). Linkage editor tables after processing MAIN in Link 0.

---ENTAB CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
16		6	0	13	0	0	13	1	000000	0	22
22		6	0	19	0	0	19	1	000000	16	28
28		6	0	25	0	0	25	1	000000	22	34
34		6	0	31	0	0	31	1	000000	28	40
40		6	0	37	0	0	37	1	000000	34	46
46		6	0	43	0	0	43	1	000000	40	52
52		6	0	49	0	0	49	1	000000	46	0

---SYMBOL CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
13	QBNTRY	7	0	0	000000	16	0	2	000000	0	19
19	FIELDLN	7	0	0	000000	22	0	2	000000	13	25
25	ZAP	7	0	0	000000	28	0	2	000000	19	31
31	OUTPTC	7	0	0	000000	34	0	2	000000	25	37
37	LINK	7	0	0	000000	40	0	2	000000	31	43
43	STOP	7	0	0	000000	46	0	2	000000	37	49
49	END	7	0	0	000000	52	0	2	000000	43	0

Figure 21(b). Linkage editor tables after processing MAIN in Link 0.

For example, in the sample problem, Q8ENTRY is an entry point in SYSTEM., which in turn references SIØ, which is an entry point in SIØ$ which in turn references GETBA which is an entry point in GETBA, and, in fact, the single INCLUDE ØBJ (MAIN) statement results in 14 additional LINKLIB subprograms to resolve all cross references for Link 0.

When the SYSLIB pass is complete, any entries remaining in the undefined segment chain are truly undefined and an error message is printed for each one.

At this point, a certain amount of "clean up" processing is necessary. For example, a number of call chain entries which were created because an entry was undefined at the time, may now be resolved and need to be removed.

The final processing in this phase of the linkage editor is to create an ENTAB$ entry in the GT for each segment with calls not in the path. Relative addresses are computed for each entry in each ENTAB$ chain. At this point sufficient information is available to perform the assignment of final storage addresses to each entry and control passes to the Address Assignment Processor, LKED050. (see section 7.2.2.6)

The linkage editor tables as they appear after object deck processing for Link 0 is shown in Figure 22. Similarly, Figure 23 shows the tables after Link 1.

7.2.2.6 Address Assignment Processing

The computation of final storage addresses is relatively straightforward with the order of the computations being the key factor. When LKED050 receives control, each of the control section entries in the GT has a length assigned so what remains essentially is to accumulate the lengths of each of the control sections. The way in which the segments will reside in storage (the overlay tree) must be taken into consideration. As a result, the computation proceeds as follows:

1. Each entry in a segment chain is traced. If the entry defines a control section (CLASS = 1 or 2), the length is accumulated. For each control section, an additional word is added to the length to account for the control section identification word which is placed at the beginning of each control section during relocation processing.

2. The length of the segment is stored in the SDT (section 7.2.2.1.7)

DUMP OF LINKAGE EDITOR TABLES AFTER LKED025

---LIBRARY TABLE---

LIBNAME LIBCNT

LINKLIB 1
OBJ 103
117

---REGION DEFINITION TABLE---

REGION 1ST SEG LAST SEG REG ADDR

1 1 1 000000

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	310	0	0
2	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT NAME OR ADDRESS,LENGTH PARENT

1 000000 000000 0

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		4	XTRACE
4	SYSTEM	0		0	SYSTEM.

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	LINK0$	2	0	0	001273	0	0	1	000000	0	4
4	MAIN	1	0	103	001106	0	0	1	000014	1	7
7	COM0	2	0	0	000001	0	0	1	000000	4	10
10	COM3	2	0	0	000001	0	0	1	000000	7	55

Figure 22(a). Linkage editor tables after object deck processing for Link 0.

55	SYSTEM.	1	0	7	001060	0	0	1	000206	10	58
58	MAPFNS	1	0	6	000240	0	0	1	000000	55	31
31	OUTPTC	1	0	9	000073	34	0	1	000002	58	61
61	XLOADER	1	0	2	000321	0	0	1	000006	31	64
64	LOADER.	3	0	0	000075	0	0	1	000107	61	37
37	LINK	3	0	0	000075	40	0	1	000001	64	67
67	XTRACE	3	0	0	000075	0	0	1	000236	37	70
70	XDUMP	3	0	0	000075	0	0	1	000213	67	73
73	COMPARE	3	0	0	000075	0	0	1	000232	70	76
76	ABSENT.	3	0	0	000075	0	0	1	000316	73	82
82	XTORTNS	1	0	3	000311	0	0	1	000002	76	88
88	LINKERR	1	0	17	000175	0	0	1	000001	82	91
91	CORDUMP	1	0	16	000452	0	0	1	000001	88	94
94	CPC	1	0	14	000242	0	0	1	000046	91	97
97	XOPEN	3	0	0	000122	0	0	1	000012	94	100
100	XCLOSE	3	0	0	000122	0	0	1	000045	97	103
103	XEVICT	3	0	0	000122	0	0	1	000054	100	106
106	REINDX	3	0	0	000122	0	0	1	000061	103	109
109	XWRITE	3	0	0	000122	0	0	1	000067	106	112
112	XREAD	3	0	0	000122	0	0	1	000110	109	115
115	XREWIND	3	0	0	000122	0	0	1	000137	112	118
118	XBKREC	3	0	0	000122	0	0	1	000146	115	121
121	XFRDREC	3	0	0	000122	0	0	1	000161	118	124
124	XBKPREC	3	0	0	000122	0	0	1	000154	121	127
127	XREQST	3	0	0	000122	0	0	1	000166	124	130
130	WRITEX	3	0	0	000122	0	0	1	000202	127	79
79	READX	3	0	0	000122	0	0	1	000243	130	136
136	IORANDM	1	0	13	000203	0	0	1	000000	79	145
145	IO	1	0	12	000213	0	0	1	000000	136	151
151	ANDF	3	0	0	000072	0	0	1	000016	145	154
154	ORF	3	0	0	000072	0	0	1	000016	151	157
157	COMPLF	3	0	0	000072	0	0	1	000025	154	160
160	XORF	3	0	0	000072	0	0	1	000001	157	163
163	RSHIFT	3	0	0	000072	0	0	1	000037	160	166
166	LSHIFT	3	0	0	000072	0	0	1	000025	163	169
169	CORSZ	3	0	0	000072	0	0	1	000005	166	172
172	CORWDS	3	0	0	000072	0	0	1	000074	169	175
175	XSTORE	3	0	0	000072	0	0	1	000051	172	178
178	XFETCH	3	0	0	000072	0	0	1	000056	175	181
181	LWORDS	3	0	0	000072	0	0	1	000070	178	184
184	XJUMP	3	0	0	000072	0	0	1	000101	181	25
25	ZAP	3	0	0	000072	28	0	1	000104	184	187
187	LOCF	3	0	0	000072	0	0	1	000113	25	19
19	FIELDLN	3	0	0	000072	22	0	1	000116	187	190
190	FLUSH	3	0	0	000072	0	0	1	000132	19	193
193	RECOVRY	3	0	0	000072	0	0	1	000135	190	196
196	TDATE	3	0	0	000072	0	0	1	000155	193	199

Figure 22(b). Linkage editor tables after object deck processing for Link 0.

199	DAYTIME	3	0	0	000072	0	0	1	000175	196	202
202	KLOCK	3	0	0	000072	0	0	1	000213	199	205
205	LINK20.	3	0	0	000072	0	0	1	000235	202	208
208	XCOMMON	3	0	0	000072	0	0	1	000225	205	13
13	QBNTRY	3	0	0	000067	16	0	1	000001	208	214
214	SYSTEMC	3	0	0	000067	0	0	1	000154	13	217
217	SYSTEMP	3	4	0	000067	0	0	1	000201	214	49
49	END	3	0	0	000067	52	0	1	000075	217	43
43	STOP	3	0	0	000067	46	0	1	000125	49	85
85	EXIT	3	0	0	000067	211	0	1	000117	43	220
220	ABNORML	3	0	0	000067	0	0	1	000136	85	226
226	SIO$	1	0	8	001317	0	0	1	000000	220	244
244	CIO1.	3	0	0	000342	0	0	1	001035	226	247
247	RCL1.	3	0	0	000342	0	0	1	001046	244	250
250	DAT.	3	0	0	000342	0	0	1	000002	247	241
241	SIO.CTL	3	0	0	000342	0	0	1	000230	250	235
235	INITL.	3	0	0	000342	0	0	1	000250	241	232
232	SIO.	3	0	0	000342	0	0	1	000314	235	238
238	SIO.END	3	0	0	000342	0	0	1	001011	232	229
229	OPEN.	3	0	0	000342	0	0	1	001054	238	253
253	RDPRU.	3	0	0	000342	0	0	1	001115	229	256
256	BKSPRU.	3	0	0	000342	0	0	1	001132	253	223
223	ADVIN.	3	0	0	000342	0	0	1	001137	256	259
259	POSFI.	3	0	0	000342	0	0	1	001164	223	262
262	MVWDS.	3	0	0	000342	0	0	1	001304	259	265
265	GETBA	1	0	11	000017	0	0	1	000001	262	268
268	KODER	1	0	18	001216	0	0	1	000001	265	142
142	IOREAD	3	0	0	000221	0	0	1	000040	268	148
148	IOWRITE	3	0	0	000221	0	0	1	000046	142	271
271	IOREWRT	3	0	0	000221	0	0	1	000043	148	274
274	IOIO	3	0	0	000221	0	0	1	000051	271	277
277	IOSAV	3	0	0	000221	0	0	1	000011	274	280
280	IOZZ	3	0	0	000221	0	0	1	000204	277	283
283	IOZW	3	0	0	000221	0	0	1	000210	280	286
286	D.BCDRD	3	0	0	000221	0	0	1	000030	283	289
289	D.BCDWR	3	0	0	000221	0	0	1	000034	286	133
133	IORR	3	0	0	000210	0	0	1	000000	289	139
139	IORW	3	0	0	000210	0	0	1	000013	133	301
301	IORRW	3	0	0	000210	0	0	1	000046	139	304
304	CPC02	3	0	0	000136	0	0	1	000124	301	292
292	CPC03	3	0	0	000136	0	0	1	000000	304	295
295	CPC04	3	0	0	000136	0	0	1	000017	292	298
298	CPC999	3	0	0	000136	307	0	1	000232	295	310
310	ACGOER	1	0	21	000012	0	0	1	000001	298	0

Figure 22(c). Linkage editor tables after object deck processing for Link 0.

DUMP OF LINKAGE EDITOR TABLES AFTER LKED025

---LIBRARY TABLE---

LIBNAME	LIBCNT
	0
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	5	000000
2	6	8	000000

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	367	343	349
2	295	370	352	352
3	298	373	355	361
4	304	376	364	364
5	313	316	0	0
6	319	322	0	0
7	325	328	0	0
8	331	340	0	0
9	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS	LENGTH	PARENT
1		000000	000000	0
2	A00000A	333333	333301	1
3	A00000A	333333	333301	1
4	B00000B	333333	333302	3
5	B00000B	333333	333302	3
6	C00000C	333333	333303	0
7	D00000D	333333	333304	6
8	D00000D	333333	333304	6

Figure 23(a). Linkage editor tables after object deck processing for Link 1.

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		0	XTRACE

---LINK 0 DICTIONARY---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
4	LINK0*	0	0	0	000000	0	0	0	000101	0	0
7	MAIN	0	0	0	000000	0	0	0	001376	0	0
10	COM0	0	0	0	000000	0	0	0	002504	0	0
13	COM3	0	0	0	000000	0	0	0	002506	0	0
16	SYSTEM.	0	0	0	000000	0	0	0	002716	0	0
19	MAPFNS	0	0	0	000000	0	0	0	003571	0	0
22	OUTPTC	0	0	0	000000	0	0	0	004034	0	0
25	XLOADER	0	0	0	000000	0	0	0	004126	0	0
28	LOADER.	0	0	0	000000	0	0	0	004235	0	0
31	LINK	0	0	0	000000	0	0	0	004127	0	0
34	XTRACE	0	0	0	000000	0	0	0	004364	0	0
37	XDUMP	0	0	0	000000	0	0	0	004341	0	0
40	COMPARE	0	0	0	000000	0	0	0	004360	0	0
43	ABSENT.	0	0	0	000000	0	0	0	004444	0	0
46	XIORTNS	0	0	0	000000	0	0	0	004450	0	0
49	LINKERR	0	0	0	000000	0	0	0	004763	0	0
52	CORDUMP	0	0	0	000000	0	0	0	005161	0	0
55	CPC	0	0	0	000000	0	0	0	005701	0	0
58	XOPEN	0	0	0	000000	0	64	0	004460	0	0
61	XCLOSE	0	0	0	000000	0	0	0	004515	0	0
64	XEVICT	0	0	0	000000	0	0	0	004524	0	0
67	REINDX	0	0	0	000000	0	271	0	004531	0	0
70	XWRITE	0	0	0	000000	0	0	0	004537	0	0
73	XREAD	0	0	0	000000	0	0	0	004560	0	0
76	XREWIND	0	0	0	000000	0	0	0	004607	0	0
79	XBKREC	0	0	0	000000	0	0	0	004616	0	0
82	XFRDREC	0	0	0	000000	0	0	0	004631	0	0
85	XBKPREC	0	0	0	000000	0	0	0	004624	0	0
88	XREQST	0	0	0	000000	0	0	0	004636	0	0
91	WRITEX	0	0	0	000000	0	0	0	004652	0	0
94	READX	0	0	0	000000	0	0	0	004713	0	0
97	IORANDM	0	313	0	000000	0	0	0	006076	0	0
100	IO	0	0	0	000000	0	0	0	006302	0	0
103	ANDF	0	0	0	000000	0	0	0	003603	0	0
106	ORF	0	0	0	000000	0	0	0	003607	0	0
109	COMPLF	0	0	0	000000	0	0	0	003613	0	0
112	XORF	0	0	0	000000	0	0	0	003572	0	0

Figure 23(b). Linkage editor tables after object deck processing for Link 1.

115	RSHIFT	0	0	0	000000	0	0	0	00363o	0	0
118	LSHIFT	0	0	0	000000	0	0	0	003616	0	0
121	CORSZ	0	0	0	000000	0	0	0	003576	0	0
124	CORWDS	0	0	0	000000	0	0	0	003665	0	0
127	XSTORE	0	0	0	000000	0	0	0	003542	0	0
130	XFETCH	0	0	0	000000	0	0	0	003647	0	0
133	LWORDS	0	0	0	000000	0	0	0	003661	0	0
136	XJUMP	0	0	0	000000	0	334	0	003676	0	0
139	ZAP	0	0	0	000000	0	0	0	003675	0	0
142	LOCF	0	0	0	000000	0	0	0	003704	0	0
145	FIELDLN	0	0	0	000000	0	0	0	003707	0	0
148	FLUSH	0	0	0	000000	0	0	0	003723	0	0
151	RECOVRY	0	0	0	000000	0	0	0	003726	0	0
154	TDATE	0	0	0	000000	0	0	0	003746	0	0
157	DAYTIME	0	0	0	000000	0	0	0	003766	0	0
160	KLOCK	0	0	0	000000	0	0	0	004004	0	0
163	LINK20.	0	0	0	000000	0	0	0	004020	0	0
166	XCOMMON	0	0	0	000000	0	0	0	004010	0	0
169	QBNTRY	0	0	0	000000	0	0	0	002511	0	0
172	SYSTEMC	0	0	0	000000	0	0	0	00266e	0	0
175	SYSTEMP	0	0	0	000000	0	0	0	002711	0	0
178	END	0	0	0	000000	0	0	0	002605	0	0
181	STOP	0	0	0	000000	0	0	0	002635	0	0
184	EXIT	0	0	0	000000	0	0	0	002627	0	0
187	ABNORML	0	0	0	000000	0	0	0	002645	0	0
190	SIO$	0	0	0	000000	0	0	0	006516	0	0
193	CIO1.	0	0	0	000000	0	0	0	007553	0	0
196	RCL1.	0	0	0	000000	0	0	0	007564	0	0
199	DAT.	0	0	0	000000	0	0	0	006526	0	0
202	SIO.CTL	0	0	0	000000	0	0	0	006746	0	0
205	INITL.	0	0	0	000000	0	0	0	006766	0	0
208	SIO.	0	0	0	000000	0	0	0	007032	0	0
211	SIO.END	0	0	0	000000	0	0	0	007527	0	0
214	OPEN.	0	0	0	000000	0	0	0	007572	0	0
217	RDPRU.	0	0	0	000000	0	0	0	007633	0	0
220	BKSPRU.	0	0	0	000000	0	0	0	007650	0	0
223	ADVIN.	0	0	0	000000	0	0	0	007655	0	0
226	POSFI.	0	0	0	000000	0	0	0	007702	0	0
229	MVWDS.	0	0	0	000000	0	0	0	010022	0	0
232	GETBA	0	0	0	000000	0	0	0	010037	0	0
235	KODER	0	0	0	000000	0	0	0	010057	0	0
238	IOREAD	0	0	0	000000	0	0	0	006342	0	0
241	IOWRITE	0	0	0	000000	0	0	0	006350	0	0
244	IOREWRT	0	0	0	000000	0	0	0	006345	0	0
247	IOIO	0	0	0	000000	0	0	0	006353	0	0
250	IOSAV	0	0	0	000000	0	0	0	006313	0	0
253	IOZZ	0	0	0	000000	0	0	0	006500	0	0

Figure 23(c). Linkage editor tables after object deck processing for Link 1.

256	IOZW	0	0	0	000000	0	0	0	006512	0	0
259	D.BCDRD	0	0	0	000000	0	0	0	006332	0	0
262	D.BCDWR	0	0	0	000000	0	0	0	006336	0	0
265	IORR	0	0	0	000000	0	0	0	006076	0	0
268	IORW	0	0	0	000000	0	0	0	006111	0	0
271	IORRW	0	0	0	000000	0	0	0	006136	0	0
274	CPC02	0	0	0	000000	0	0	0	005762	0	0
277	CPC03	0	0	0	000000	0	0	0	005634	0	0
280	CPC04	0	0	0	000000	0	0	0	005652	0	0
283	CPC999	0	0	0	000000	0	0	0	006065	0	0
286	ACGOER	0	0	0	000000	0	0	0	011276	0	0

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	SEGTAB$	2	0	0	000012	0	0	1	000000	0	289
289	PRT0	1	0	106	000164	0	0	1	000001	1	367
367	ENTAB$	2	0	0	000017	0	0	1	000000	289	0

---ENTAB CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
343		6	0	295	0	1	295	1	000001	0	346
346		6	0	331	0	12	331	1	000014	343	349
349		6	0	298	0	1	298	1	000015	346	0

---SYMBOL CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
295	PRT1	1	0	108	000032	343	0	2	000001	0	292
292	COM1	2	0	105	000001	0	0	2	000000	295	370
370	ENTAB$	2	0	0	000003	0	0	2	000000	292	0

---ENTAB CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN

Figure 23(d). Linkage editor tables after object deck processing for Link 1.

352		6	0	325	364	1	325	2	000001	0	0

---SYMBOL CHAIN FOR SEGMENT 3---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
298	PRT2	1	0	109	000036	349	0	3	000001	0	301
301	COM2	2	0	105	000001	0	0	3	000000	298	373
373	ENTAB$	2	0	0	000011	0	0	3	000000	301	0

---ENTAB CHAIN FOR SEGMENT 3---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
355		6	0	304	0	1	304	3	000001	0	358
358		6	0	313	0	1	313	3	000004	355	361
361		6	0	307	0	1	307	3	000007	358	0

---SYMBOL CHAIN FOR SEGMENT 4---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
304	PRT3	1	0	110	000032	355	0	4	000001	0	307
307	PRT4	1	0	111	000032	361	0	4	000001	304	310
310	COM4	2	0	105	000001	0	0	4	000000	307	376
376	ENTAB$	2	0	0	000003	0	0	4	000000	310	0

---ENTAB CHAIN FOR SEGMENT 4---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
364		6	0	352	0	1	325	4	000001	0	0

---SYMBOL CHAIN FOR SEGMENT 5---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
313	PRT5	1	0	112	000030	358	0	5	000001	0	316
316	COM5	2	0	105	000005	0	0	5	000000	313	0

---SYMBOL CHAIN FOR SEGMENT 6---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
319	COM6	2	0	105	000001	0	0	6	000000	0	322
322	PRT6	1	0	113	000030	0	0	6	000001	319	0

Figure 23(e). Linkage editor tables after object deck processing for Link 1.

---SYMBOL CHAIN FOR SEGMENT 7---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
325	PRT7	1	0	114	000042	352	0	7	000001	0	328
328	COM7	2	0	0	000001	0	0	7	000000	325	0

---SYMBOL CHAIN FOR SEGMENT 8---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
331	PRT8	1	0	115	000147	346	0	8	000007	0	334
334	COM8	2	0	0	000001	0	0	8	000000	331	337
337	PRT9	1	0	116	000030	0	0	8	000001	334	340
340	COM9	2	0	0	000001	0	0	8	000000	337	0

Figure 23(f). Linkage editor tables after object deck processing for Link 1.

3. Steps (1) and (2) are repeated for each segment in the link.

4. The segment numbers defining a region are extracted from the RDT (section 7.2.2.1.5).

5. Starting with the last segment in the region, each possible path in the region is traced and lengths of the paths are accumulated. Inspection of the RDT for Link 1 in Figure 25 indicates the segment numbers for Region one are 1 through 5. Looking at the SDT in the same figure, one sees that the possible paths are 5-3-1, 4-3-1, 3-1, 2-1, 1. While it is true that certain of these paths are subsets of others, the longest path will be found by a "brute force" technique.

6. Steps (4) and (5) are repeated for each region in the link.

7. If Link 0, the initial address in Region 1 is assigned as 100_8. Otherwise, the initial address in Region 1 is the last address in Link 0 plus one.

8. The initial address in each region is stored in the RDT by starting with the initial address for Region 1 and accumulating the lengths of each region.

9. The logic of steps (4) and (5) is repeated and final addresses are thus assigned to each of the segments. These addresses are stored in the SDT.

10. It now remains to assign addresses to each of the entries in each of the segments. This is accomplished by following the chain for each segment. Starting with the initial address in the segment, lengths of each control section entry (CLASS = 1 or 2) are accumulated. Addresses for alternate entry points (CLASS = 3) are assigned by adding the address of the primary entry (the L field points to it) to the relative address of the entry point in the A field (see GT explanation, section 7.2.2.1.9). When a primary entry (CLASS = 1) is completed, the ARG bit is set to indicate this. If an alternate entry point is encountered prior to assigning an address to the primary entry, a logic error abort (LKED990) occurs.

Figures 24 and 25 show the tables as they appear after address assignment processing for Links 0 and 1, respectively. The asterisk in certain of the symbol entries indicates that the ARG bit is on.

DUMP OF LINKAGE EDITOR TABLES AFTER LKED050

---LIBRARY TABLE---

LIBNAME	LIBCNT
LINKLIB	1
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	1	000100

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	310	0	0
2	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS,LENGTH	PARENT
1	4 AJG	000100 011207	0

---RENAME TABLE---

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		4	XTRACE
4	SYSTEM	0		0	SYSTEM.

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	LINK0$	2	0	0	001273	0	0	1	000101	0	4
4	MAIN	1	0	103	001375	0 *	0	1	001376	1	7
7	COM0	2	0	0	000001	0	0	1	002504	4	10
10	COM3	2	0	0	000001	0	0	1	002506	7	55

Figure 24(a). Linkage editor processing after address assignment processing for Link 0.

55	SYSTEM.	1	0	7	002510	0	*	0	1	002710	10	58
58	MAPFNS	1	0	6	003571	0	*	0	1	003571	55	31
31	OUTPTC	1	0	9	004032	34	*	0	1	004034	58	61
61	XLOADER	1	0	2	004126	0	*	0	1	004126	31	64
64	LOADER.	3	0	0	000075	0		0	1	004235	61	37
37	LINK	3	0	0	000075	40		0	1	004127	64	67
67	XTRACE	3	0	0	000075	0		0	1	004364	37	70
70	XDUMP	3	0	0	000075	0		0	1	004341	67	73
73	COMPARE	3	0	0	000075	0		0	1	004360	70	76
76	ABSENT.	3	0	0	000075	0		0	1	004444	73	82
82	XIORTNS	1	0	3	004450	0	*	0	1	004456	76	88
88	LINKERR	1	0	17	004762	0	*	0	1	004763	82	91
91	CORDUMP	1	0	16	005160	0	*	0	1	005161	88	94
94	CPC	1	0	14	005633	0	*	0	1	005701	91	97
97	XOPEN	3	0	0	000122	0		0	1	004460	94	100
100	XCLOSE	3	0	0	000122	0		0	1	004515	97	103
103	XEVICT	3	0	0	000122	0		0	1	004524	100	106
106	REINDX	3	0	0	000122	0		0	1	004531	103	109
109	XWRITE	3	0	0	000122	0		0	1	004537	106	112
112	XREAD	3	0	0	000122	0		0	1	004560	109	115
115	XREWIND	3	0	0	000122	0		0	1	004607	112	118
118	XBKREC	3	0	0	000122	0		0	1	004616	115	121
121	XFRDREC	3	0	0	000122	0		0	1	004631	118	124
124	XBKPREC	3	0	0	000122	0		0	1	004624	121	127
127	XREQST	3	0	0	000122	0		0	1	004636	124	130
130	WRITEX	3	0	0	000122	0		0	1	004652	127	79
79	READX	3	0	0	000122	0		0	1	004713	130	136
136	IORANDM	1	0	13	006076	0	*	0	1	006076	79	145
145	IO	1	0	12	006302	0	*	0	1	006305	136	151
151	ANDF	3	0	0	000072	0		0	1	003603	145	154
154	ORF	3	0	0	000072	0		0	1	003607	151	157
157	COMPLF	3	0	0	000072	0		0	1	003613	154	160
160	XORF	3	0	0	000072	0		0	1	003572	157	163
163	RSHIFT	3	0	0	000072	0		0	1	003630	160	166
166	LSHIFT	3	0	0	000072	0		0	1	003616	163	169
169	CORSZ	3	0	0	000072	0		0	1	003576	166	172
172	CORWDS	3	0	0	000072	0		0	1	003665	169	175
175	XSTORE	3	0	0	000072	0		0	1	003642	172	178
178	XFETCH	3	0	0	000072	0		0	1	003647	175	181
181	LWORDS	3	0	0	000072	0		0	1	003665	178	184
184	XJUMP	3	0	0	000072	0		0	1	003672	181	25
25	ZAP	3	0	0	000072	28		0	1	003675	184	187
187	LOCF	3	0	0	000072	0		0	1	003704	25	19
19	FIELDLN	3	0	0	000072	22		0	1	003707	187	190
190	FLUSH	3	0	0	000072	0		0	1	003723	19	193
193	RECOVRY	3	0	0	000072	0		0	1	003724	190	196

Figure 24(b). Linkage editor processing after address assignment processing for Link 0.

196	TDATE	3	0	0	000072	0		0	1	003746	193	199
199	DAYTIME	3	0	0	000072	0		0	1	003766	196	202
202	KLOCK	3	0	0	000072	0		0	1	004004	199	205
205	LINK20.	3	0	0	000072	0		0	1	004026	202	208
208	XCOMMON	3	0	0	000072	0		0	1	004014	205	13
13	QBNTRY	3	0	0	000067	16		0	1	002511	208	214
214	SYSTEMC	3	0	0	000067	0		0	1	002662	13	217
217	SYSTEMP	3	4	0	000067	0		0	1	002711	214	49
49	END	3	0	0	000067	52		0	1	002605	217	43
43	STOP	3	0	0	000067	46		0	1	002635	49	85
85	EXIT	3	0	0	000067	211		0	1	002627	43	220
220	ABNORML	3	0	0	000067	0		0	1	002645	85	226
226	SIO$	1	0	8	006516	0	*	0	1	006516	220	244
244	CIO1.	3	0	0	000342	0		0	1	007553	226	247
247	RCLI.	3	0	0	000342	0		0	1	007564	244	250
250	DAT.	3	0	0	000342	0		0	1	006520	247	241
241	SIO.CTL	3	0	0	000342	0		0	1	006746	250	235
235	INITL.	3	0	0	000342	0		0	1	006766	241	232
232	SIO.	3	0	0	000342	0		0	1	007032	235	238
238	SIO.END	3	0	0	000342	0		0	1	007527	232	229
229	OPEN.	3	0	0	000342	0		0	1	007575	238	253
253	RDPRU.	3	0	0	000342	0		0	1	007633	229	256
256	BKSPRU.	3	0	0	000342	0		0	1	007650	253	223
223	ADVIN.	3	0	0	000342	0		0	1	007655	256	259
259	POSFI.	3	0	0	000342	0		0	1	007702	223	262
262	MVWDS.	3	0	0	000342	0		0	1	010022	259	265
265	GETBA	1	0	11	010036	0	*	0	1	010037	262	268
268	KODER	1	0	18	010056	0	*	0	1	010057	265	142
142	IOREAD	3	0	0	000221	0		0	1	006345	268	148
148	IOWRITE	3	0	0	000221	0		0	1	006350	142	271
271	IOREWRT	3	0	0	000221	0		0	1	006345	148	274
274	IOIO	3	0	0	000221	0		0	1	006353	271	277
277	IOSAV	3	0	0	000221	0		0	1	006313	274	280
280	IOZZ	3	0	0	000221	0		0	1	006506	277	283
283	IOZW	3	0	0	000221	0		0	1	006515	280	286
286	D.BCDRD	3	0	0	000221	0		0	1	006332	283	289
289	D.BCDWR	3	0	0	000221	0		0	1	006336	286	133
133	IORR	3	0	0	000210	0		0	1	006076	289	139
139	IORW	3	0	0	000210	0		0	1	006111	133	301
301	IORRW	3	0	0	000210	0		0	1	006136	139	304
304	CPC02	3	0	0	000136	0		0	1	005760	301	292
292	CPC03	3	0	0	000136	0		0	1	005634	304	295
295	CPC04	3	0	0	000136	0		0	1	005652	292	298
298	CPC999	3	0	0	000136	307		0	1	006065	295	310
310	ACGOER	1	0	21	011275	0	*	0	1	011276	298	0

Figure 24(c). Linkage editor processing after address assignment processing for Link 0.

DUMP OF LINKAGE EDITOR TABLES AFTER LKED050

---LIBRARY TABLE---

LIBNAME	LIBCNT
	0
OBJ	103
	117

---REGION DEFINITION TABLE---

REGION	1ST SEG	LAST SEG	REG ADDR
1	1	5	011307
2	6	8	011676

---SEGMENT CHAINS TABLE---

SEGMENT	PTR TO 1ST IN SEG CHN	PTR TO LAST IN SEG CHN	PTR TO 1ST IN ENTAB CHN	PTR TO LAST IN ENTAB CHN
1	1	367	343	349
2	295	370	352	352
3	298	373	355	361
4	304	376	364	364
5	313	316	0	0
6	319	322	0	0
7	325	328	0	0
8	331	340	0	0
9	0	0	0	0

---SEGMENT DEFINITION TABLE---

SEGMENT	NAME	OR ADDRESS	LENGTH	PARENT
1	AKG BP	011307	000220	0
2	AMW 6	011527	000041	1
3	AMW %	011527	000053	1
4	ANB <	011602	000074	3
5	ANB 4	011602	000037	3
6	AN¬ 0	011676	000033	0
7	AOY +	011731	000045	6
8	AOY BE	011731	000205	6

---RENAME TABLE---

Figure 25(a). Linkage editor processing after address assignment processing for Link 1.

ENTRY	OLDNAME	HASH PTR	DECK	HASH CHN	NEWNAME
1	XDUMP	1		0	XTRACE

---LINK 0 DICTIONARY---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
4	LINK0$	0	0	0	000000	0	0	0	000101	0	0
7	MAIN	0	0	0	000000	0	0	0	001376	0	0
10	COM0	0	0	0	000000	0	0	0	002504	0	0
13	COM3	0	0	0	000000	0	0	0	002506	0	0
16	SYSTEM.	0	0	0	000000	0	0	0	002710	0	0
19	MAPFNS	0	0	0	000000	0	0	0	003571	0	0
22	OUTPTC	0	0	0	000000	0	0	0	004034	0	0
25	XLOADER	0	0	0	000000	0	0	0	004126	0	0
28	LOADER.	0	0	0	000000	0	0	0	004235	0	0
31	LINK	0	0	0	000000	0	0	0	004127	0	0
34	XTRACE	0	0	0	000000	0	0	0	004364	0	0
37	XDUMP	0	0	0	000000	0	0	0	004341	0	0
40	COMPARE	0	0	0	000000	0	0	0	004360	0	0
43	ABSENT.	0	0	0	000000	0	0	0	004444	0	0
46	XIORTNS	0	0	0	000000	0	0	0	004450	0	0
49	LINKERR	0	0	0	000000	0	0	0	004763	0	0
52	CORDUMP	0	0	0	000000	0	0	0	005161	0	0
55	CPC	0	0	0	000000	0	0	0	005701	0	0
58	XOPEN	0	0	0	000000	0	64	0	004460	0	0
61	XCLOSE	0	0	0	000000	0	0	0	004515	0	0
64	XEVTCT	0	0	0	000000	0	0	0	004524	0	0
67	REINDX	0	0	0	000000	0	271	0	004531	0	0
70	XWRITE	0	0	0	000000	0	0	0	004537	0	0
73	XREAD	0	0	0	000000	0	0	0	004560	0	0
76	XREWIND	0	0	0	000000	0	0	0	004607	0	0
79	XBKREC	0	0	0	000000	0	0	0	004616	0	0
82	XFRDREC	0	0	0	000000	0	0	0	004637	0	0
85	XBKPREC	0	0	0	000000	0	0	0	004624	0	0
88	XREQST	0	0	0	000000	0	0	0	004635	0	0
91	WRITEX	0	0	0	000000	0	0	0	004652	0	0
94	READX	0	0	0	000000	0	0	0	004713	0	0
97	IORANDM	0	313	0	000000	0	0	0	006076	0	0
100	IO	0	0	0	000000	0	0	0	006305	0	0
103	ANDF	0	0	0	000000	0	0	0	003603	0	0
106	ORF	0	0	0	000000	0	0	0	003607	0	0
109	COMPLF	0	0	0	000000	0	0	0	003613	0	0
112	XORF	0	0	0	000000	0	0	0	003572	0	0
115	RSHIFT	0	0	0	000000	0	0	0	003630	0	0

Figure 25(b). Linkage editor processing after address assignment processing for Link 1.

118	LSHIFT	0	0	0	000000	0	0	0	003616	0	0
121	CORSZ	0	0	0	000000	0	0	0	003570	0	0
124	CORWDS	0	0	0	000000	0	0	0	003665	0	0
127	XSTORE	0	0	0	000000	0	0	0	003643	0	0
130	XFETCH	0	0	0	000000	0	0	0	003647	0	0
133	LWORDS	0	0	0	000000	0	0	0	003665	0	0
136	XJUMP	0	0	0	000000	0	334	0	003672	0	0
139	ZAP	0	0	0	000000	0	0	0	003675	0	0
142	LOCF	0	0	0	000000	0	0	0	003704	0	0
145	FIELDLN	0	0	0	000000	0	0	0	003707	0	0
148	FLUSH	0	0	0	000000	0	0	0	003723	0	0
151	RECOVRY	0	0	0	000000	0	0	0	003726	0	0
154	TDATE	0	0	0	000000	0	0	0	003746	0	0
157	DAYTIME	0	0	0	000000	0	0	0	003760	0	0
160	KLOCK	0	0	0	000000	0	0	0	004004	0	0
163	LINK20.	0	0	0	000000	0	0	0	004020	0	0
166	XCOMMON	0	0	0	000000	0	0	0	004016	0	0
169	QBNTRY	0	0	0	000000	0	0	0	002511	0	0
172	SYSTEMC	0	0	0	000000	0	0	0	002664	0	0
175	SYSTEMP	0	0	0	000000	0	0	0	002711	0	0
178	END	0	0	0	000000	0	0	0	002605	0	0
181	STOP	0	0	0	000000	0	0	0	002635	0	0
184	EXIT	0	0	0	000000	0	0	0	002627	0	0
187	ABNORML	0	0	0	000000	0	0	0	002645	0	0
190	SIO$	0	0	0	000000	0	0	0	006516	0	0
193	CIO1.	0	0	0	000000	0	0	0	007553	0	0
196	RCLI.	0	0	0	000000	0	0	0	007564	0	0
199	DAT.	0	0	0	000000	0	0	0	006520	0	0
202	SIO.CTL	0	0	0	000000	0	0	0	006746	0	0
205	INITL.	0	0	0	000000	0	0	0	006766	0	0
208	SIO.	0	0	0	000000	0	0	0	007035	0	0
211	SIO.END	0	0	0	000000	0	0	0	007527	0	0
214	OPEN.	0	0	0	000000	0	0	0	007572	0	0
217	RDPRU.	0	0	0	000000	0	0	0	007633	0	0
220	BKSPRU.	0	0	0	000000	0	0	0	007653	0	0
223	ADVIN.	0	0	0	000000	0	0	0	007656	0	0
226	POSFI.	0	0	0	000000	0	0	0	007702	0	0
229	MVWDS.	0	0	0	000000	0	0	0	010026	0	0
232	GETHA	0	0	0	000000	0	0	0	010037	0	0
235	KODER	0	0	0	000000	0	0	0	010057	0	0
238	IOREAD	0	0	0	000000	0	0	0	006342	0	0
241	IOWRITE	0	0	0	000000	0	0	0	006350	0	0
244	IOREWRT	0	0	0	000000	0	0	0	006345	0	0
247	IOIO	0	0	0	000000	0	0	0	006353	0	0
250	IOSAV	0	0	0	000000	0	0	0	006313	0	0
253	IOZZ	0	0	0	000000	0	0	0	006506	0	0

Figure 25(c). Linkage editor processing after address assignment processing for Link 1.

256	IOZW	0	0	0	000000	0	0	0	006512	0	0
259	D.HCDRD	0	0	0	000000	0	0	0	006332	0	0
262	D.HCDWR	0	0	0	000000	0	0	0	006336	0	0
265	IORR	0	0	0	000000	0	0	0	006076	0	0
268	IORW	0	0	0	000000	0	0	0	006111	0	0
271	IORRW	0	0	0	000000	0	0	0	006136	0	0
274	CPC02	0	0	0	000000	0	0	0	005760	0	0
277	CPC03	0	0	0	000000	0	0	0	005634	0	0
280	CPC04	0	0	0	000000	0	0	0	005652	0	0
283	CPC999	0	0	0	000000	0	0	0	006065	0	0
286	ACGOER	0	0	0	000000	0	0	0	011276	0	0

---SYMBOL CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
1	SEGTAB$	2	0	0	000012	0	0	1	011310	0	289
289	PRT0	1	0	106	011323	0 *	0	1	011324	1	367
367	ENTAB$	2	0	0	000017	0	0	1	011510	289	0

---ENTAB CHAIN FOR SEGMENT 1---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
343		6	0	295	0	1	295	1	011511	0	346
346		6	0	331	0	12	331	1	011522	343	349
349		6	0	298	0	1	298	1	011525	346	0

---SYMBOL CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
295	PRT1	1	0	108	011530	343 *	0	2	011531	0	292
292	COM1	2	0	105	000001	0	0	2	011563	295	370
370	ENTAB$	2	0	0	000003	0	0	2	011565	292	0

---ENTAB CHAIN FOR SEGMENT 2---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS	PTR TO CALL FROM SEG		ADDRESS	-SEG CHN	+SEG CHN
352		6	0	325	364	1	325	2	011566	0	0

---SYMBOL CHAIN FOR SEGMENT 3---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN

Figure 25(d). Linkage editor processing after address assignment processing for Link 1.

298	PRT2	1	0	109	011530	349 *	0	3	011531	0	301
301	COM2	2	0	105	000001	0	0	3	011567	298	373
373	ENTAB$	2	0	0	000011	0	0	3	011575	301	0

---ENTAB CHAIN FOR SEGMENT 3---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS PTR TO CALL	FROM SEG	ADDRESS	-SEG CHN	+SEG CHN
355		6	0	304	0	1	304	3	011572	0	358
358		6	0	313	0	1	313	3	011575	355	361
361		6	0	307	0	1	307	3	011600	358	0

---SYMBOL CHAIN FOR SEGMENT 4---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
304	PRT3	1	0	110	011603	355 *	0	4	011604	0	307
307	PRT4	1	0	111	011636	361 *	0	4	011637	304	310
310	COM4	2	0	105	000001	0	0	4	011671	307	376
376	ENTAB$	2	0	0	000003	0	0	4	011673	310	0

---ENTAB CHAIN FOR SEGMENT 4---

ENTRY	NAME	CLASS	HASH PTR	-CALL	+CALL	ARGS PTR TO CALL	FROM SEG	ADDRESS	-SEG CHN	+SEG CHN
364		6	0	352	0	1	325	4	011674	0	0

---SYMBOL CHAIN FOR SEGMENT 5---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
313	PRT5	1	0	112	011603	358 *	0	5	011604	0	316
316	COM5	2	0	105	000005	0	0	5	011634	313	0

---SYMBOL CHAIN FOR SEGMENT 6---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
319	COM6	2	0	105	000001	0	0	6	011677	0	322
322	PRT6	1	0	113	011701	0 *	0	6	011705	319	0

---SYMBOL CHAIN FOR SEGMENT 7---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
325	PRT7	1	0	114	011732	352 *	0	7	011733	0	328
328	COM7	2	0	0	000001	0	0	7	011775	325	0

Figure 25(e). Linkage editor processing after address assignment processing for Link 1.

---SYMBOL CHAIN FOR SEGMENT 8---

ENTRY	NAME	CLASS	HASH PTR	INDEX	LENGTH	CALL CHN	HASH CHN	SEGMENT	ADDRESS	-SEG CHN	+SEG CHN
331	PRT8	1	0	115	011732	346 *	0	8	011741	0	334
334	COM8	2	0	0	000001	0	0	8	012104	331	337
337	PRT9	1	0	116	012104	0 *	0	8	012105	334	340
340	COM9	2	0	0	000001	0	0	8	012135	337	0

Figure 25(f). Linkage editor processing after address assignment processing for Link 1.

7.2.2.7 Relocation Processing

The primary task of the relocation processor (LKED075) is to build text for each of the control sections that comprise the link. The text is written on SYSUT1, one segment per logical record. The format of the output file is shown in Figure 26. The segment is written in such a way that each segment may be "block" loaded by the segment loader, i.e., there exists one word in the logical record for each word in the segment. Words for which no text or data is defined are set to zero.

Secondary tasks for the relocation processor are the listing on ØUTPUT of the storage map for the link (if MAP is .TRUE.) and writing information on SYSUT3 (if XREF is .TRUE.) to assist in the preparation of aalisting of cross references. See the explanation of the LINKEDIT statement, section 5.6.4.2.

In the case of Link 0, an additional task is to construct the bootstrap program as the first part of SYSUT1. A skeleton Block Data subprogram is defined in the DUMMY array in LKEDC05 (see section 7.2.6. The appropriate length fields of this skeleton Block Data subprogram are completed, the length of the common block XBØØTBD is computed as the Link 0 length + 200_8 so the bootstrap program will load beyond the storage area where Link 0 is to be loaded, and the subprogram is written as the first record on SYSUT1. The remaining subprograms which comprise the bootstrap program are defined in the array BØØTDKS in LKEDC07. These subprograms are copied from SYSUT2 to SYSUT1 (fatal error if not found). Finally, a zero length logical record is written to signify the end of the bootstrap program.

The Link 0 directory record is written next, followed by a Link 0 dictionary record which contains all the entry point and common block names and their addresses.

For links other than Link 0, the 3-word directory record is written.

The first control section for Link 0 is LINK0$. The format of LINK0$ is shown in Figure 27 (see section 5.6.4.2 for an explanation of the PARAM array). The first control section for a link other than Link 0 is SEGTAB$. Its format is shown in Figure 28. Depending on the link, LINK0$ or SEGTAB$ is assembled and written as the first part of segment one.

Thereafter, each entry in the segment chain is unpacked. If the entry is CLASS = 1, the PIDL Table (see section 7.2.5) of the subprogram is read from SYSUT2 (during relocation processing,

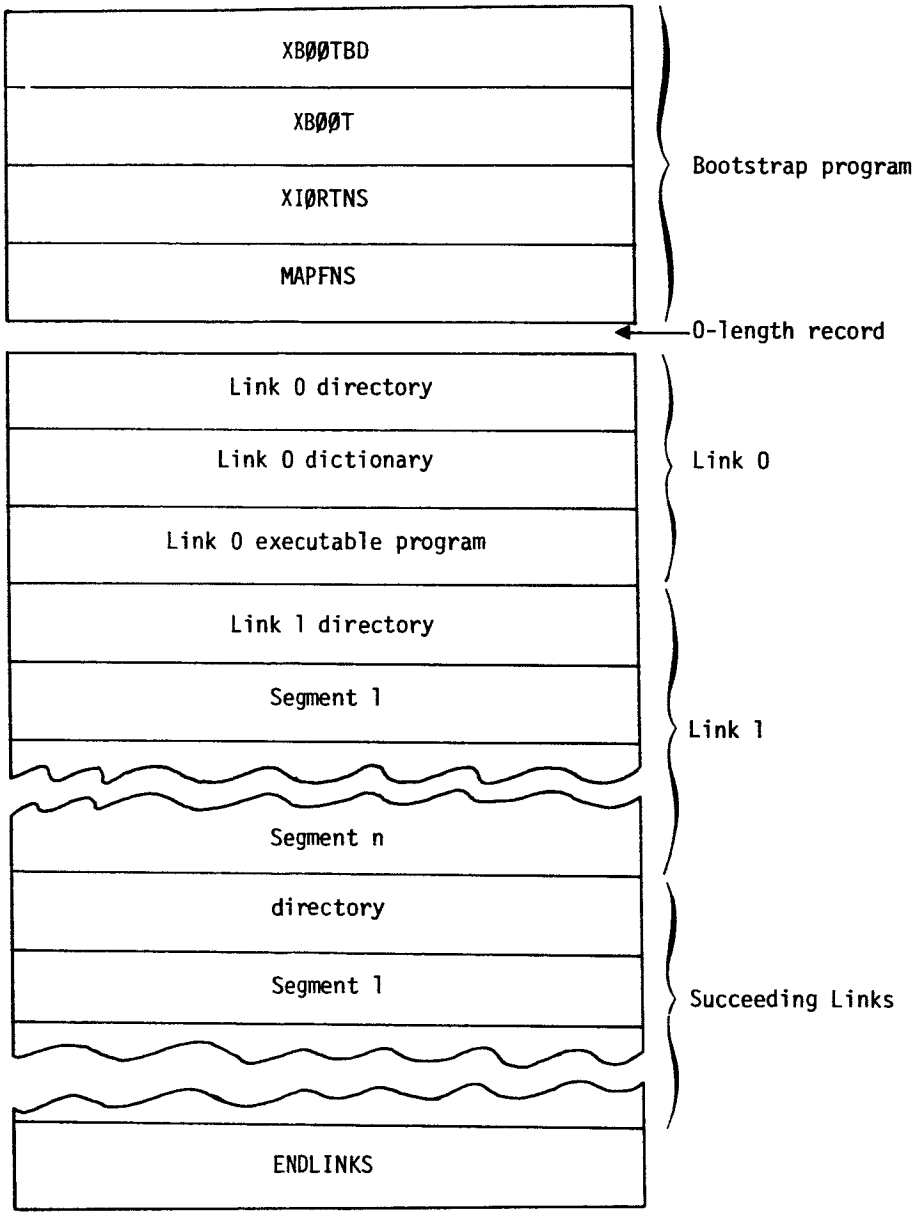


Figure 26. Format of the output file.

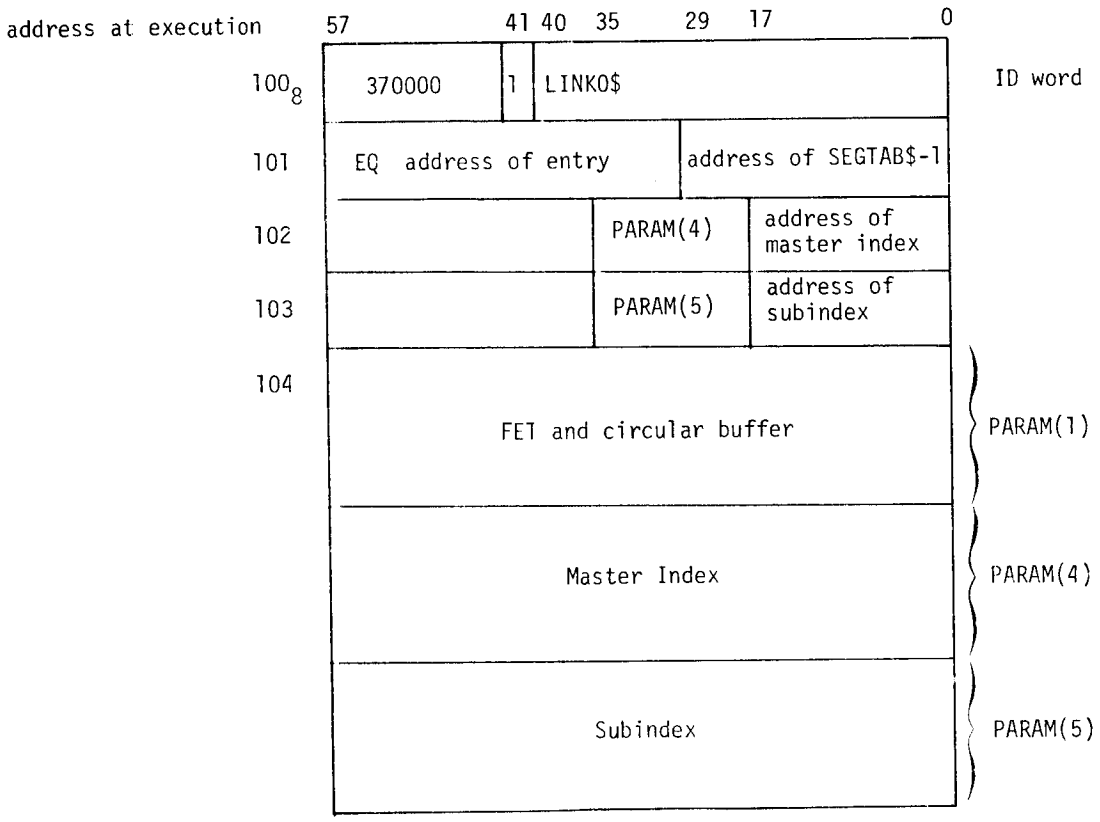


Figure 27. Format of LINKO$.

objects decks are read one table at a time thus minimizing object deck storage space and maximizing storage space available for text building). The entry corresponding to each common block in the LCT of the PIDL Table is located in the GT and the address of the common block is stored in the LCT.

The ENTR Table (see section 7.2.5) is read next. The address of each of the entry points is determined by locating the entry in the GT corresponding to the entry point name. If XREF is selected, the subprogram name and address and each of the entry point names and addresses are written on SYSUT3.

An area in working storage corresponding to the length of the control section is initialized to zero. The control section identification (ID) word (sometimes referred to as the "dump control word") is stored in the first word of the area. Thereafter, the text is assembled and relocation of relative to final addresses is performed according to the TEXT, FILL, LINK and REPL Tables of the object deck (see section 7.2.5). These tables are read one at a time from SYSUT2 and the appropriate relocation routine is called. When the end of the object deck is encountered, the text area in working storage is written in the current logical record on SYSUT1.

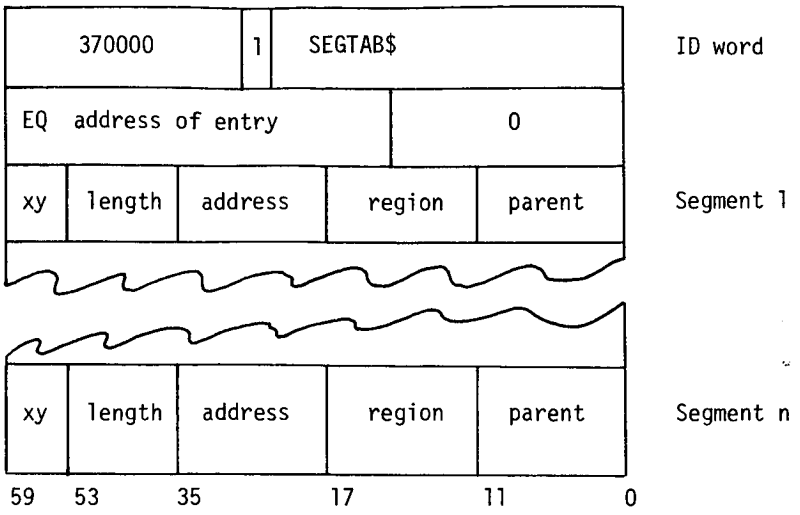
Relocation of external references in the LINK Table is performed in the following way:

1. If the call is in the load path of the segment making the call, the final address is the address of the reference.

2. Otherwise, the call chain is traced and the final address of the reference is an entry in the ENTAB$ table (see Figure 29) of the calling segment which in turn will call the segment loader to determine if the called segment is to be loaded (it may already be in storage).

If no text or data is defined for the control section, then the control section ID word is written in the logical record followed by zero words equal in number to the length of the control section.

The last control section in a segment may be ENTAB$. There will be an ENTAB$ in each segment which has references not in the path. Figure 29 shows the format of an ENTAB$ entry. If this control section is present for the segment, LKED075 assembles the text for each entry and writes it in SYSUT1.



at execution time:

x = 1: segment is in core
0: segment is not in core

y = 1: segment is scheduled to be loaded
0: segment is not scheduled to be loaded

Figure 28. Format of SEGTAB$

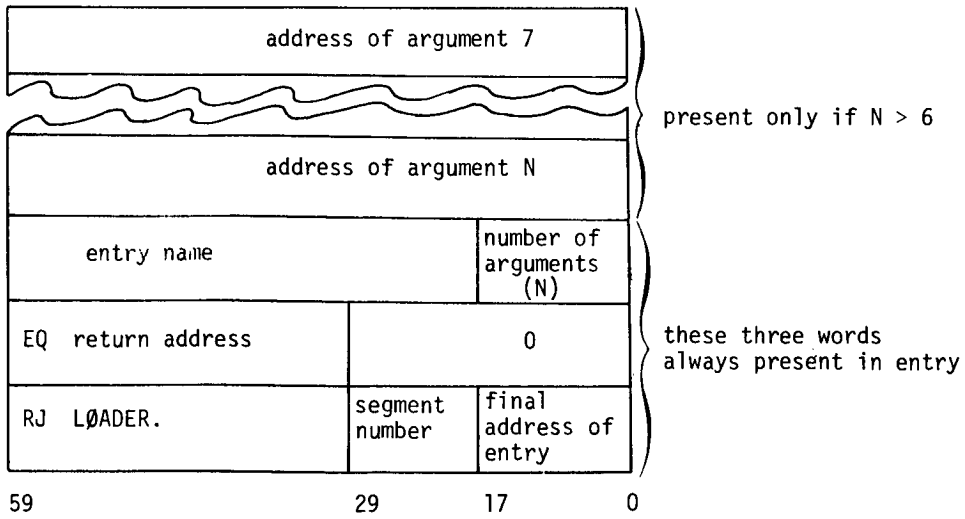


Figure 29. Format of an entry in ENTAB$.

When each of the segments of the link is complete, the status of the logical variable of XREF (see 7.2.6) is tested. If .TRUE., LKED077 is called to format and print a listing of cross references.

LKED077 begins by allocating the XREF table (see section 7.2.2.1.10) to the working space formally occupied by the RDT, SCT, SDT, RT, GT, and object deck and text building storage areas as these latter tables and areas are no longer needed.

The principal input to the cross reference processing is the information on SYSUT3 written by LKED075. Figure 30 shows the format of SYSUT3. Two types of chains are maintained. The first is a list chain in which entry-point entries are chained in order they appear in the storage map (and the order in which references will be listed) and the second is a chain of all the calls to each entry point.

Names are located in the XREF table in the same way as the GT through the hash technique (see section 7.2.2.1.1). (An inspection of the entry formats detailed in section 7.2.2.1.10 indicates that the initial hash pointer and hash chain pointer fields are in the same position as the GT.)

Up to 11 calls from a given subprogram to a given entry point are stored in one XREF entry since that is the maximum number of calls that can be listed in one printer line.

Two list options are provided in conjunction with the cross reference processing. Both are controlled by PARAM(7) (see section 5.6.4.2). The first is to produce a listing of all references from each subprogram (essentially the contents of the LINK Table of the object deck). This is provided because of a deficiency in the output of the RUN compiler. The second option is to list all references to Link 0 entry points for links other than Link 0.

7.2.2.8 Final Processing

LKED080 performs final processing. It is called when the ENDLINKS card (see section 5.6.4.12) is encountered. If the status of ØUTFILE is C, processing is already complete and LKED080 returns. Otherwise, the output file is written. Figure 26 shows the format of the output file.

The first step is to write the bootstrap program. This is done in a manner similar to that described in section 7.2.2.7 except that the required object decks are copied from LINKLIB instead

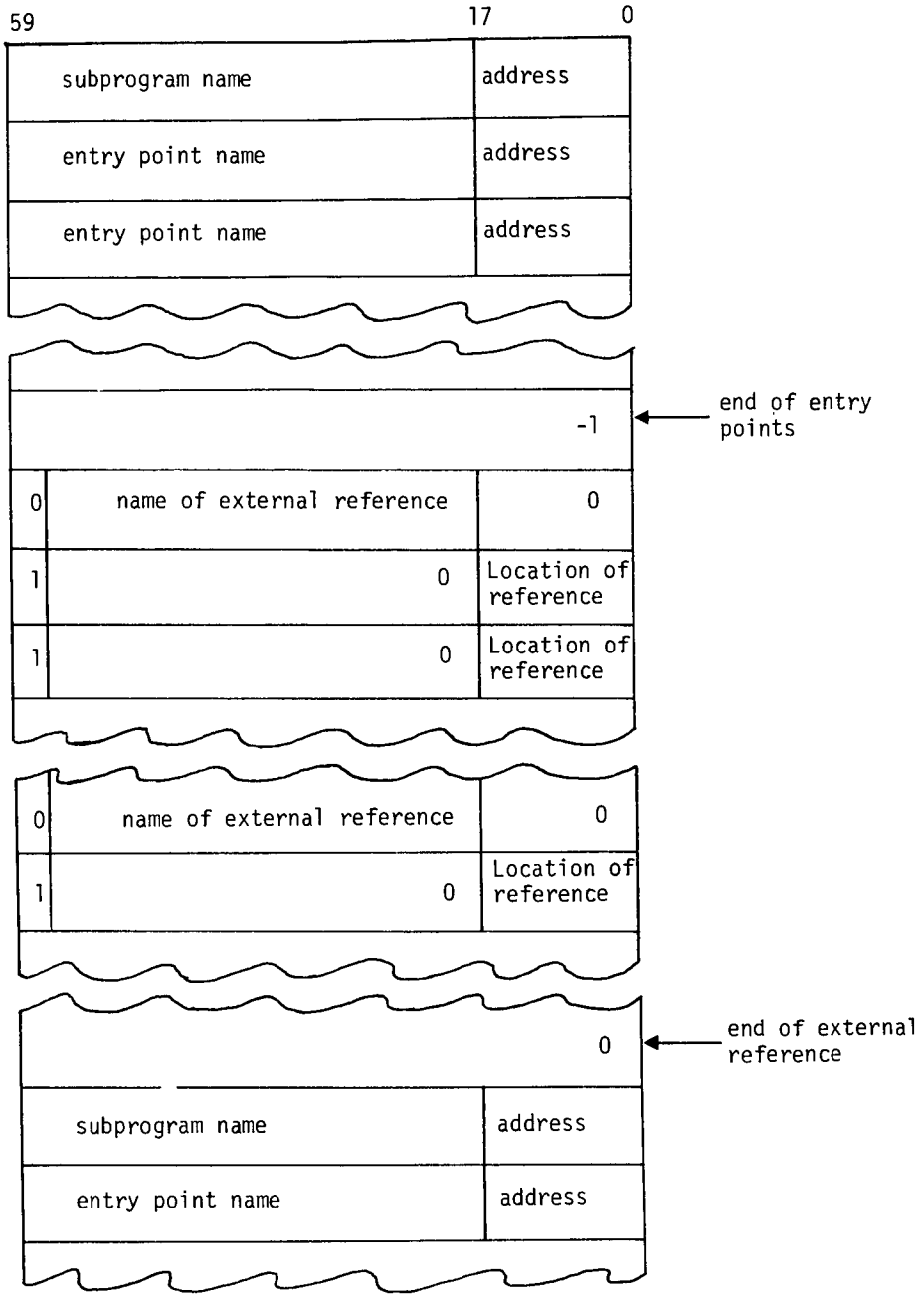
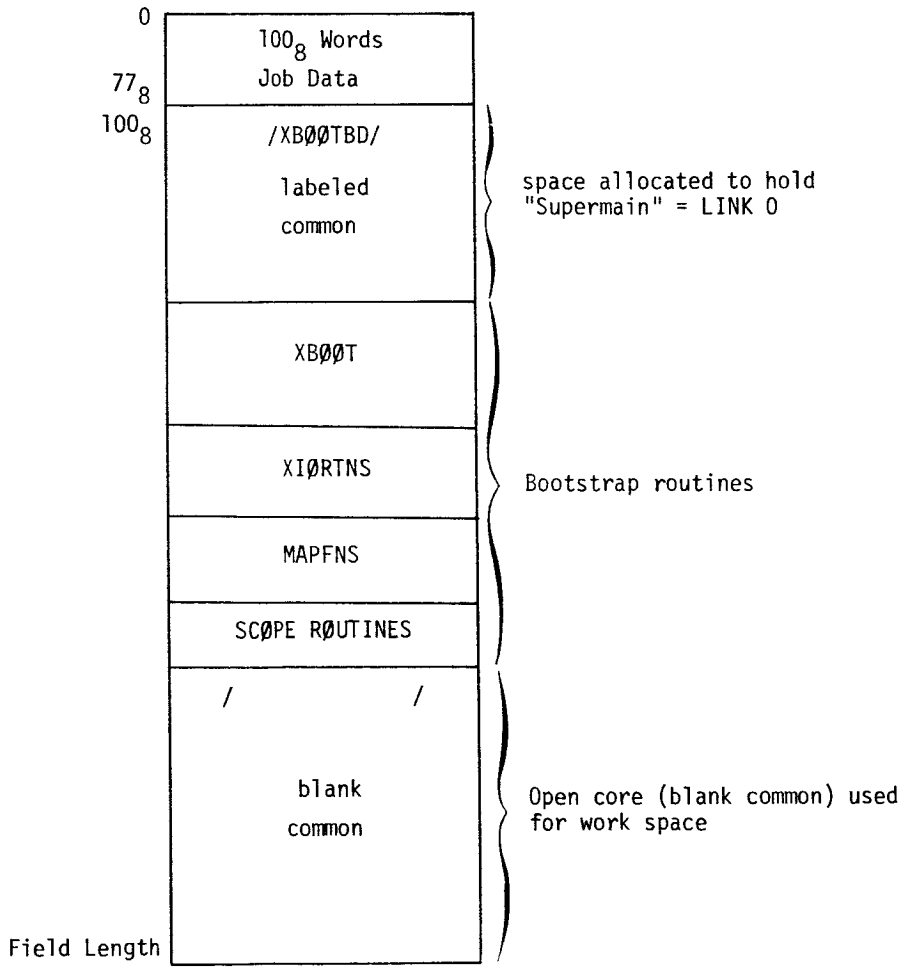


Figure 30. Format of SYSUT3.

of SYSUT2 (the reason for this difference is that in the level 1.0 version (the initial version) of the linkage editor the bootstrap decks were not necessarily on SYSUT2). Thereafter, each of the links is copied from SYSUT1 to the output file. When each link is copied, a message is written on ØUTPUT signifying the event. When all links have been copied, a 3-word record is written with the contents of the first word being ENDLINKS. This is followed by an end-of-file.

7.2.2.9 The Bootstrap Program

As discussed briefly in section 7.2.1.4.7, the bootstrap program itself loaded by the standard CDC loader. The CDC loader loads relocatable records from the beginning of information on a file until a null record or end of file is encountered. After the CDC loader completes the loading of the bootstrap program, core will be as diagrammed here.



The bootstrap driver XBØØT begins execution and immediately fetches the control card image directing the current job step. This card and subsequent control card images are normally stored in locations 70_8 through 77_8 of the job control block.

The control card should be in one of the following formats.

(1) Name1.

In this format, NAME1. is the file name of the sequential linkage editor output. Execution of the control card causes the bootstrap program to be loaded, and it in turn will copy the entire executable file to disk file SYSLMØD in direct access format. Link 0 will then be loaded and transfer of execution will be made into Link 0.

(2) Name1.CREATE(Name2)

In this format, NAME1 is the file name of the sequential linkage editor output. However in this case, the bootstrap program will copy file Name1 to a direct access file Name2 and declare it to be a common file. Link 0 will then be loaded and transfer of execution will be made into Link 0.

(3) Name1.CATLØG(Name2)

In this format Name1 is the file name of the sequential linkage editor output. However in this case, the bootstrap program will only copy file Name1 to a local direct access file Name2.

(4) Name1.ATTACH

In this case, Name1 is the direct access file containing the executable program and if it is available to the job control point either locally or through a permanent file attach or a common file attach, the bootstrap program will be loaded by the CDC loader. The bootstrap program in turn will load Link 0 into core and transfer of execution will be made into Link 0.

The bootstrap program breaks down the control card into two file names NAME1 and NAME2 (NAME2 may be blank), and ØPTIØN will be either blank, CREATE, CATLØG, or ATTACH. Having this information, the bootstrap program will then decide whether or not the file NAME1 is to be catalogued for direct access on file NAME2. If it does have to be catalogued, that process is performed immediately.

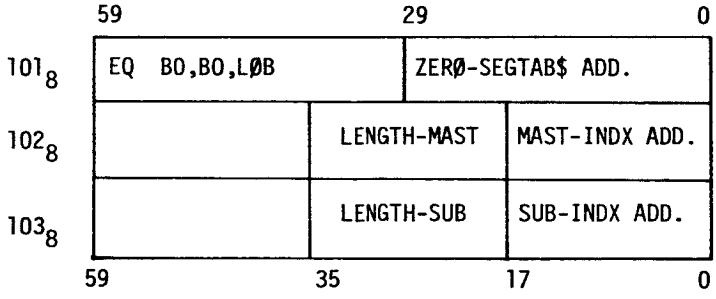
Once it is determined that the file is in direct access format (an ATTACH was made or it was put in direct access format) for execution of the program, "Supermain"=Link 0, the always-core-resident program segment, is read directly into core. A transfer is made directly to location 101_8 where a jump to the actual entry point of supermain is stored. The bootstrap program is then lost and is unrecoverable. However, it is not needed for the continuing execution of the program.

Detailed logic of the cataloguing process of the file for direct access may be found in the logic flowchart for XBØØT, Figure 39. The bootstrap program is contained entirely in one FØRTRAN subroutine which is well and heavily commented and should also be referenced. Refer also to section 7.2.1.4.7.

7.2.2.10 The Segment Loader

Detailed execution of the segment loader XLØADER is covered best in the detailed comments of the actual code and the flowcharts of XLØADER's two entry points LINK and LØADER.. (Figures 40 and 41).

Entry point LINK in the segment loader utilizes information stored in locations 101_8, 102_8, and 103_8 (in the LINKO$ table) as follows.



LØC is the entry point of Link 0.

LINK stores the contents of word 102_8 in the FET word 8 when reading in a subindex for a link. This subindex is read into the location specified by the subindex address in word 103_8. Then LINK stores the address of the subindex in the FET word 8. The FET is always stored beginning in word 104_8 as allocated by the linkage editor. The master index contains relative track addresses which point to the beginning of particular logical records on the disk as listed here.

MASTER INDEX(1) = Not used

MASTER INDEX(2) = Subindex for Link 0

MASTER INDEX(3) = Subindex for Link 1

MASTER INDEX(4) = Subindex for Link 2

⋮ ⋮

The subindex contains relative track addresses which point to particular logical records defining a particular link.

SUB INDEX(1) points to directory of 3 words containing the link number, the number of segments in the link, and longest possible length of the link when loaded.

SUB INDEX(2) points to Segment 1

SUB INDEX(3) points to Segment 2

⋮ ⋮

LØADER. is the entry point which is called in XLØADER from ENTAB$ tables to handle the automatic loading of segments as required. Each segment loaded by the segment loader results in one call to the PP (peripheral processor) routine CIØ which reads the segment from the disk directly into the core in which the segment is to reside. (This is often referred to as a blast read of a record). LØADER. calls READX for all segment loads, thus avoiding the use of the circular buffer.

LØADER. is concerned with two tables in core. One is SEGTAB$ (Figure 28) which may be located by finding its zero-address in the right 30 bits of core location 101_8. SEGTAB$ contains one word for each segment possible in a link and is terminated with a full word of zero bits. SEGTAB$ is built into the root segment (segment 1) of each link. Link 0 does not have a SEGTAB$. Each word of the SEGTAB$ has the following format:

Bits 0 through 11 = Number of the parent segment or 0 if there is no parent

Bits 12 through 17 = The number of the region the segment is in

Bits 18 through 35 = The address where the segment loads at

Bits 36 through 53 = The length of the segment

Bits 54 through 57 = Unused

Bit 58 = 1 if a segment is about to be loaded by the segment loader. (If this bit is on for any segment, LØADER. or READX should be in execution)

Bit 59 = 1 if the segment is currently considered in core and not overlayed by any other segment when exit from the loader has been made.

The other table used by LØADER. is ENTAB$, a table that resides in any segment which has "downward calls" (calls to a lower segment in a tree or outside a given region). An ENTAB$ table is made up of entries which are 3 words or more in length. See Figure 29 for the format of an entry in ENTAB$.

Often a downward call passing to ENTAB$ and then to LØADER. will, if LØADER. determines the segment is in core pass control directly to the address specified in the ENTAB$ entry. The loader knows where the ENTAB$ entry is because at the entry point to LØADER. is stored a jump back to the address + 1 of the last word of the ENTAB$ entry. This jump back is never used except to determine where LØADER. was called from. LØADER. never returns. It only calls forward. The routine called by LØADER. always returns directly to the routine that called LØADER. via the ENTAB$ entry.

Step-by-step logic is detailed in the logic flowcharts for LINK and LØADER. (Figures 40 and 41), the two subroutines of XLØADER. Segment loads are accomplished by calls to utility routine READX. The systems programmer should also consult the heavily commented CØMPASS subroutine XLØADER. This is a relatively small, self-contained routine. Refer also to section 7.2.1.4.8.

7.2.3 Flowcharts

The following pages give flowcharts for each of the major divisions of the linkage editor, (Figures 31 through 38), the bootstrap program (Figure 39) and the segment loader (Figures 40 and 41). The general flow of the linkage editor is given in Figure 3 and reference to it in connection with Figures 31 through 38 may be helpful. If a flowchart symbol (e.g., a processing rectangle, a decision diamond) is identified by a number (e.g., 910, 921) above and to the left of the symbol, the number is the FØRTRAN statement number where the processing or test can be found. A number followed by the letter "a" (e.g., 330a) in the same position on the flowchart implies the function can be found in the neighborhood of the FØRTRAN statement numbered by the number--330 in the example. If a processing symbol, a rectangular box, of the flowchart is identified by a symbol name above and near the left-hand edge of the box, the box represents a subroutine call and the symbolic name is the subroutine name. The abbreviation "nbr" stands for the word "number".

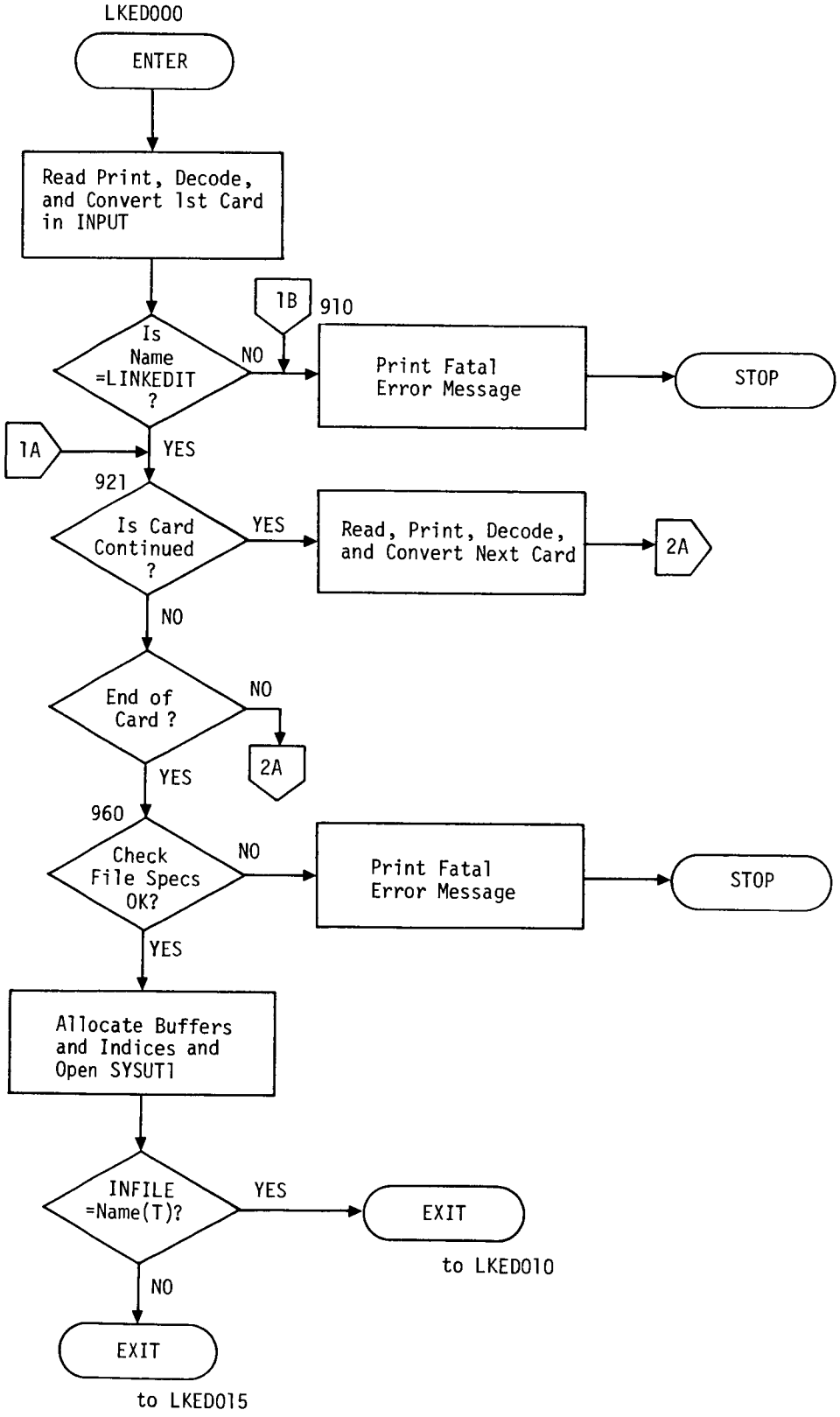


Figure 31(a). Flowchart for LKED000.

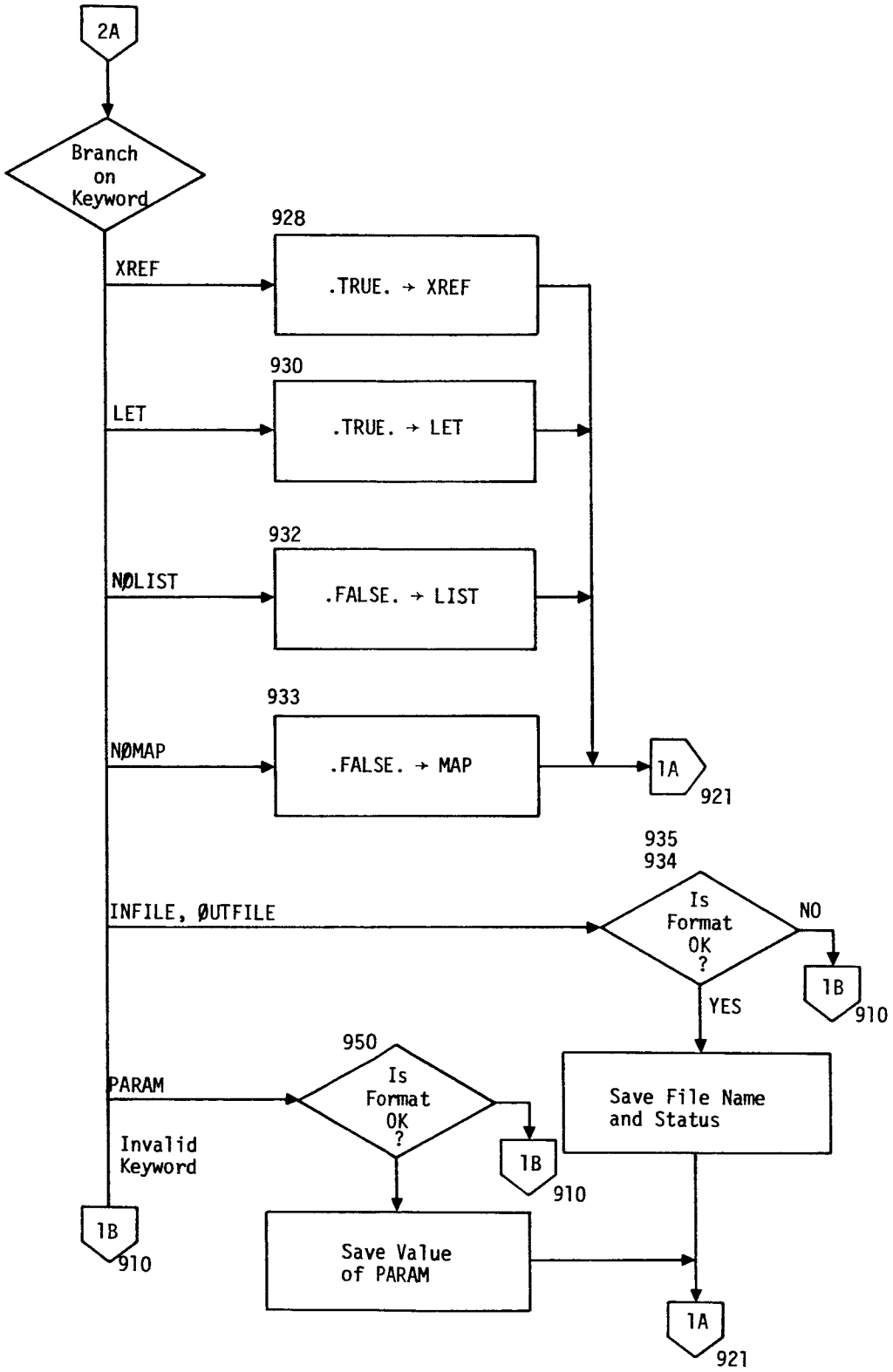


Figure 31(b). Flowchart for LKED000.

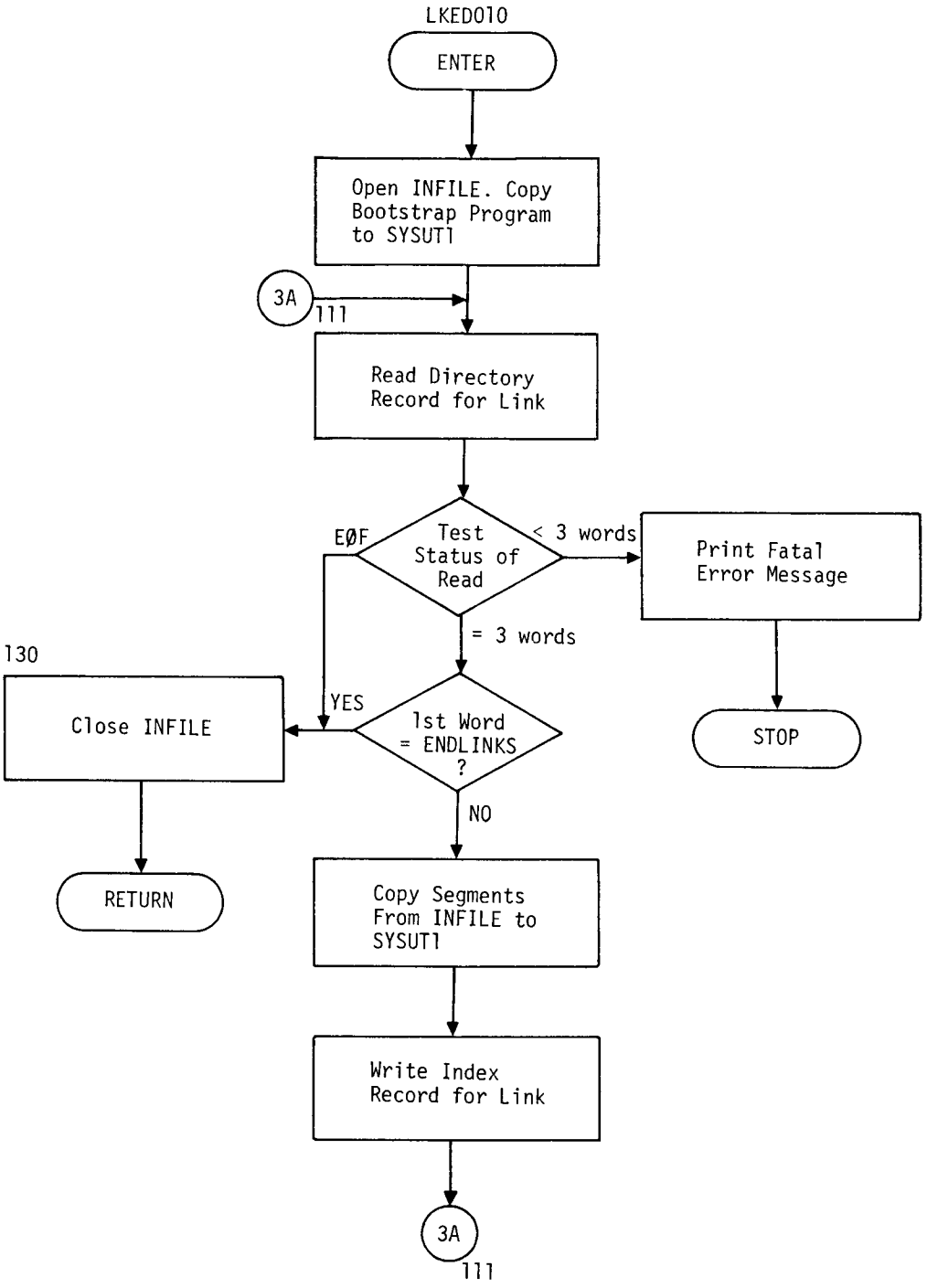


Figure 32. Flowchart for LKED010.

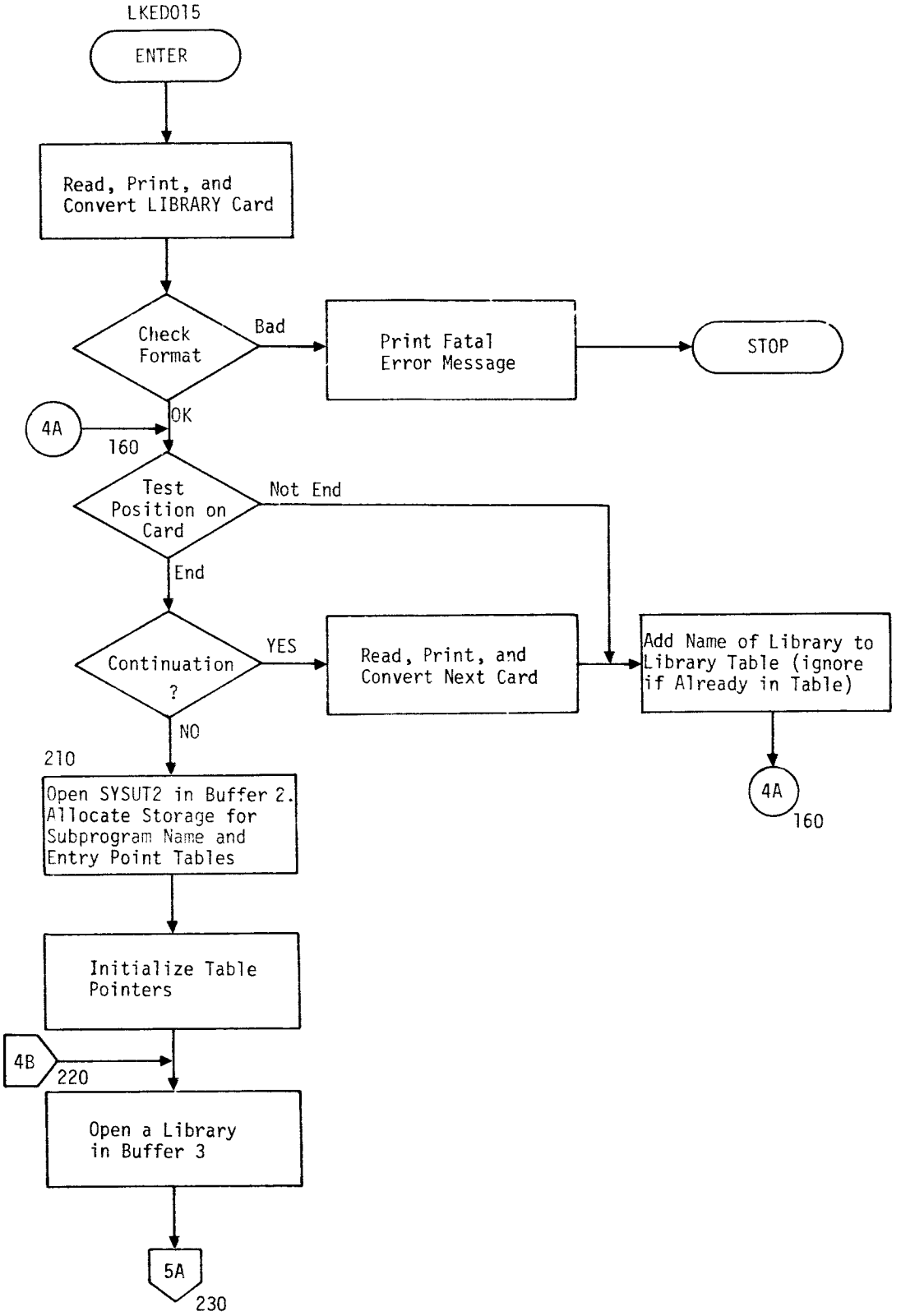


Figure 33(a). Flowchart for LKED015.

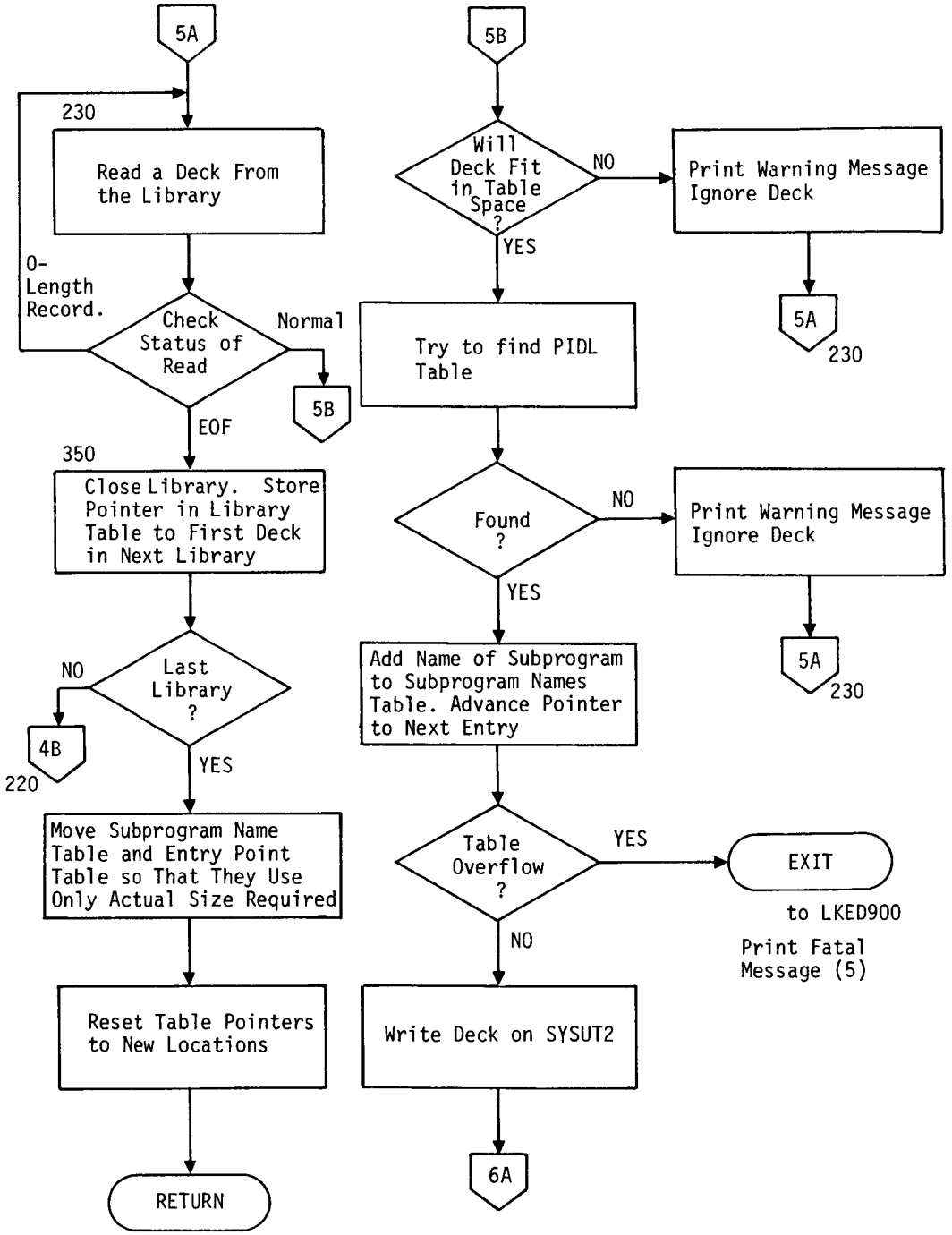


Figure 33(b). Flowchart for LKED015.

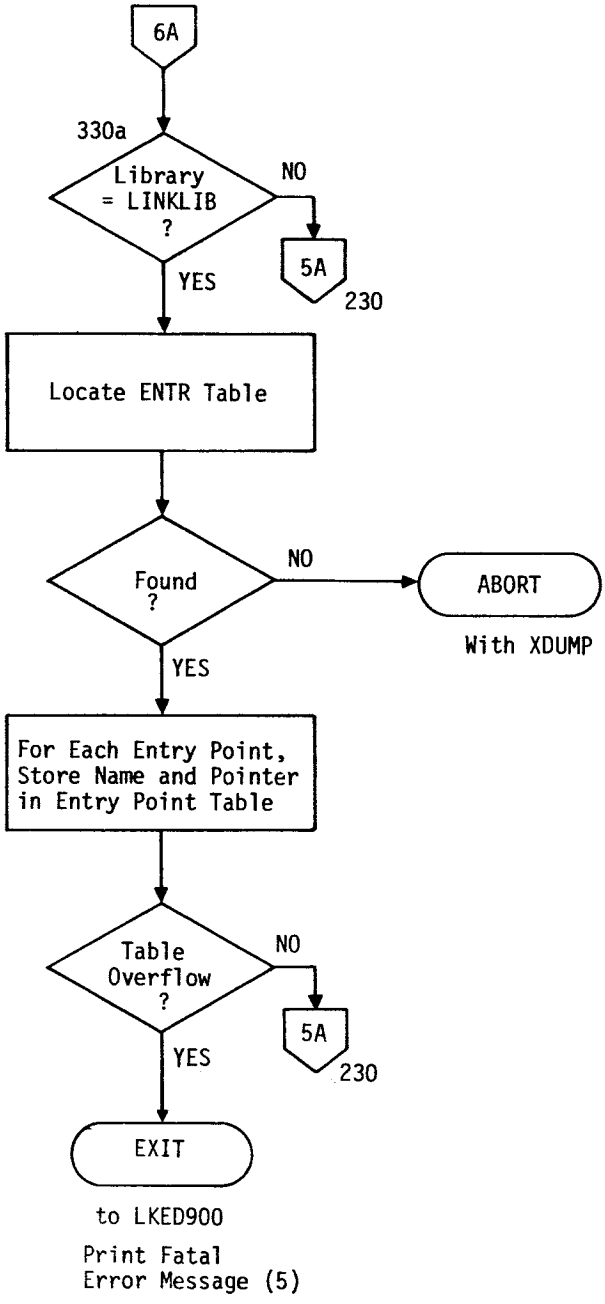


Figure 33(c). Flowchart for LKED015.

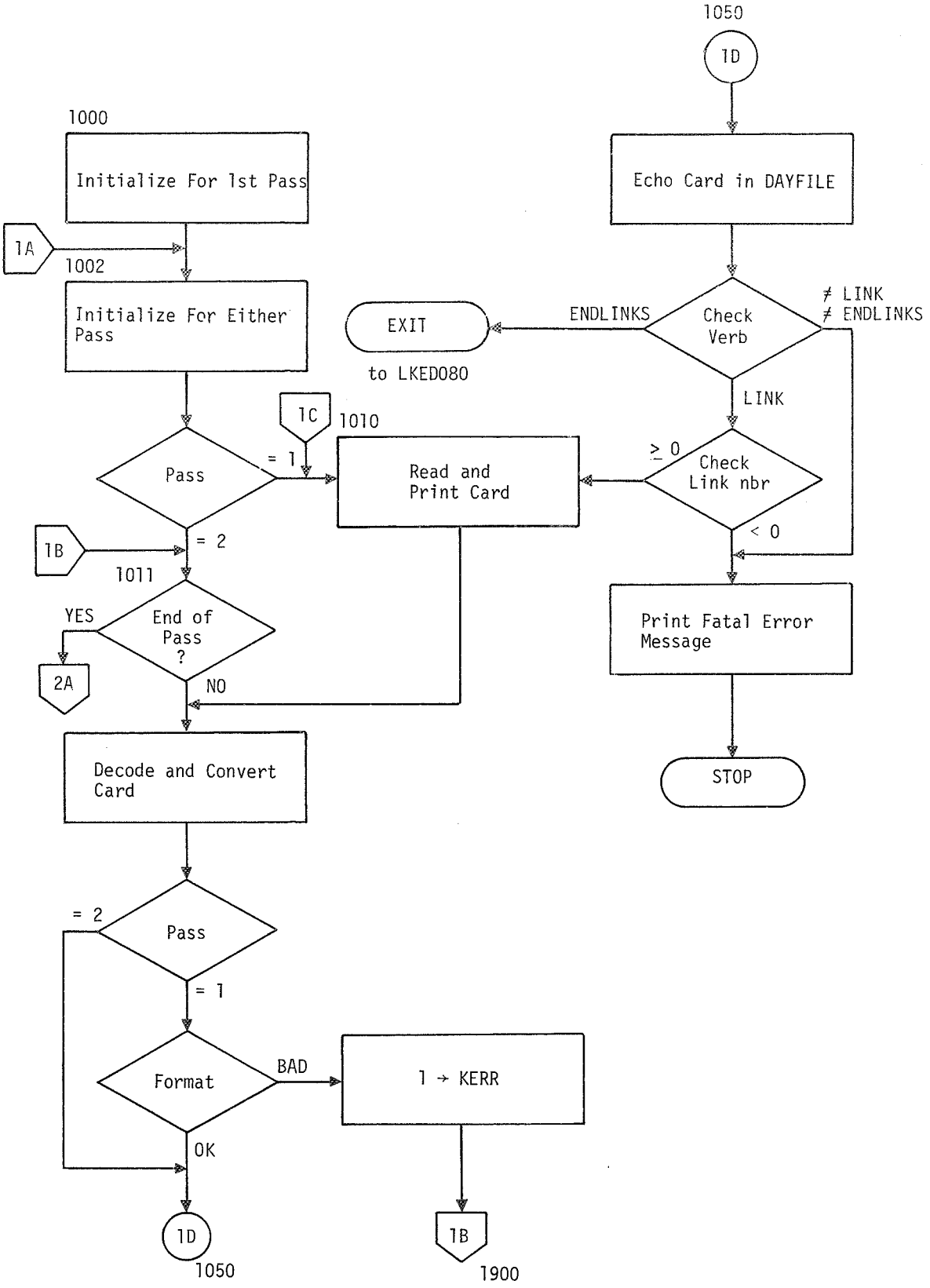


Figure 34(a). Flowchart for control statement processing.

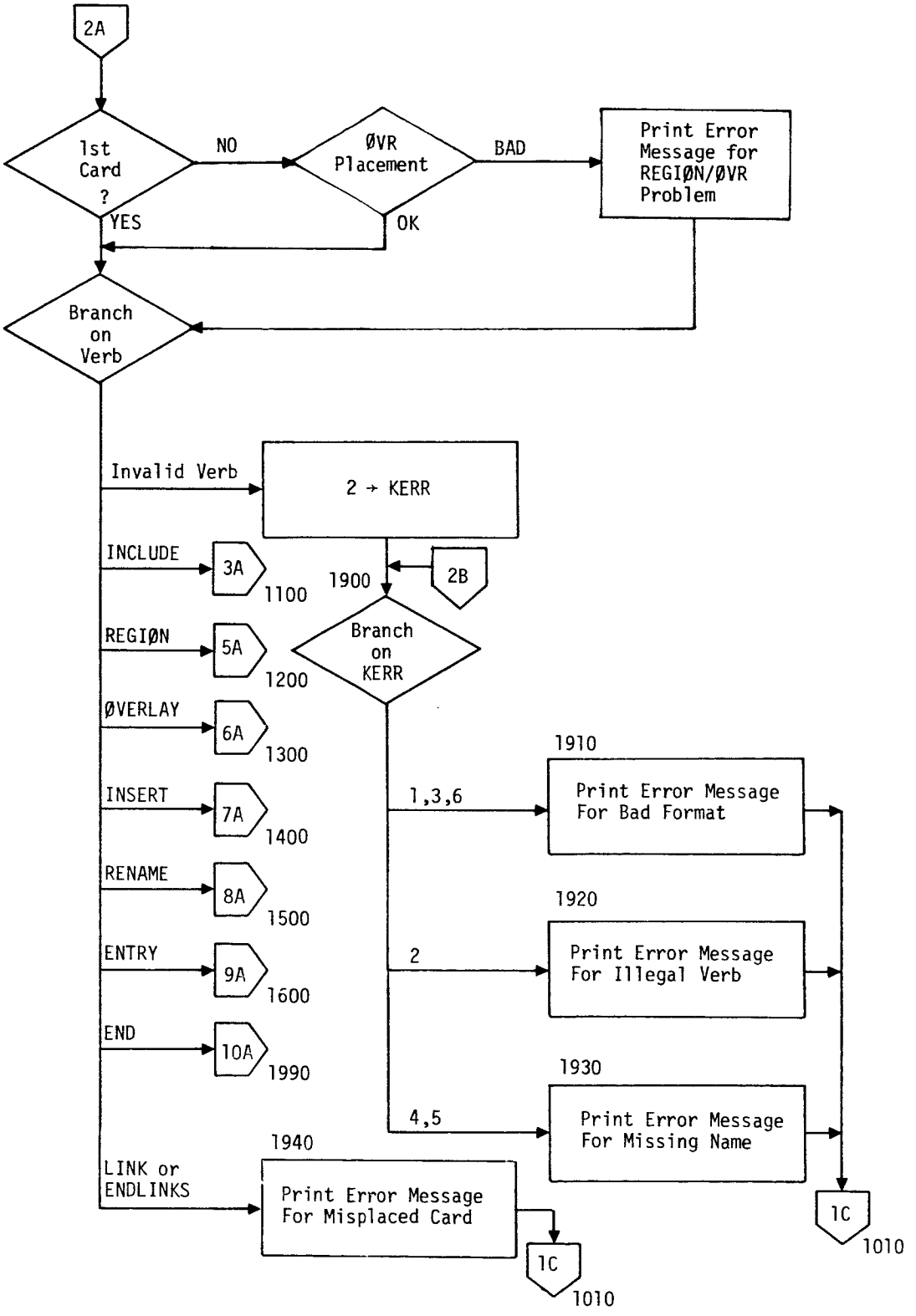


Figure 34(b). Flowchart for control statement processing.

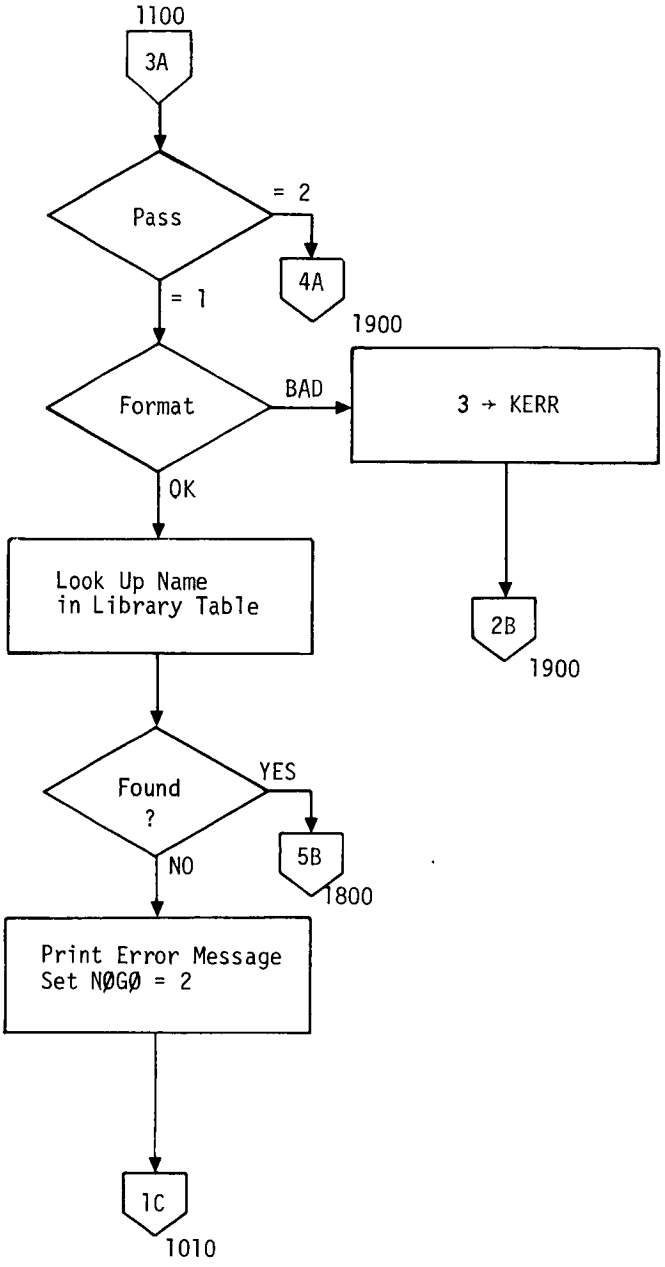


Figure 34(c). Flowchart for control statement processing.

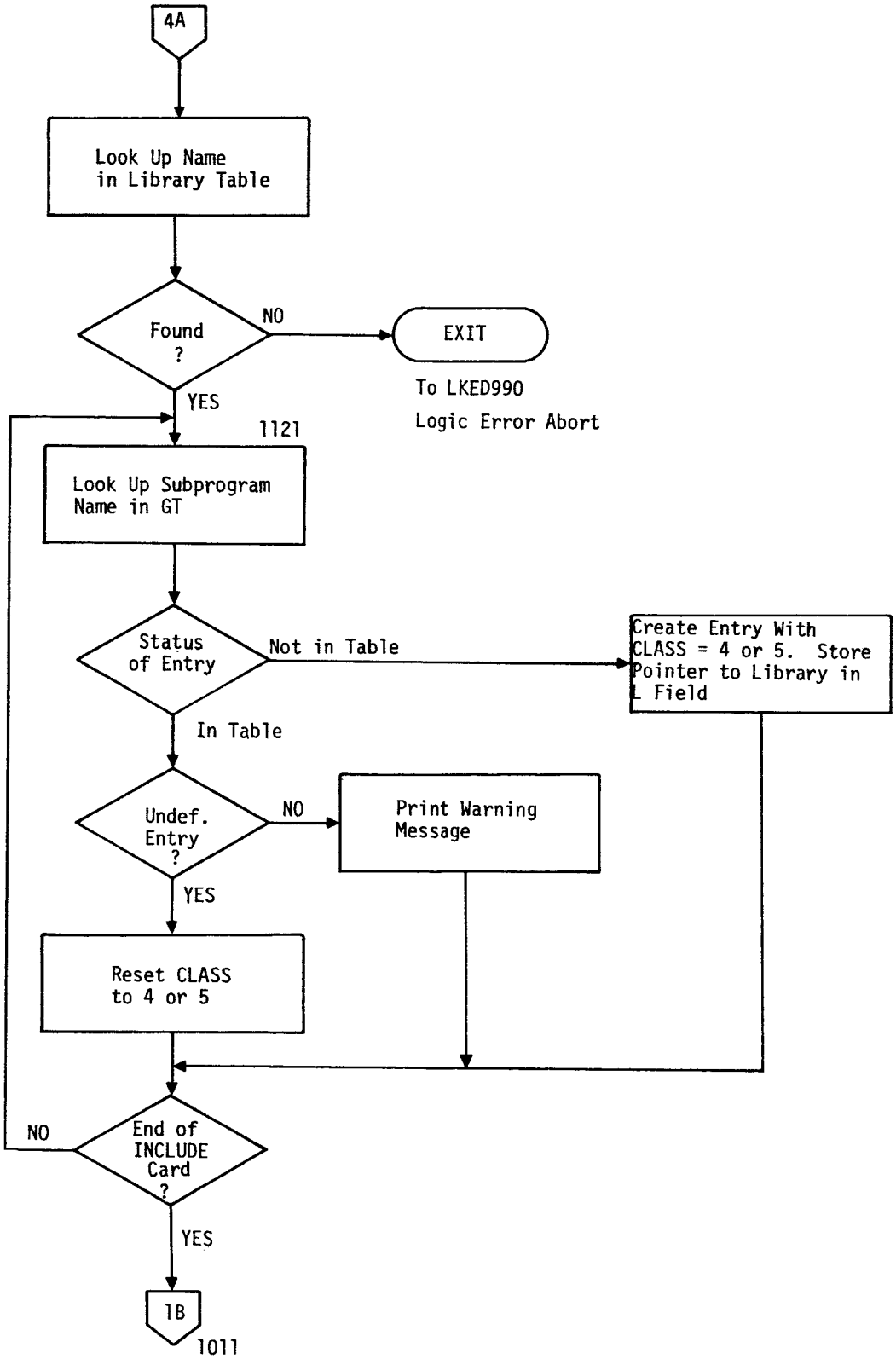


Figure 34(d). Flowchart for control statement processing.

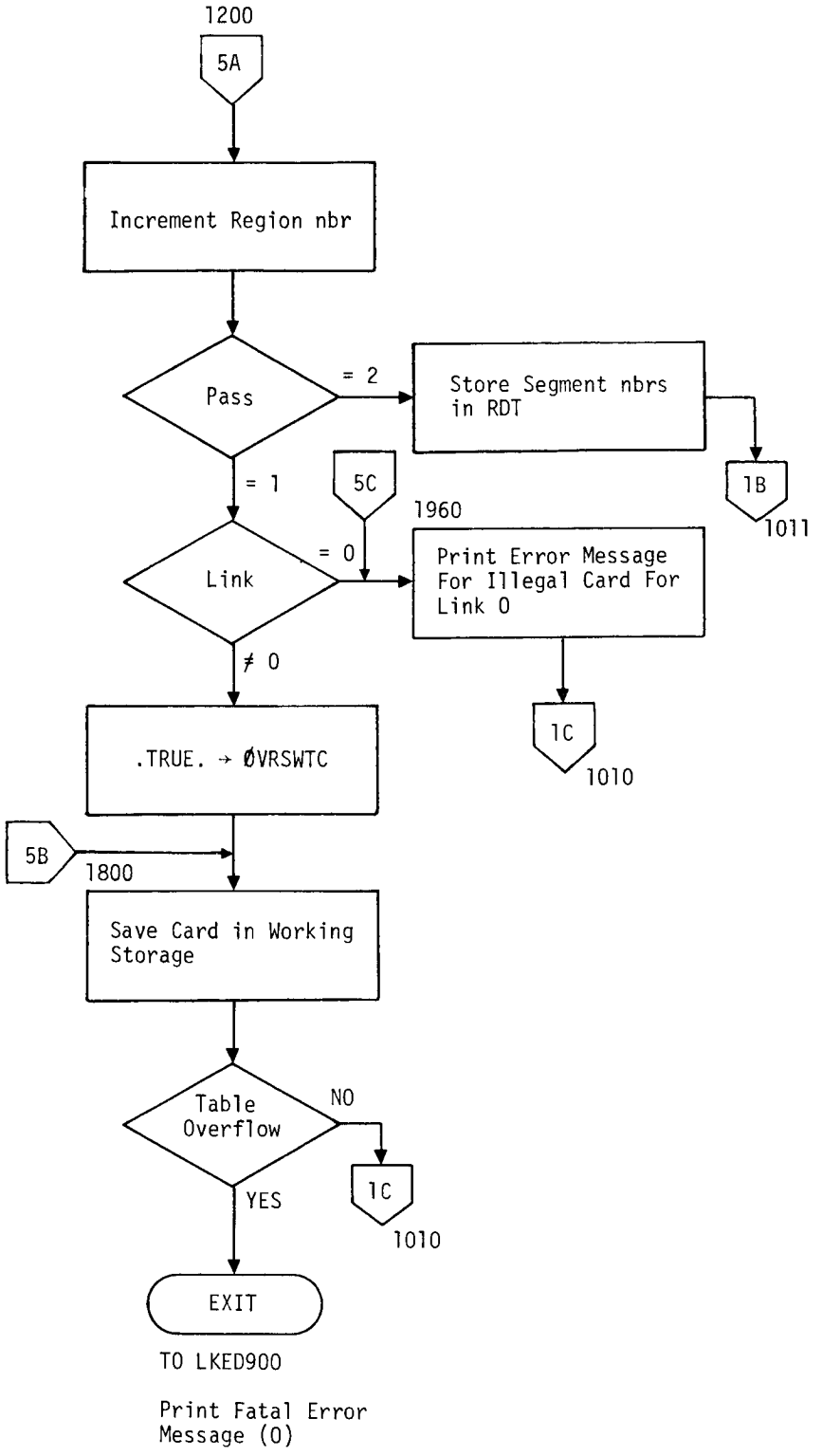


Figure 34(e). Flowchart for control statement processing

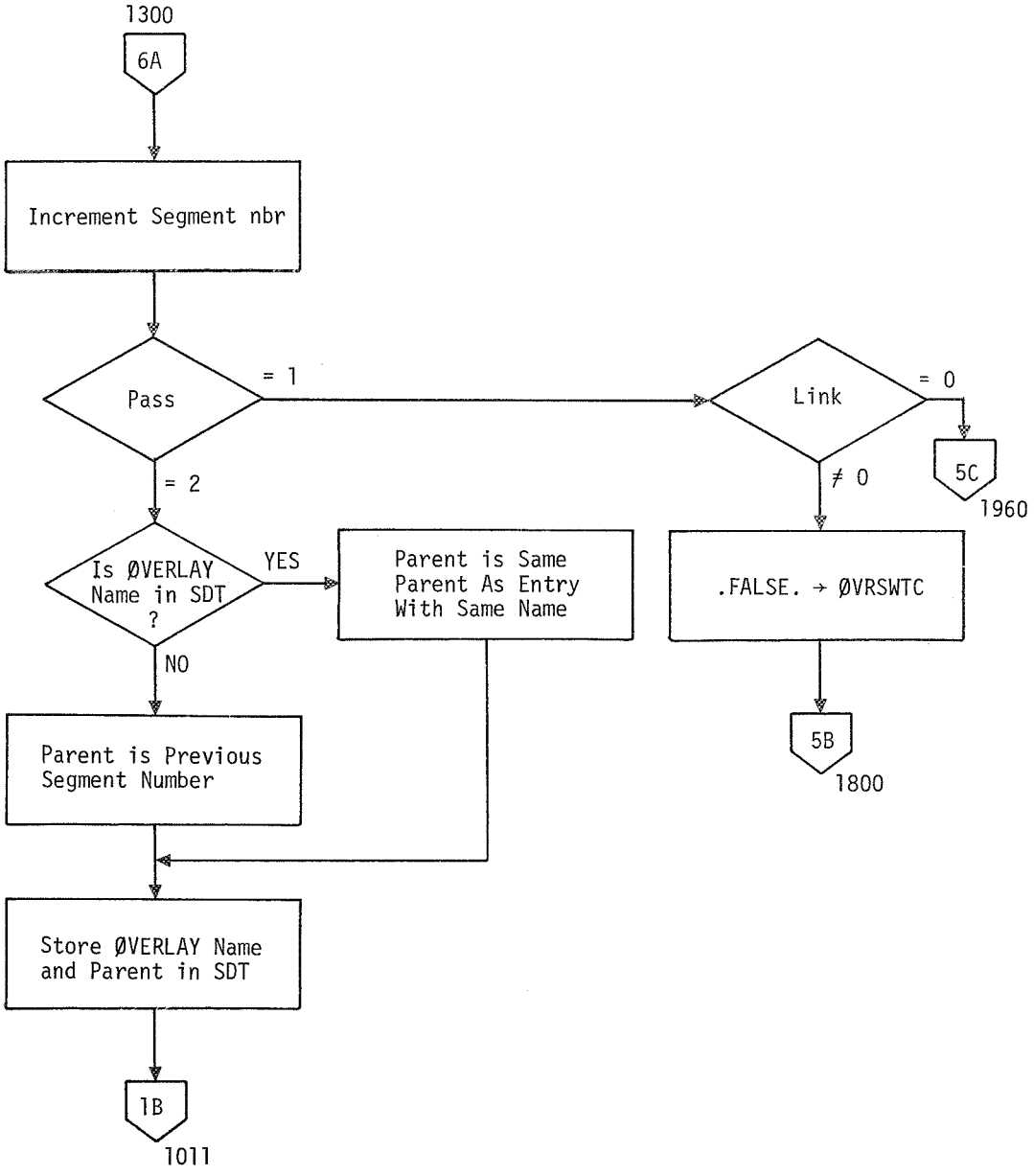


Figure 34(f). Flowchart for control statement processing.

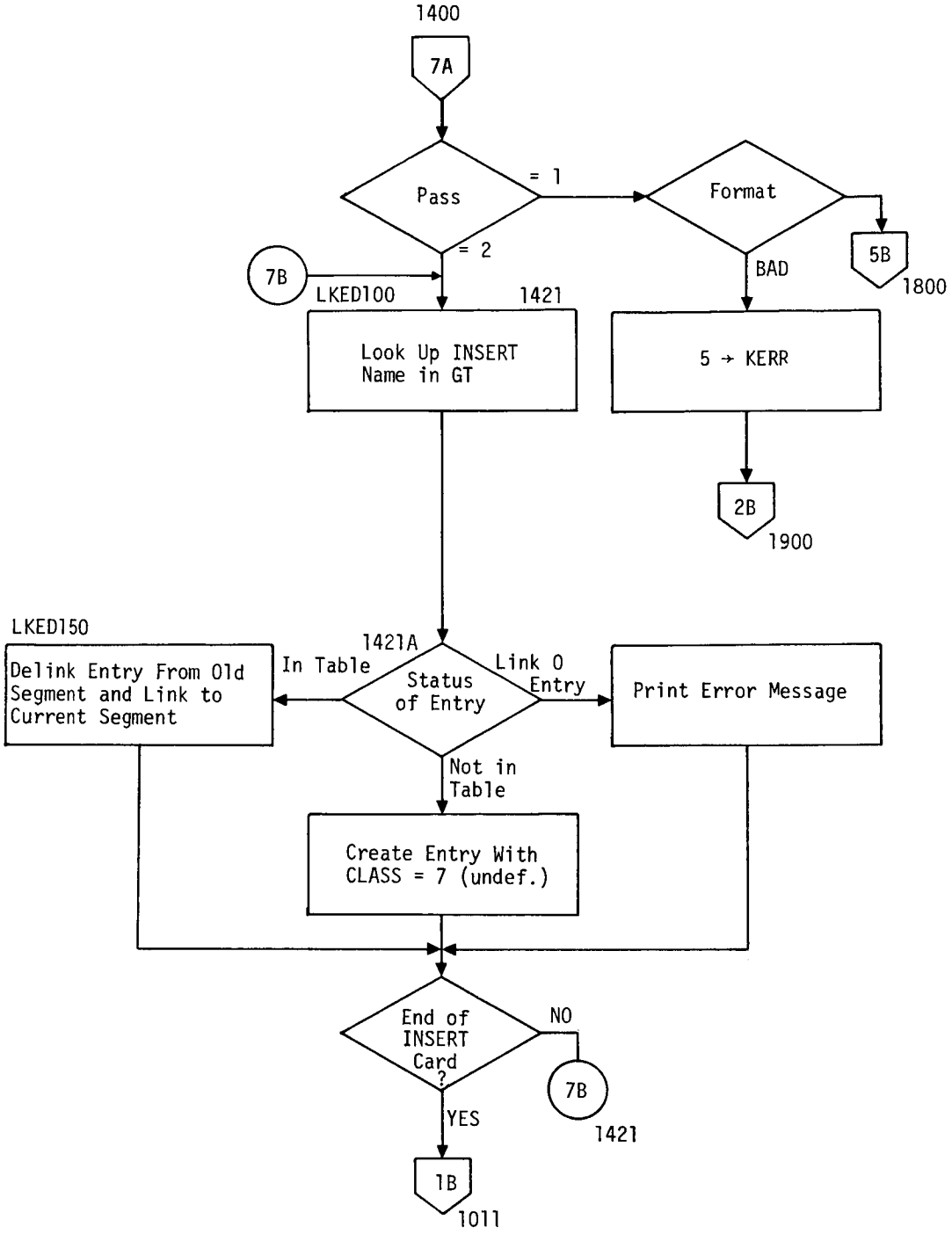


Figure 34(g). Flowchart for control statement processing.

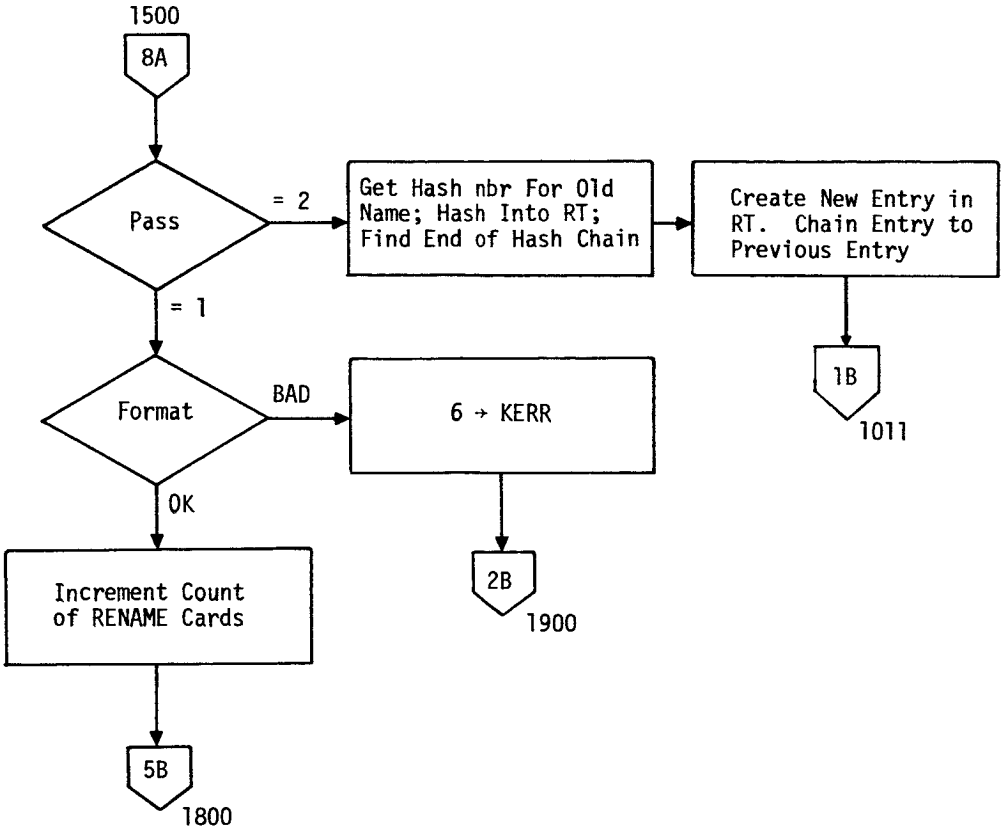


Figure 34(h). Flowchart for control statement processing.

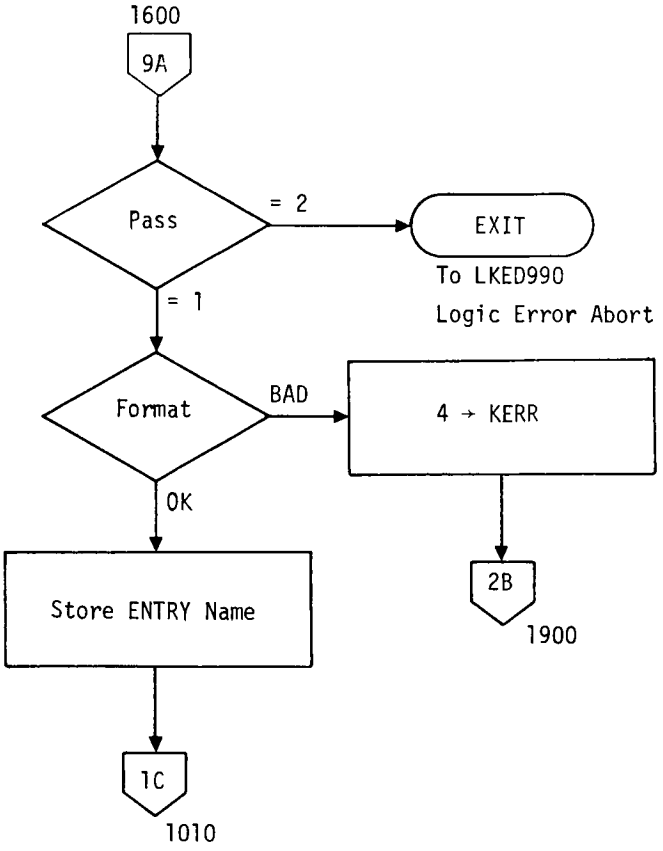


Figure 34(i). Flowchart for control statement processing.

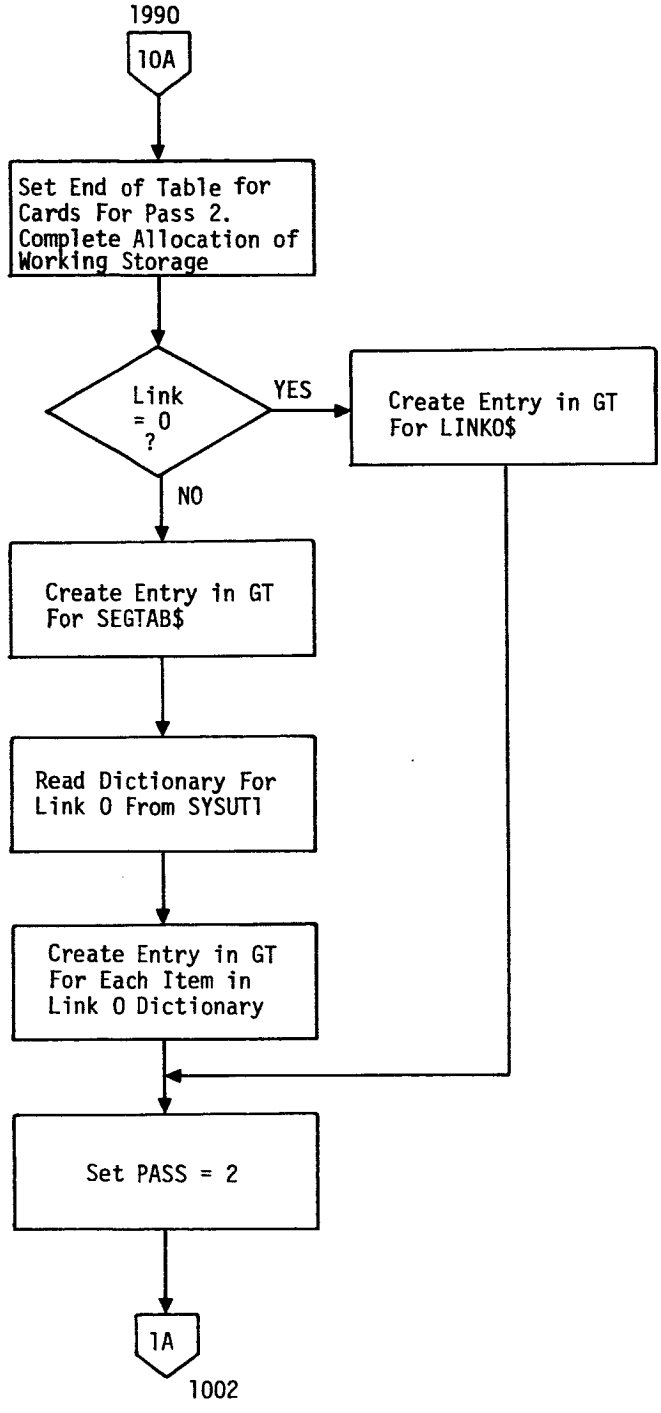


Figure 34(j). Flowchart for control statement processing.

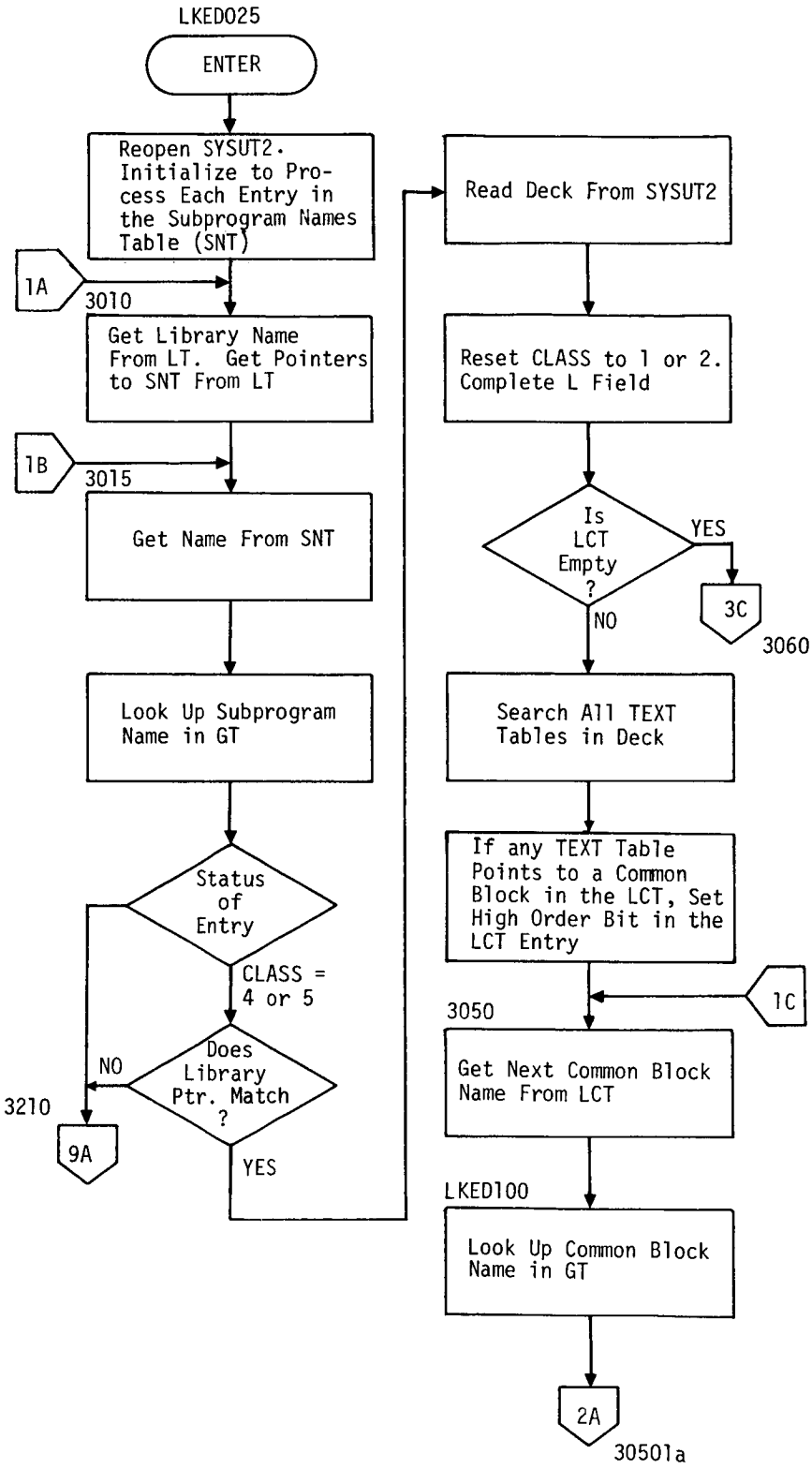


Figure 35(a). Flowchart for LKED025.

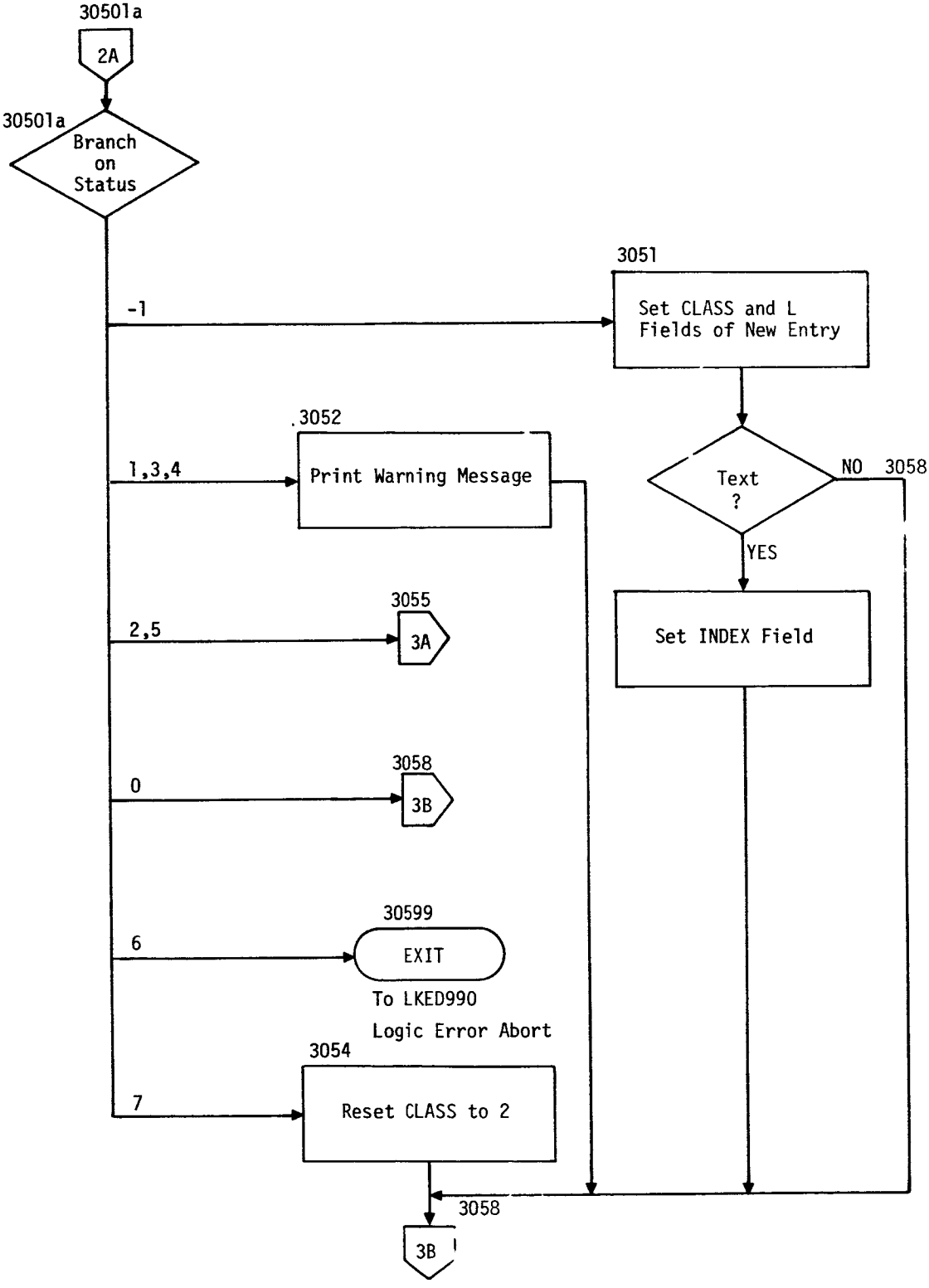


Figure 35(b). Flowchart for LKED025.

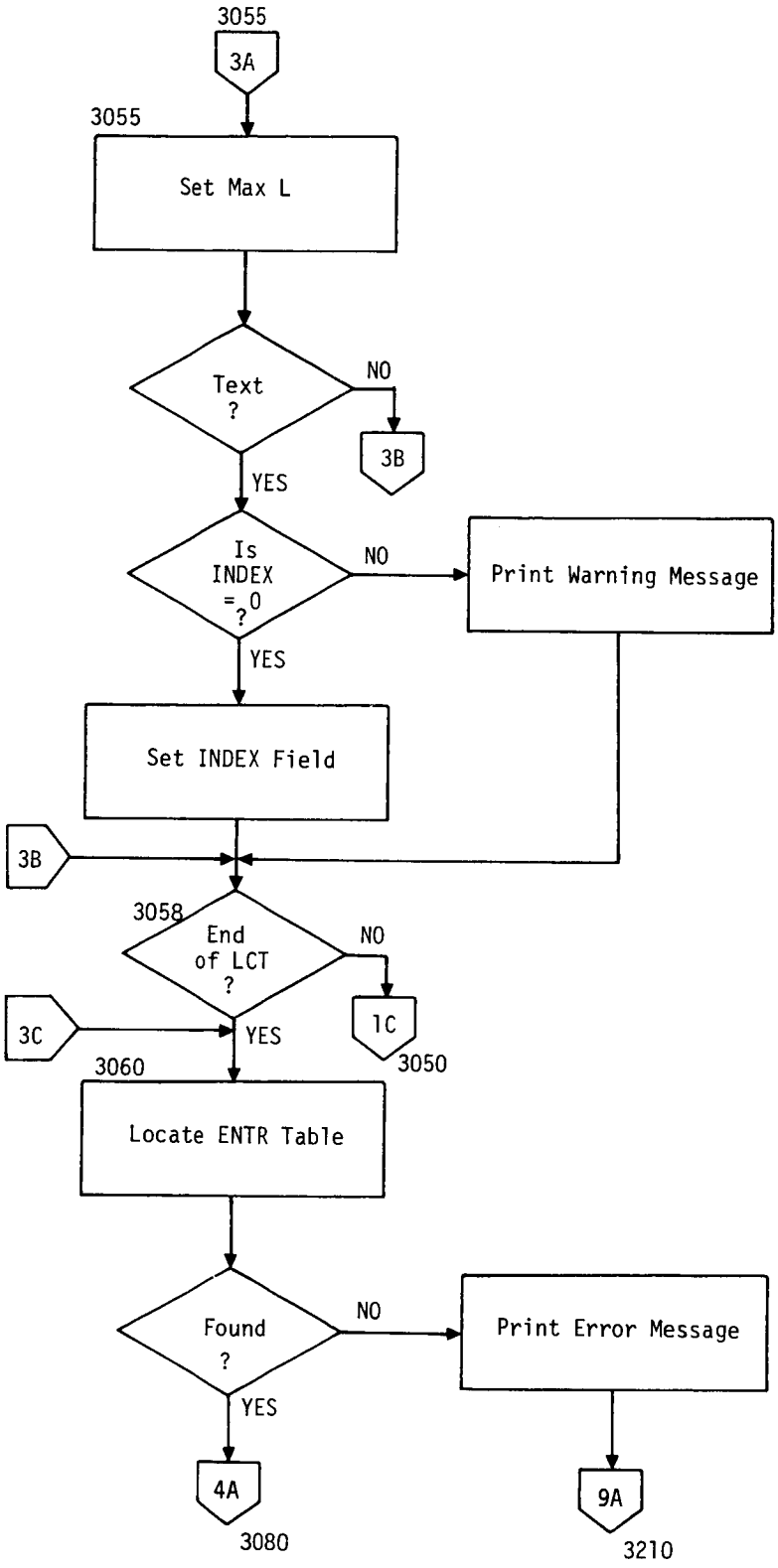


Figure 35(c). Flowchart for LKED025.

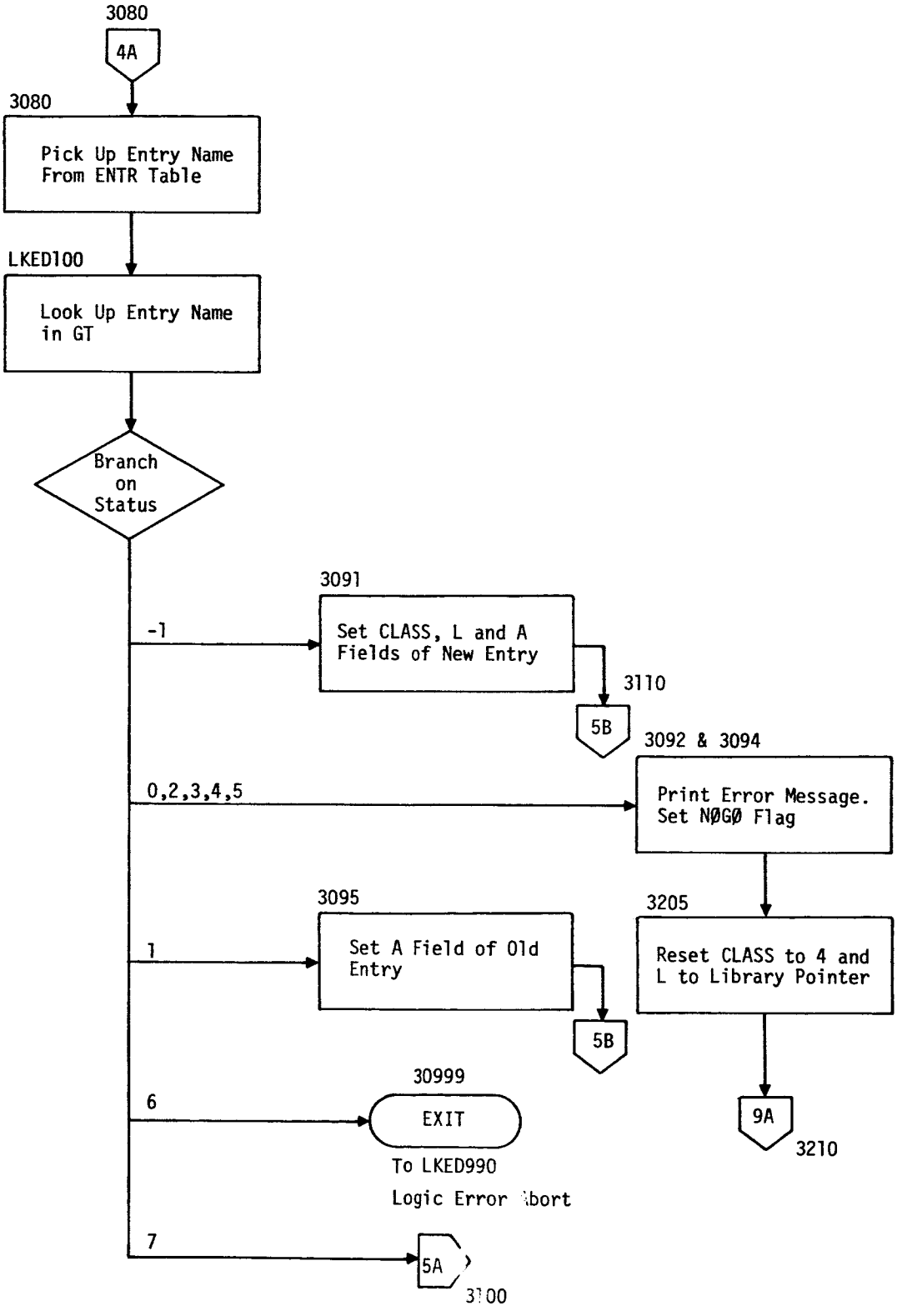


Figure 35(d). Flowchart for LKED025.

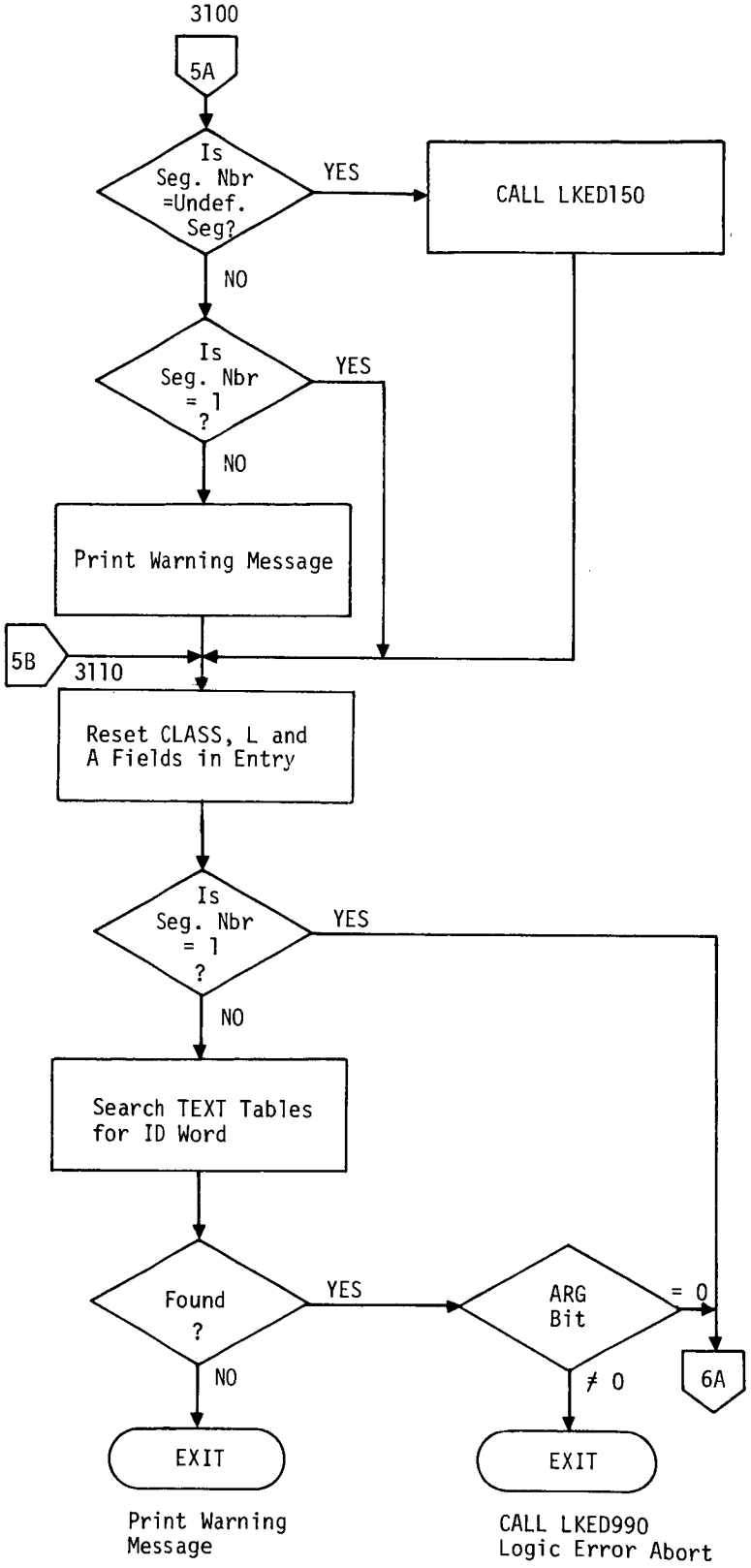


Figure 35(e). Flowchart for LKED025.

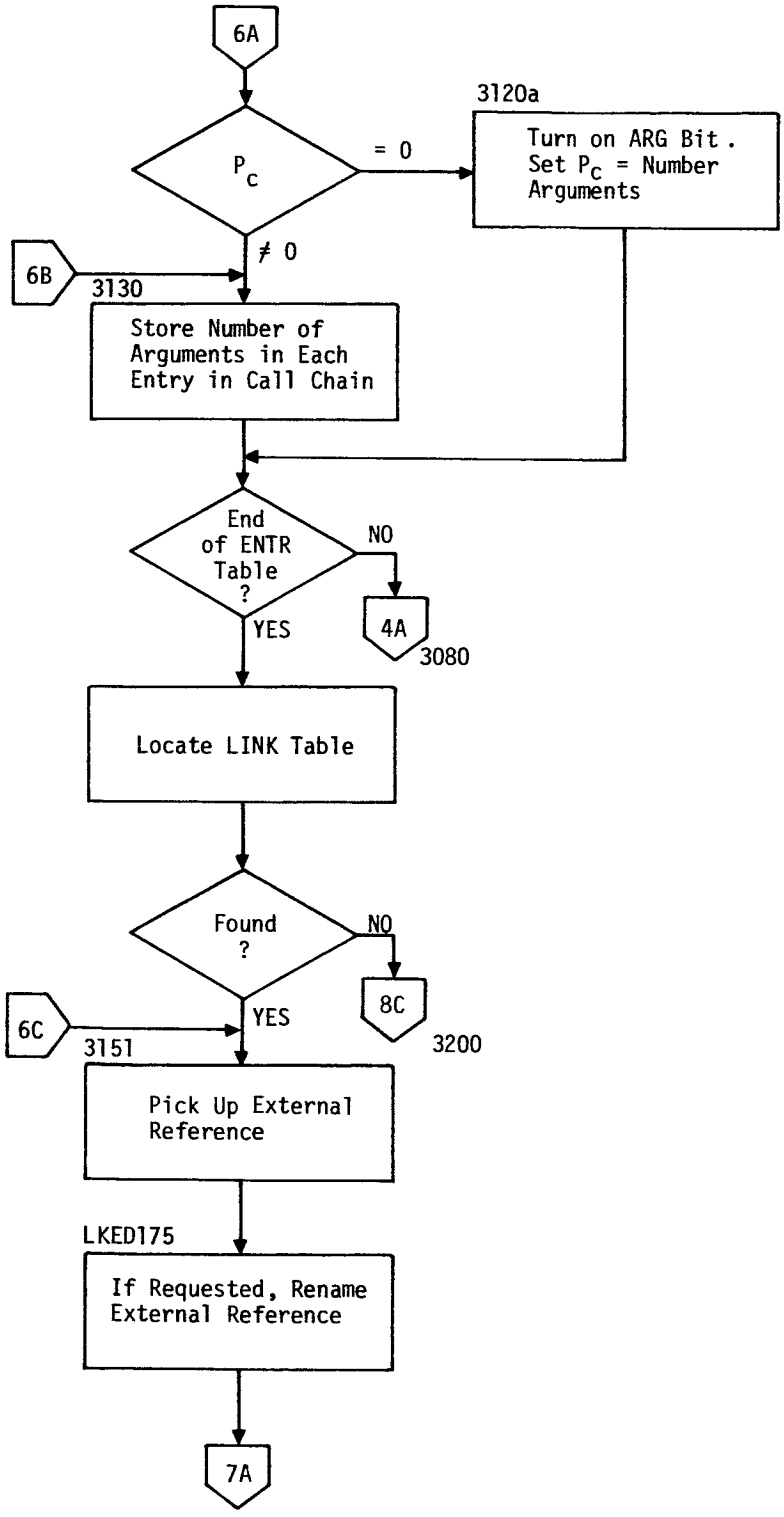


Figure 35(f). Flowchart for LKED025.

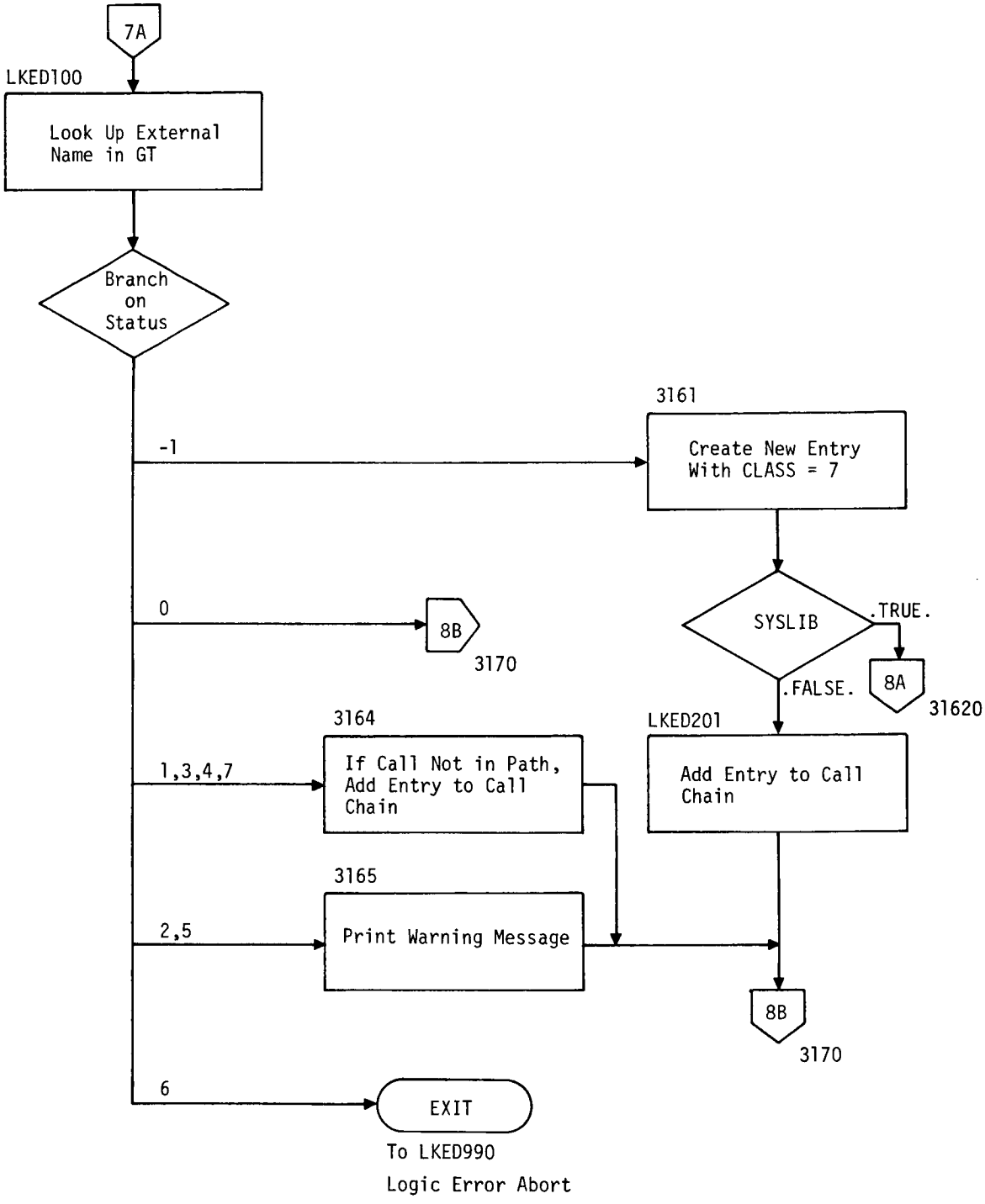


Figure 35(g). Flowchart for LKED025.

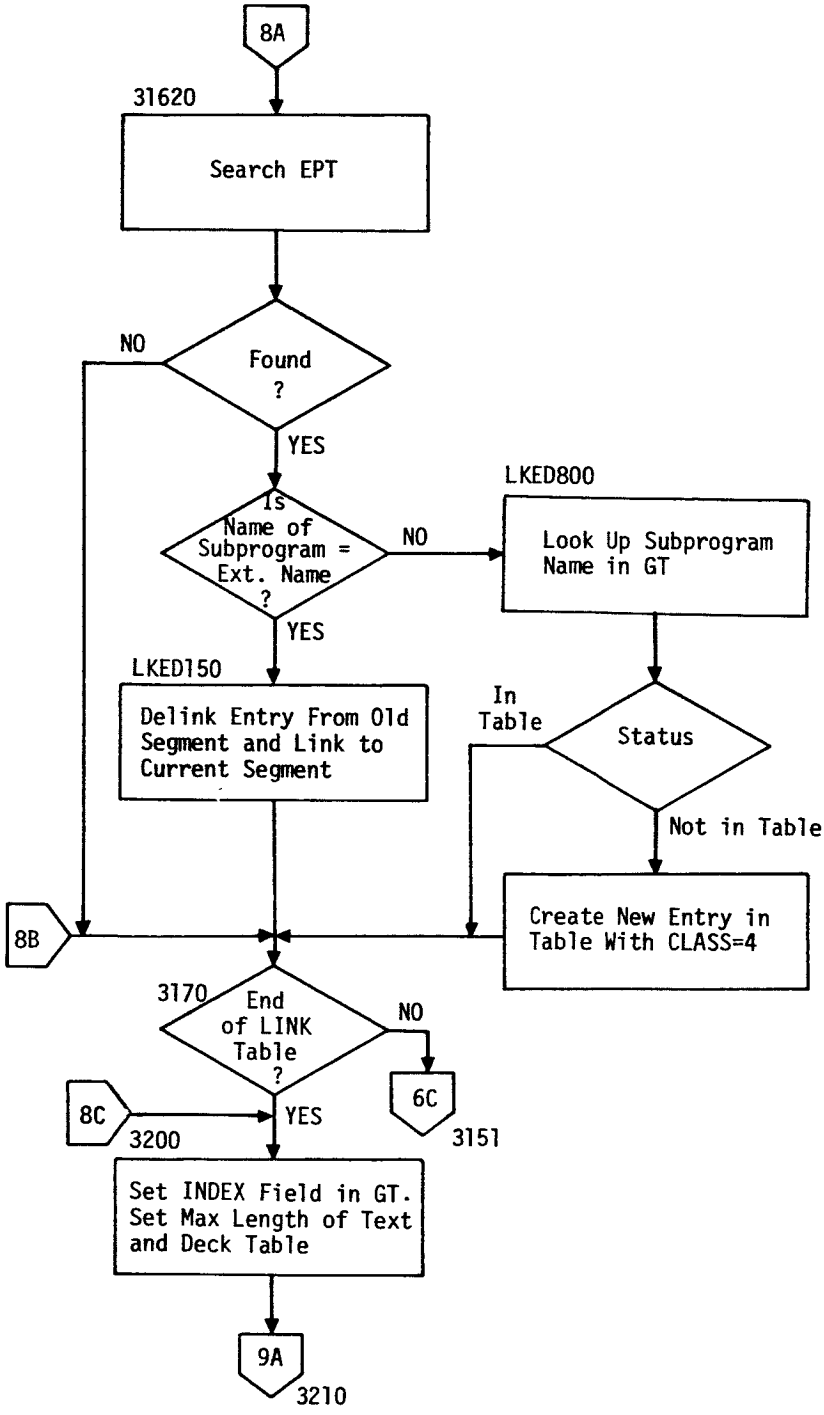


Figure 35(h). Flowchart for LKED025.

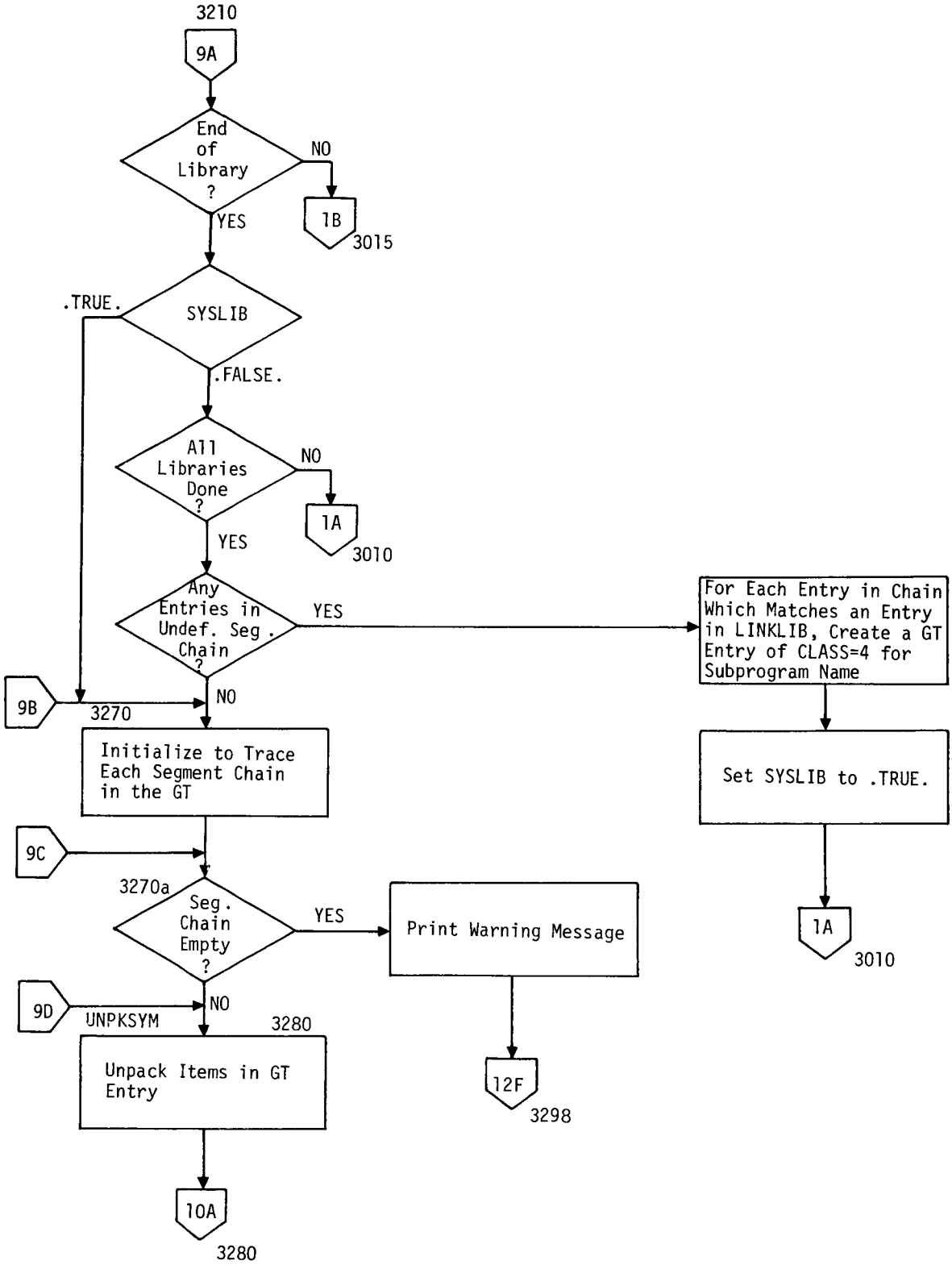


Figure 35(i). Flowchart for LKED025.

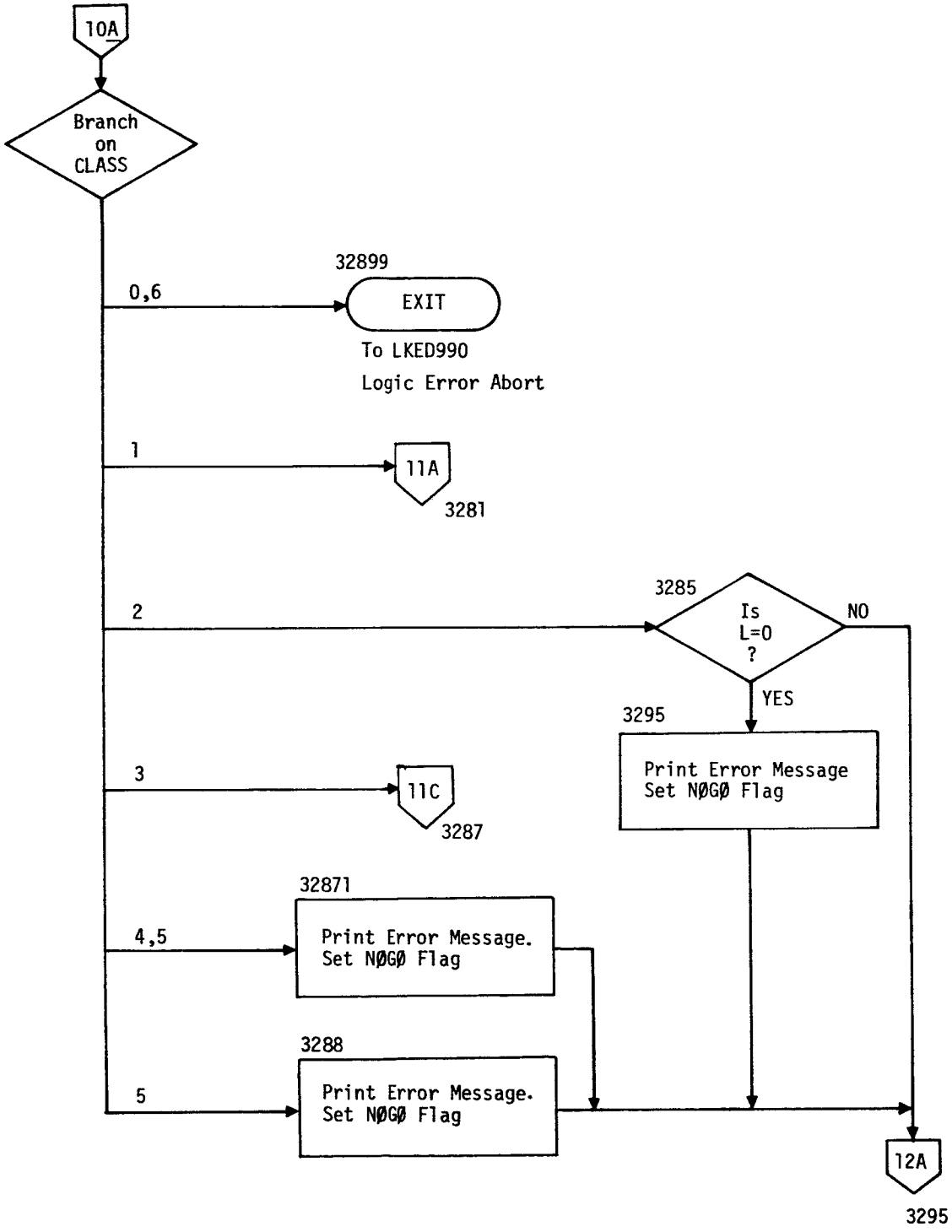


Figure 35(j). Flowchart for LKED025.

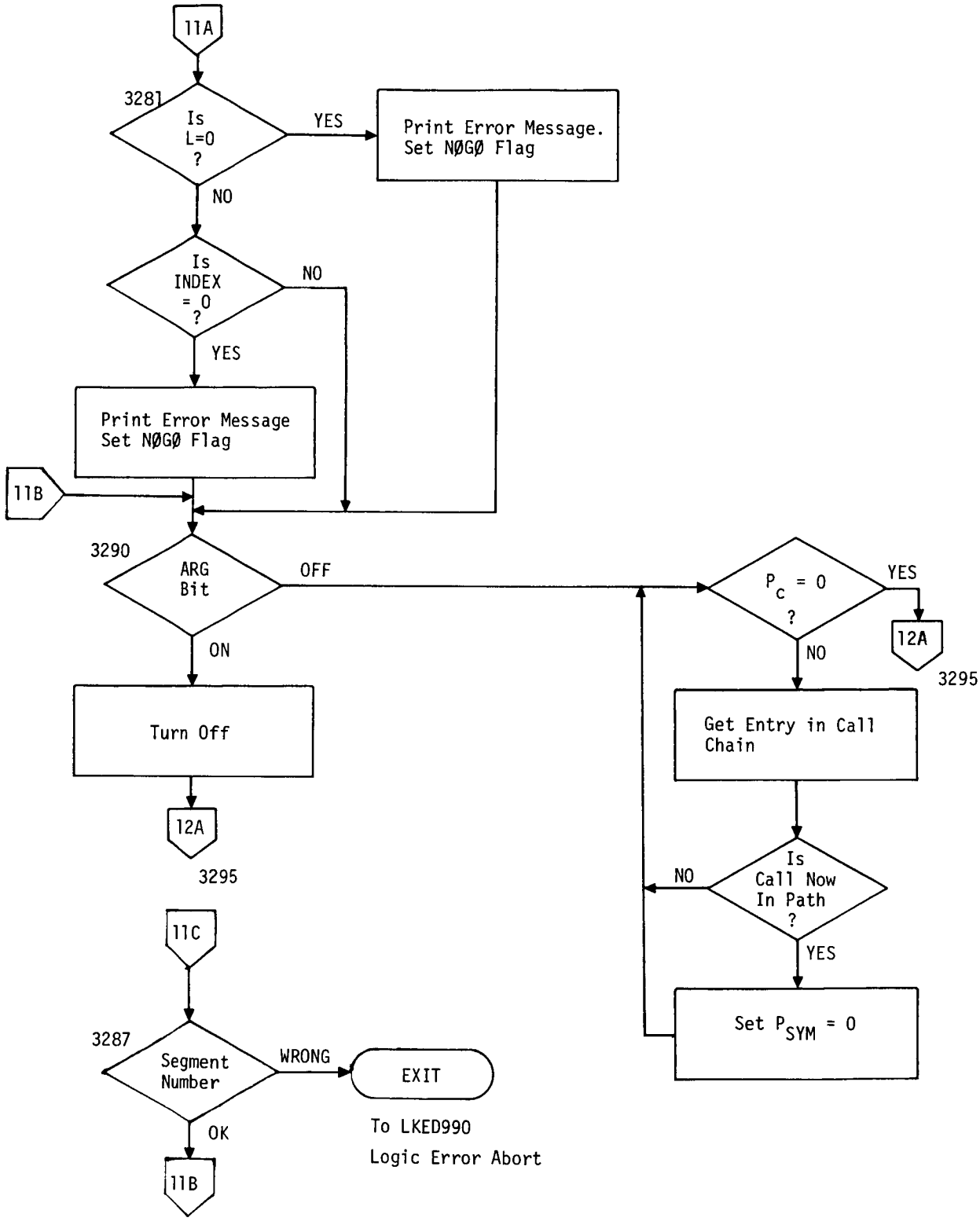


Figure 35(k). Flowchart for LKED025.

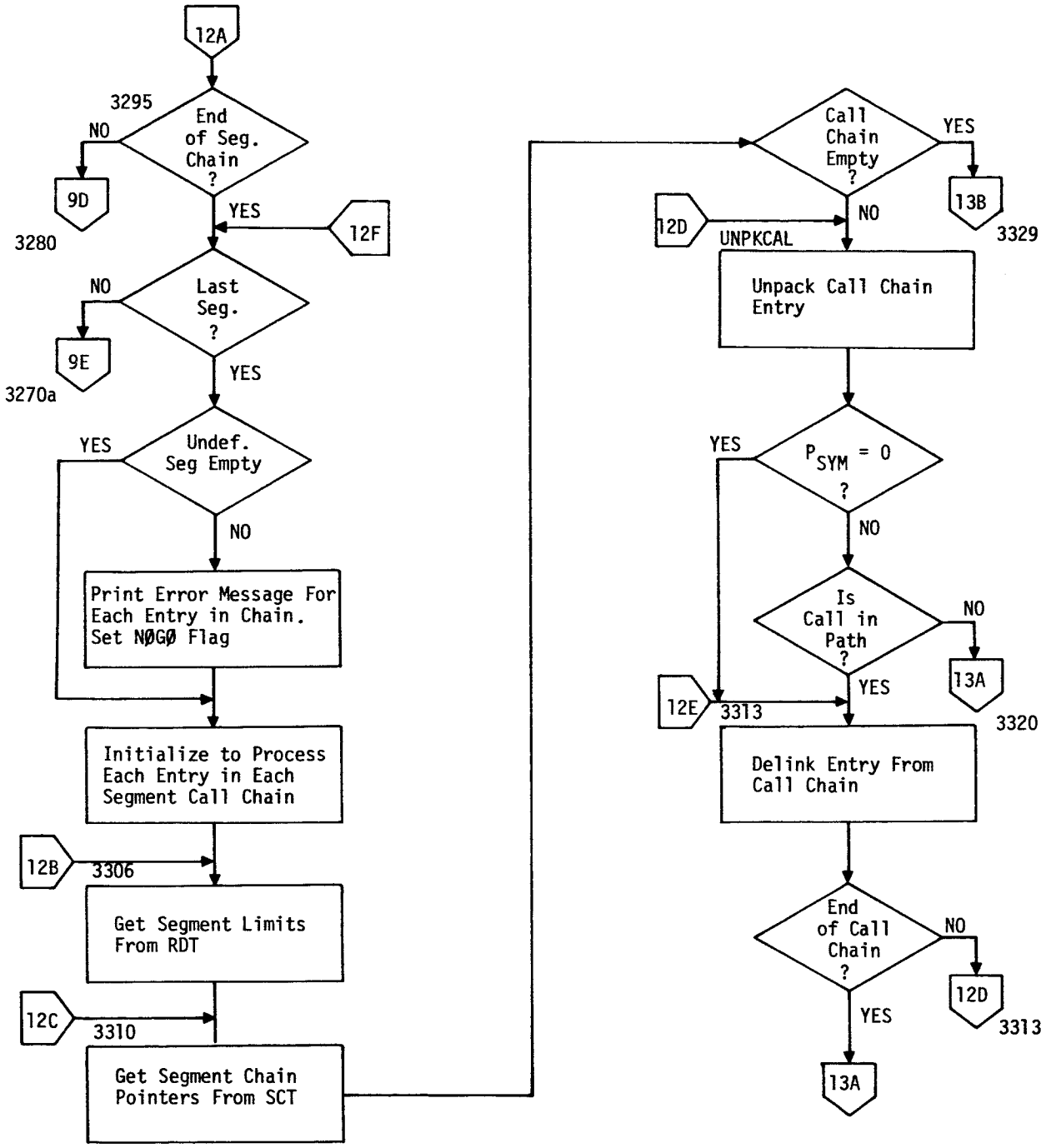


Figure 35(1). Flowchart for LKED025.

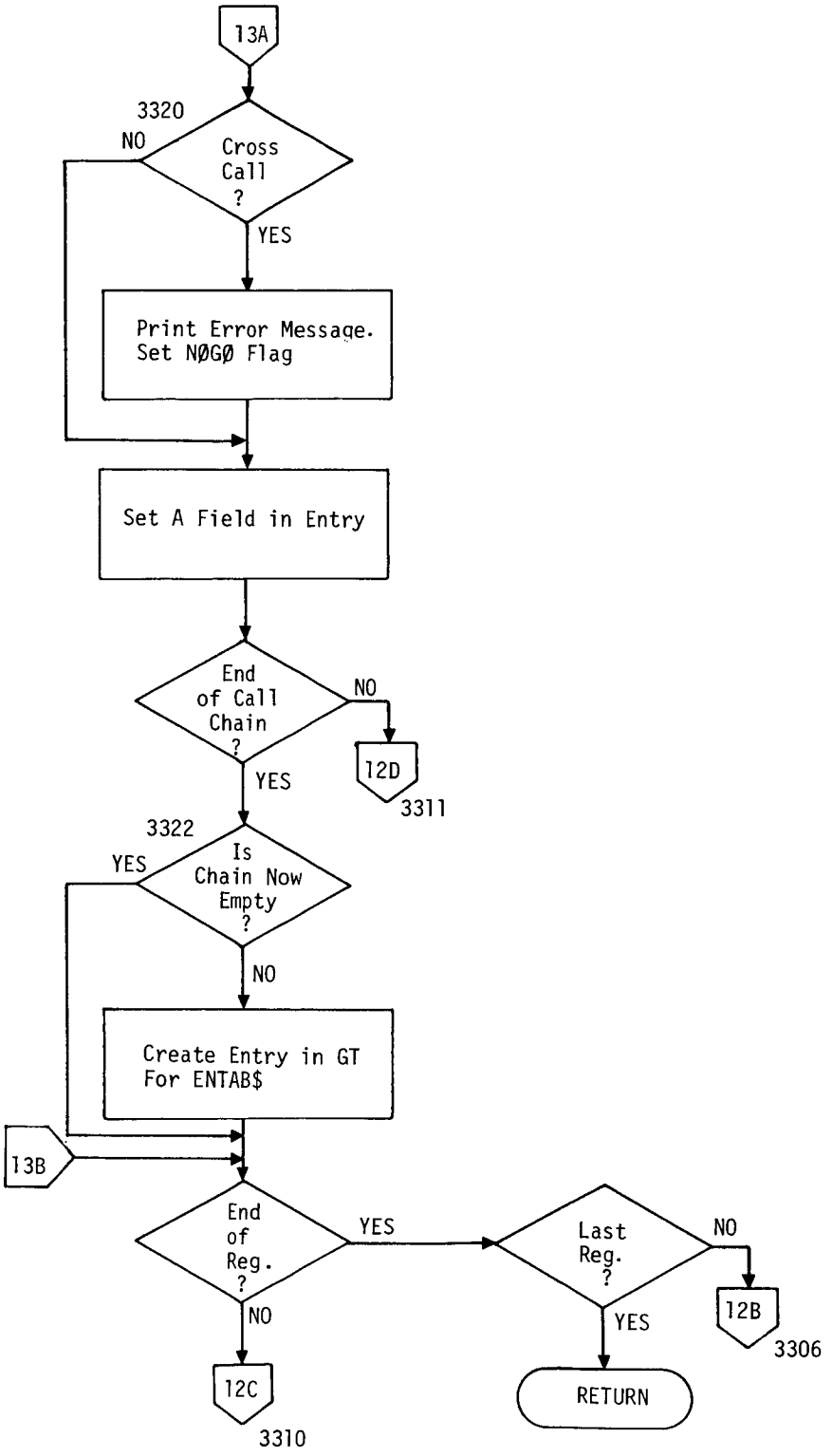


Figure 35(m). Flowchart for LKED025.

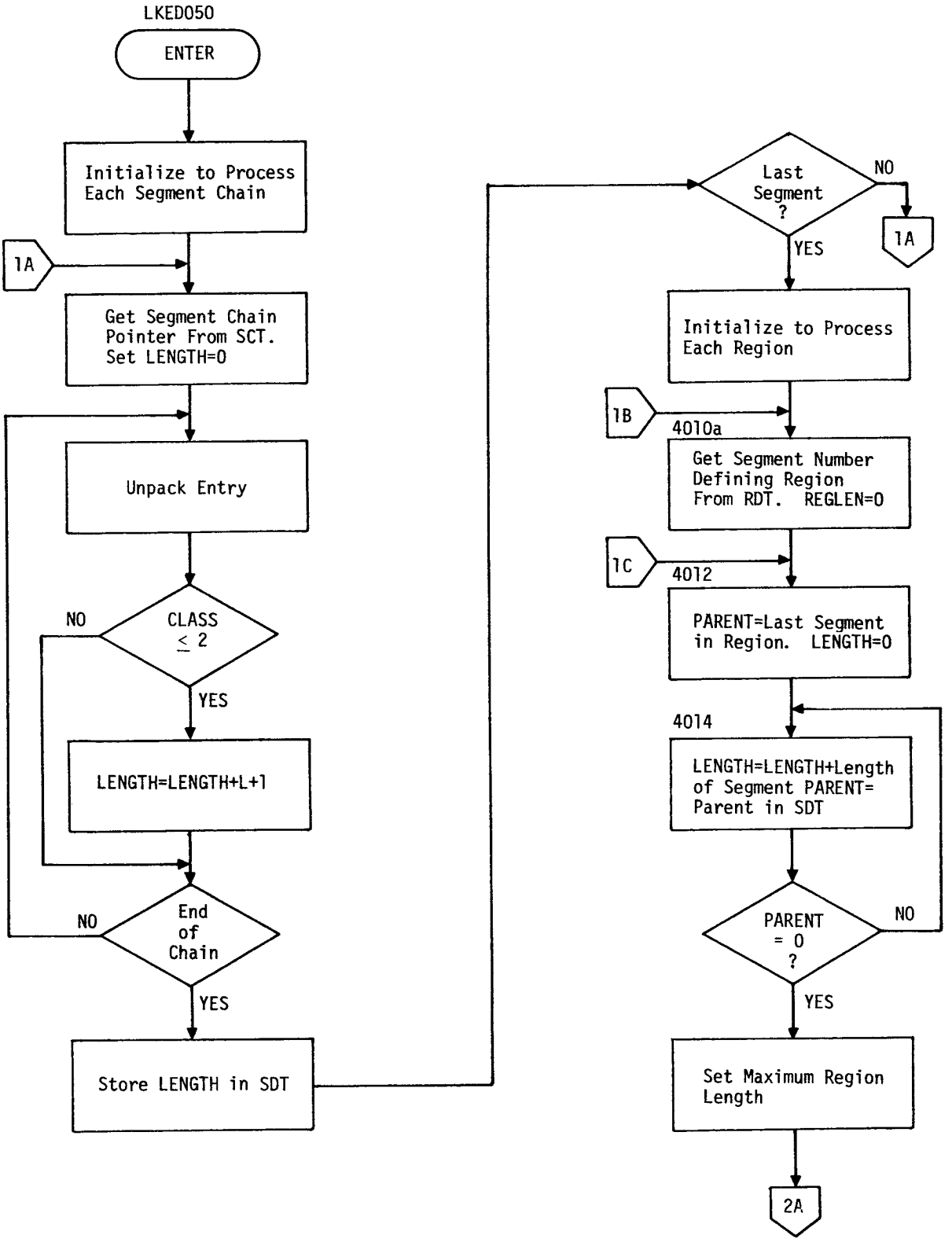


Figure 36(a). Flowchart for LKED050.

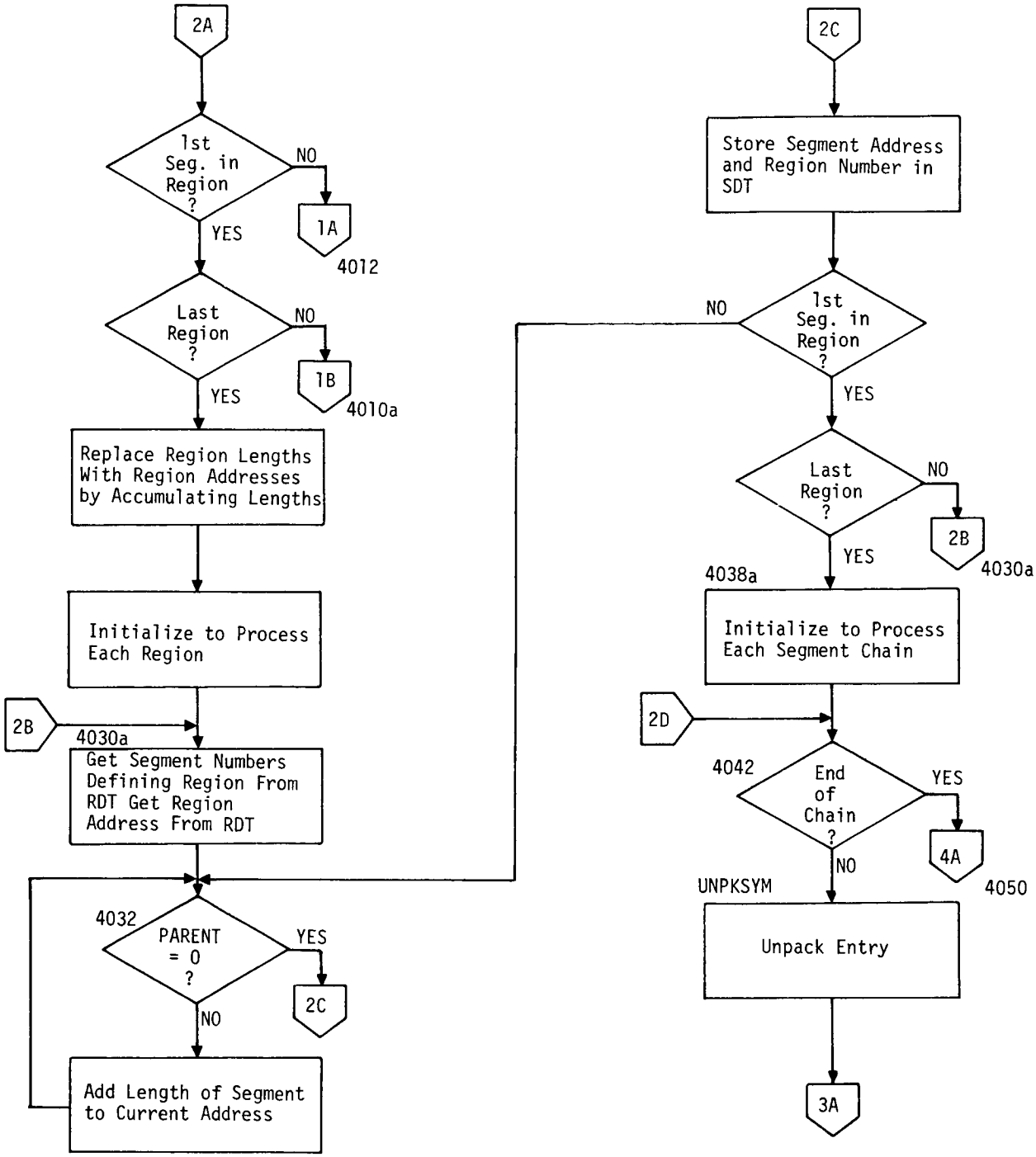


Figure 36(b). Flowchart for LKED050.

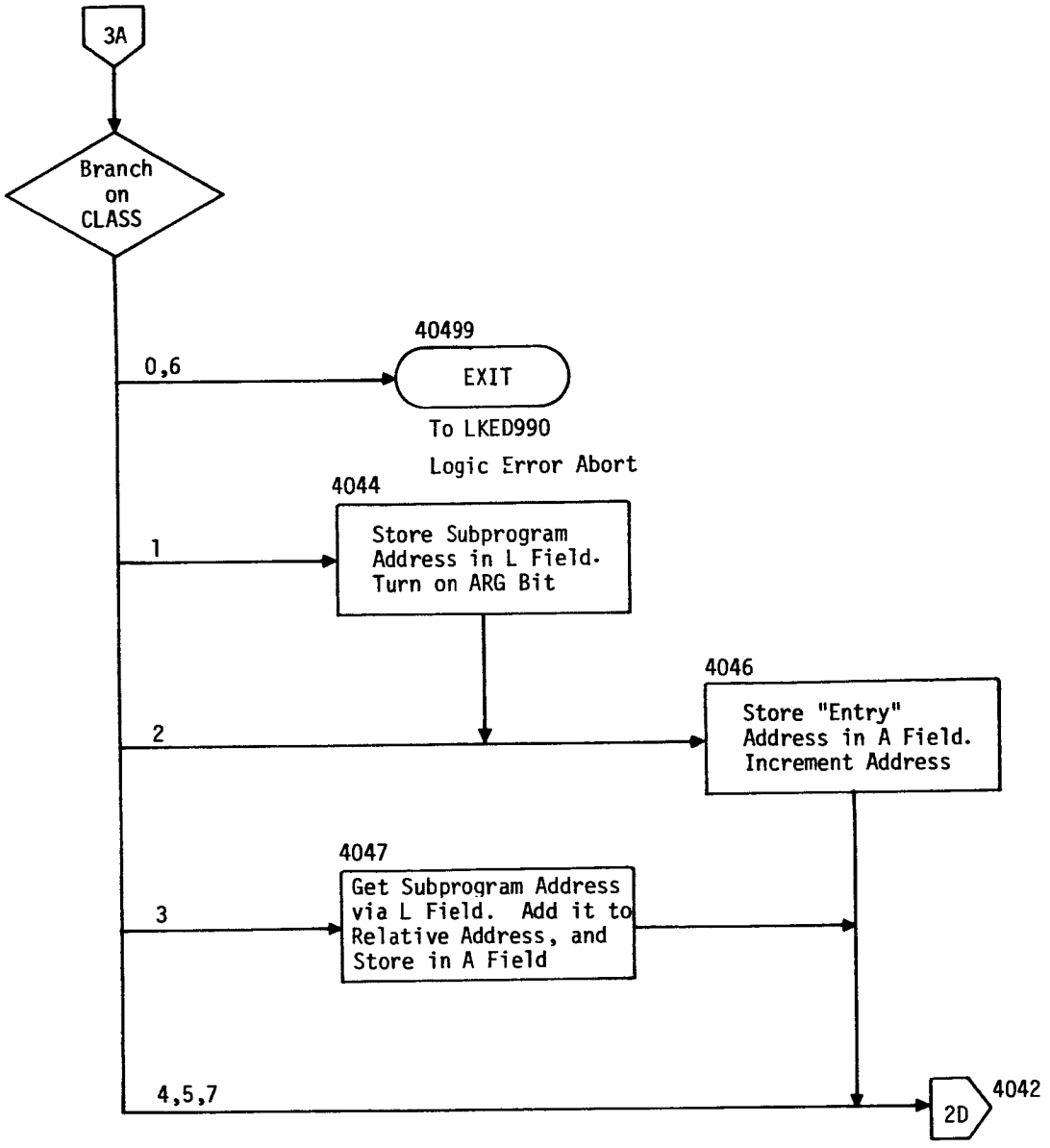


Figure 36(c). Flowchart for LKED050.

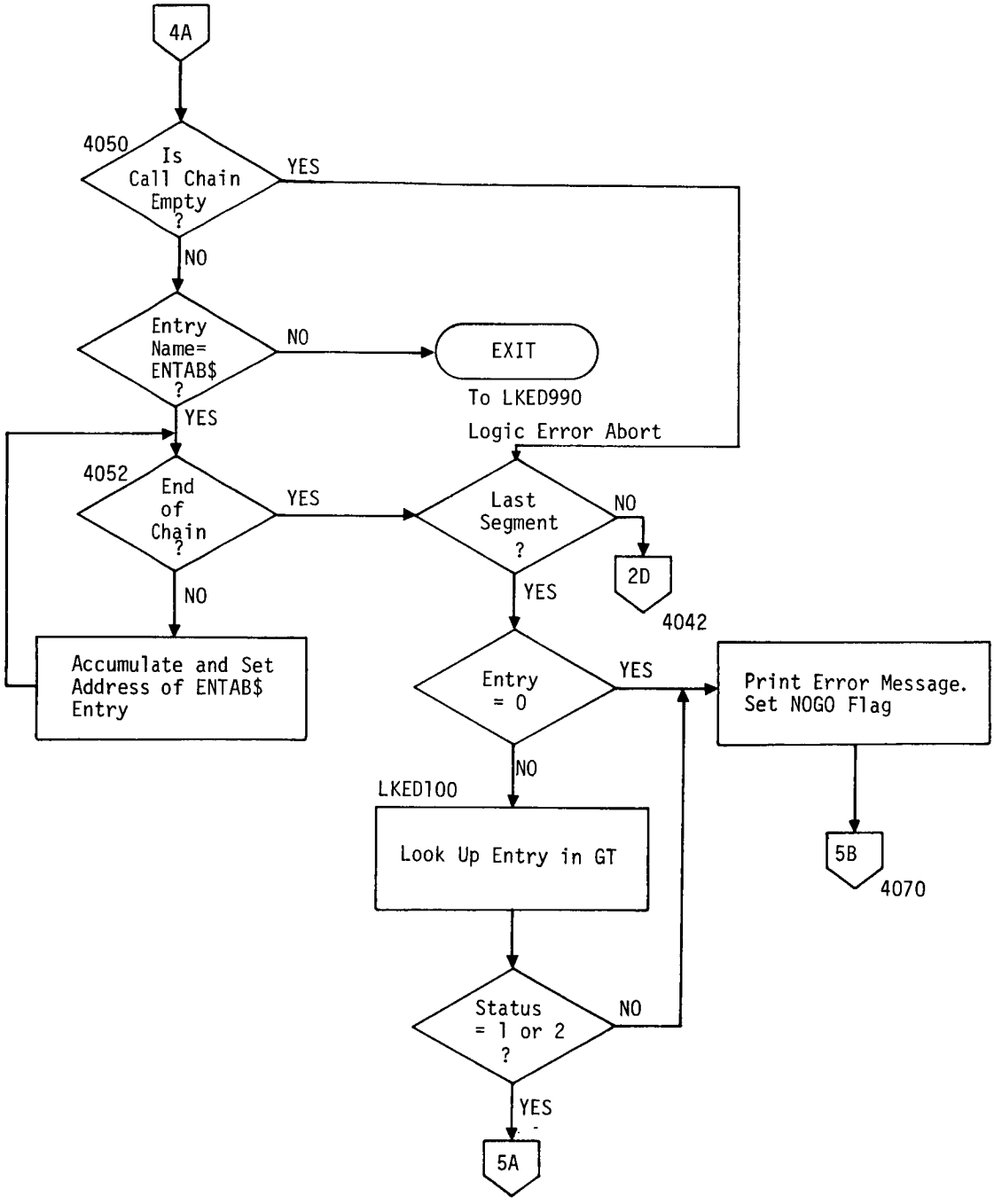


Figure 36(d). Flowchart for LKED050.

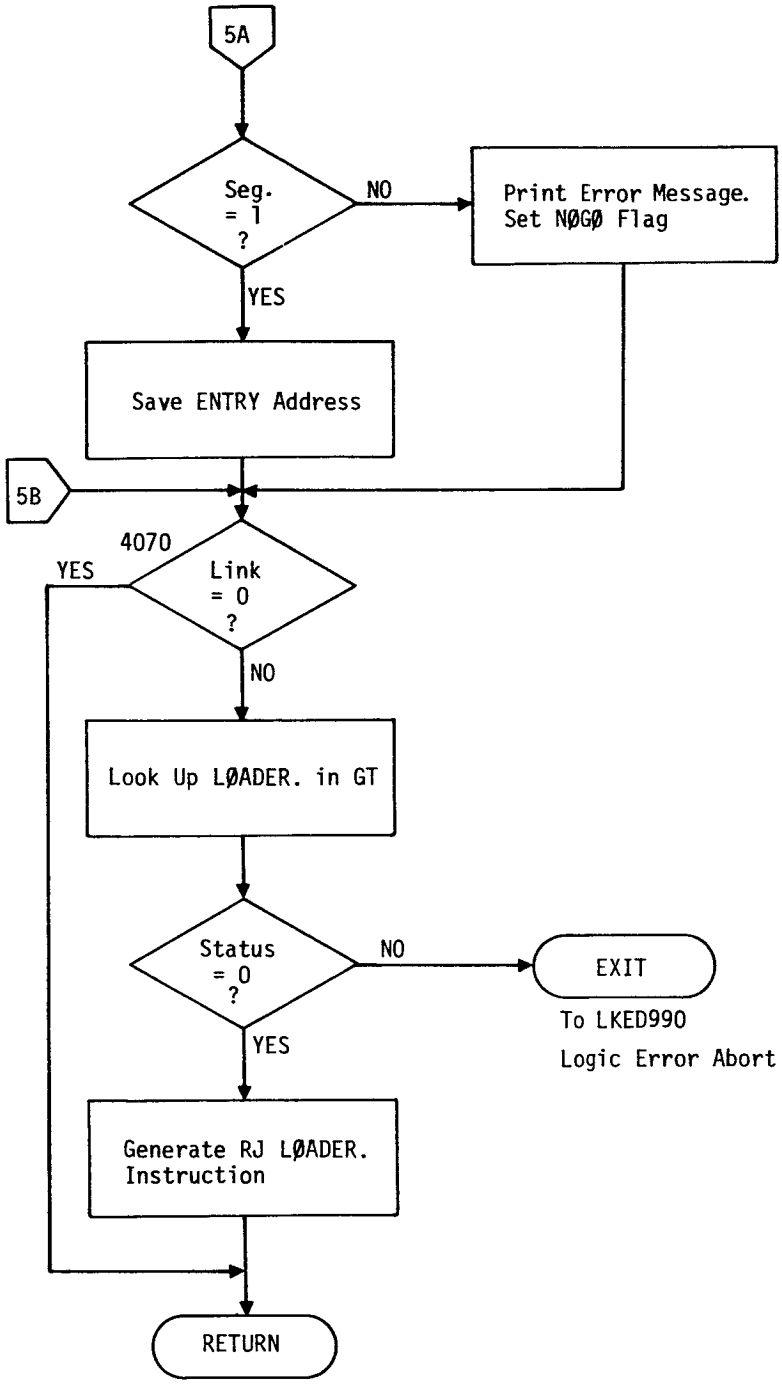


Figure 36(e). Flowchart for LKED050.

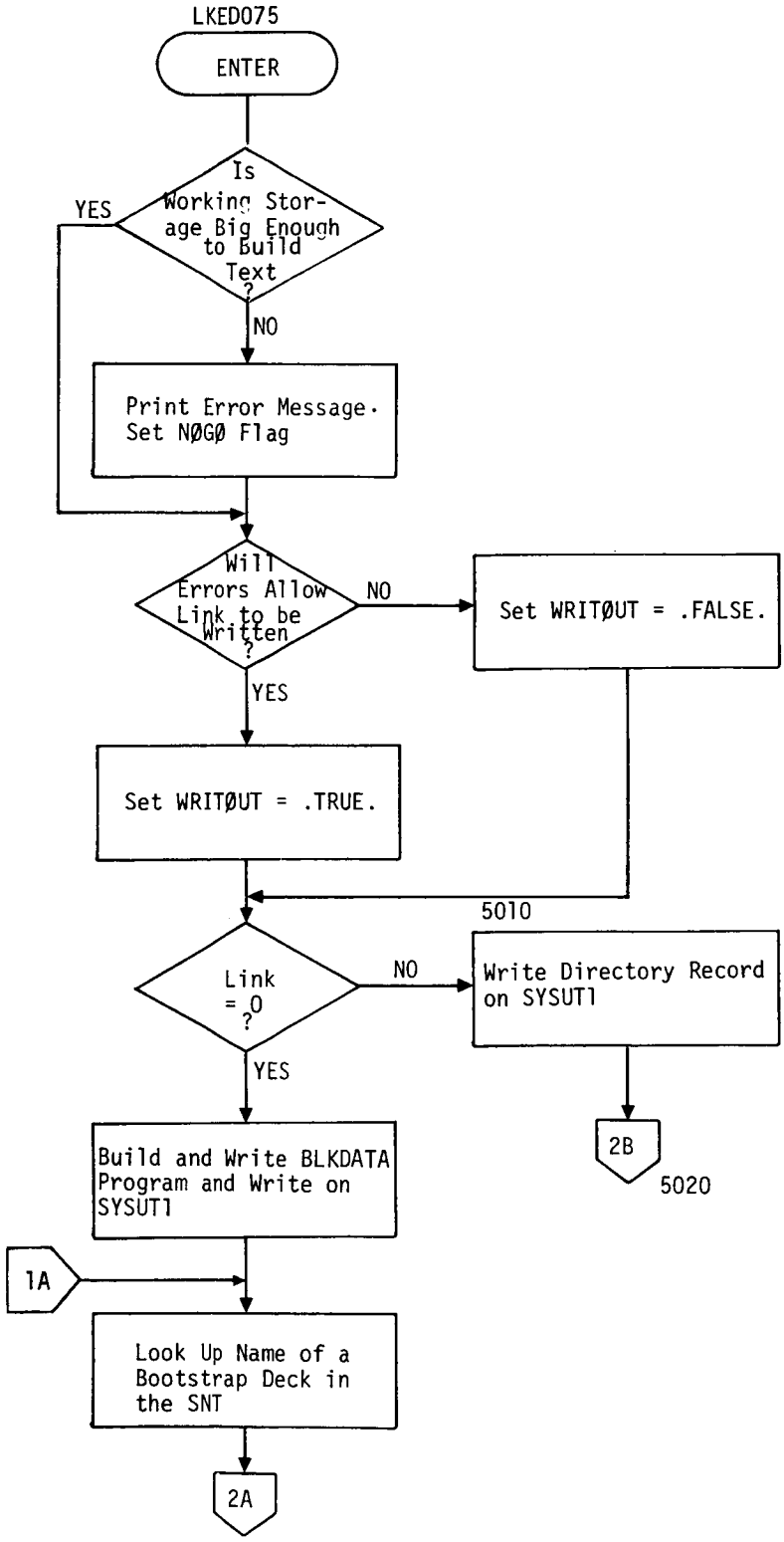


Figure 37(a). Flowchart for LKED075.

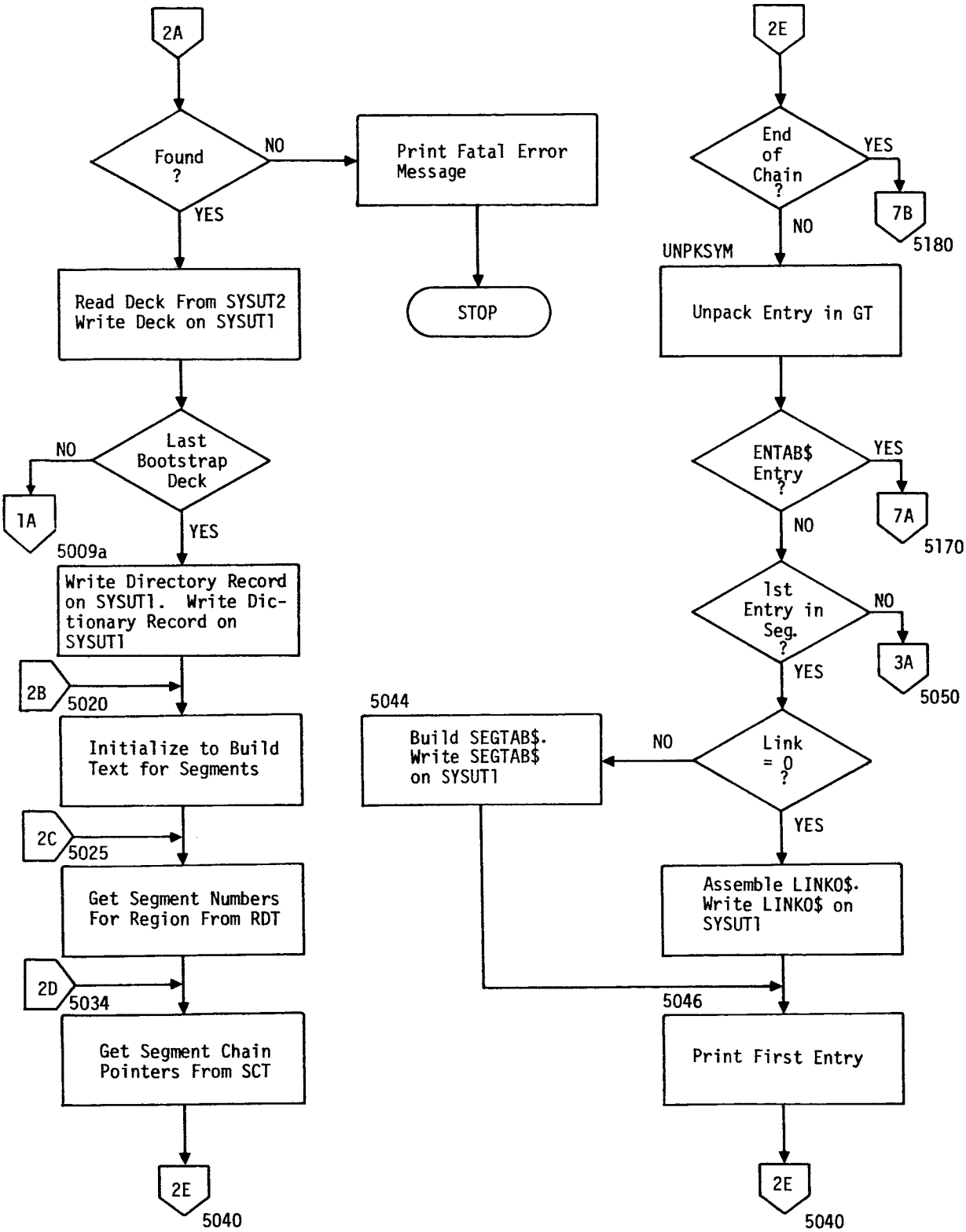


Figure 37(b). Flowchart for LKED075.

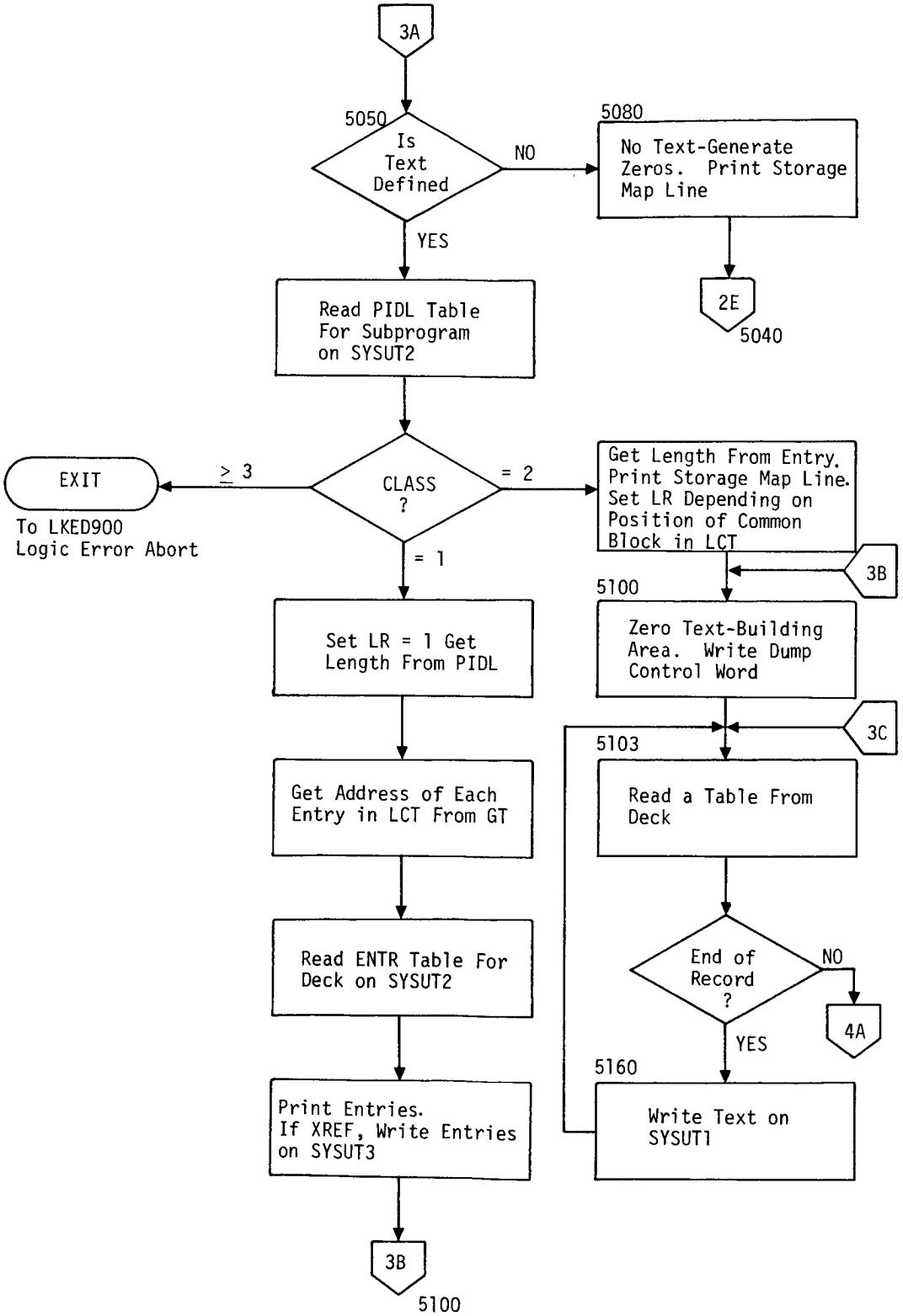


Figure 37(c). Flowchart for LKED075.

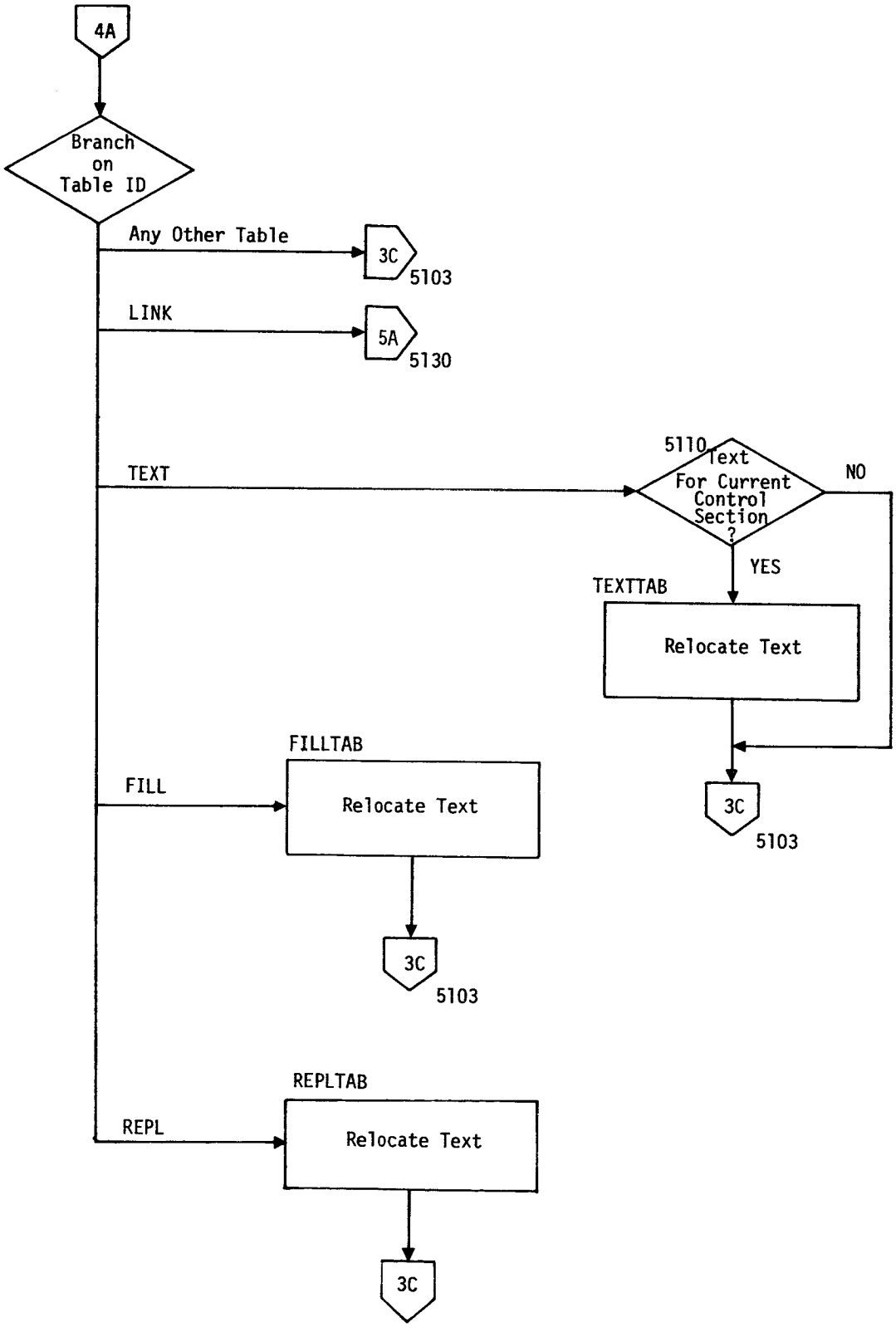


Figure 37(d). Flowchart for LKED075.

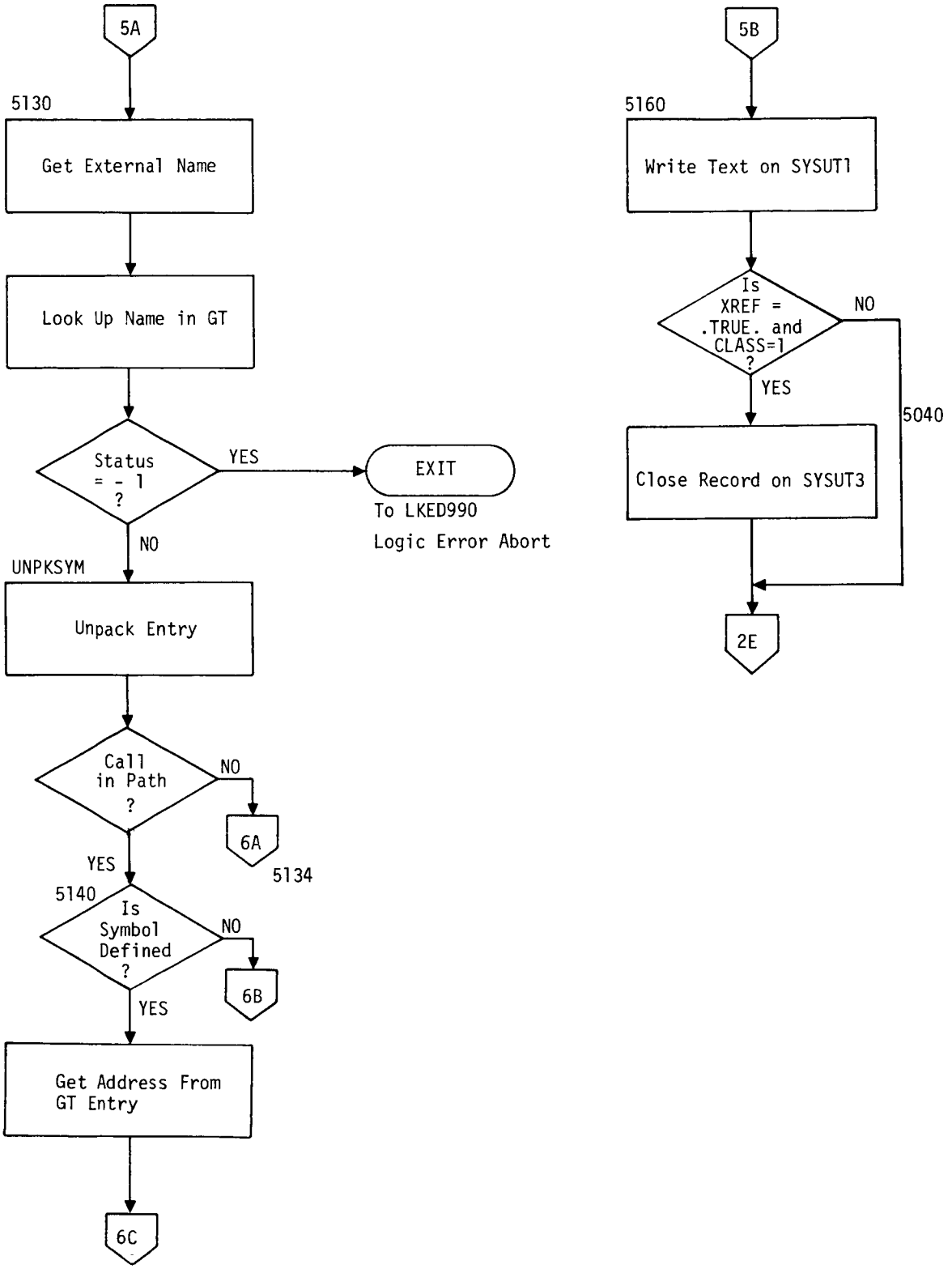


Figure 37(e). Flowchart for LKED075.

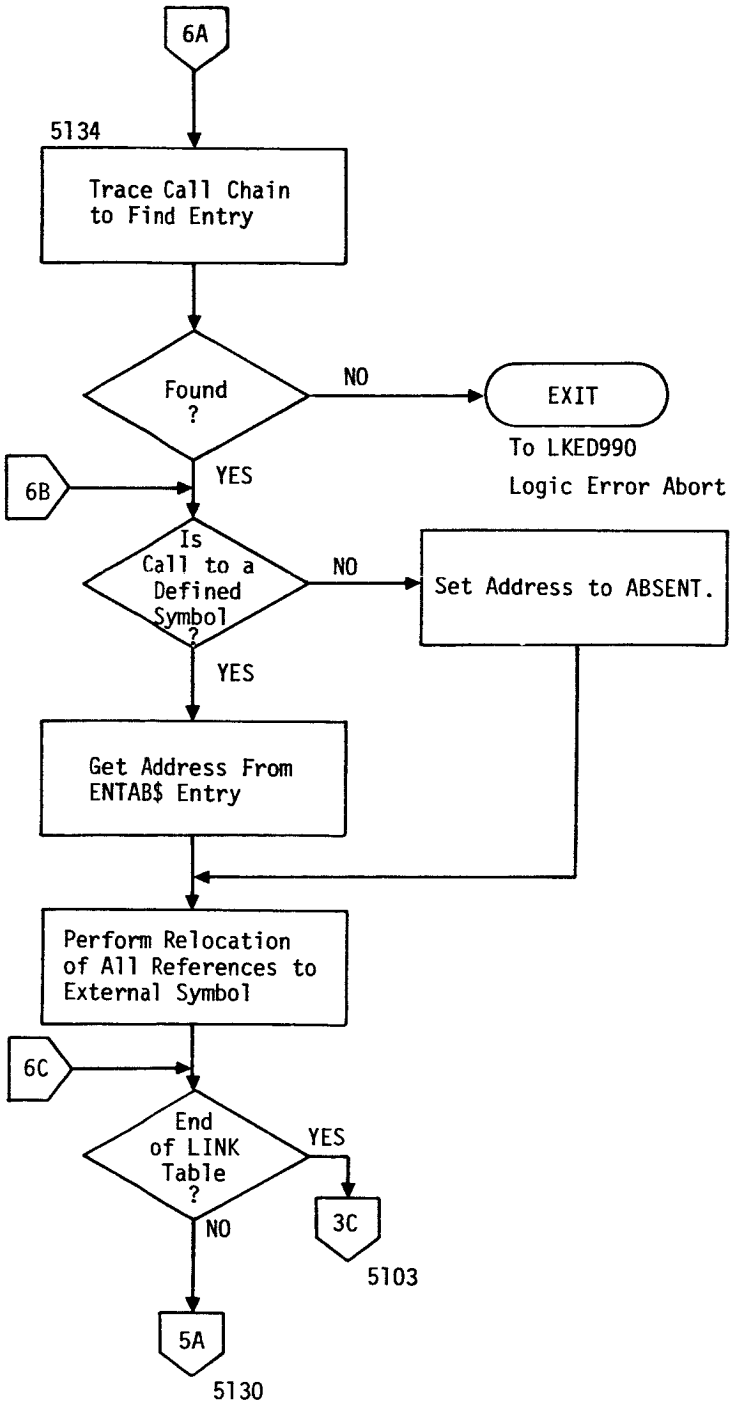


Figure 37(f). Flowchart for LKED075.

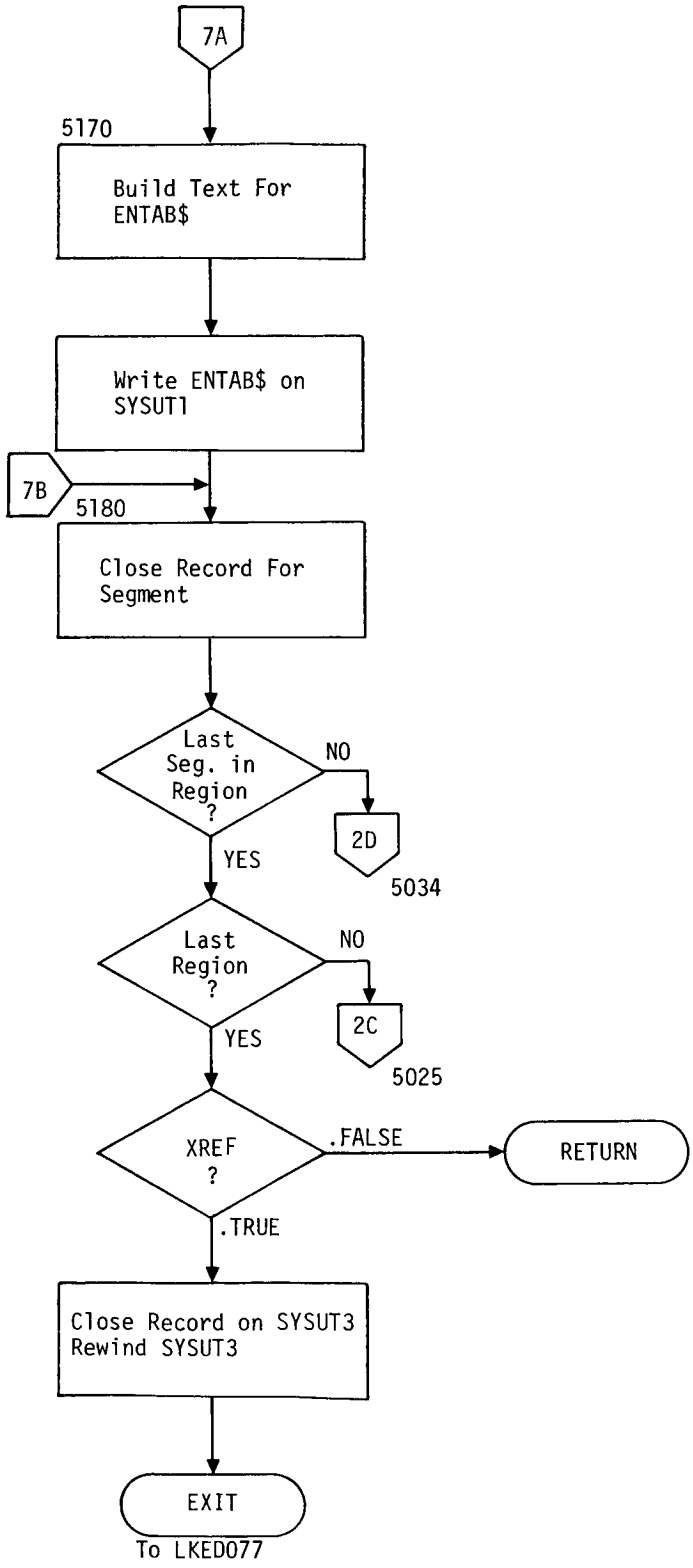


Figure 37(g). Flowchart for LKED075.

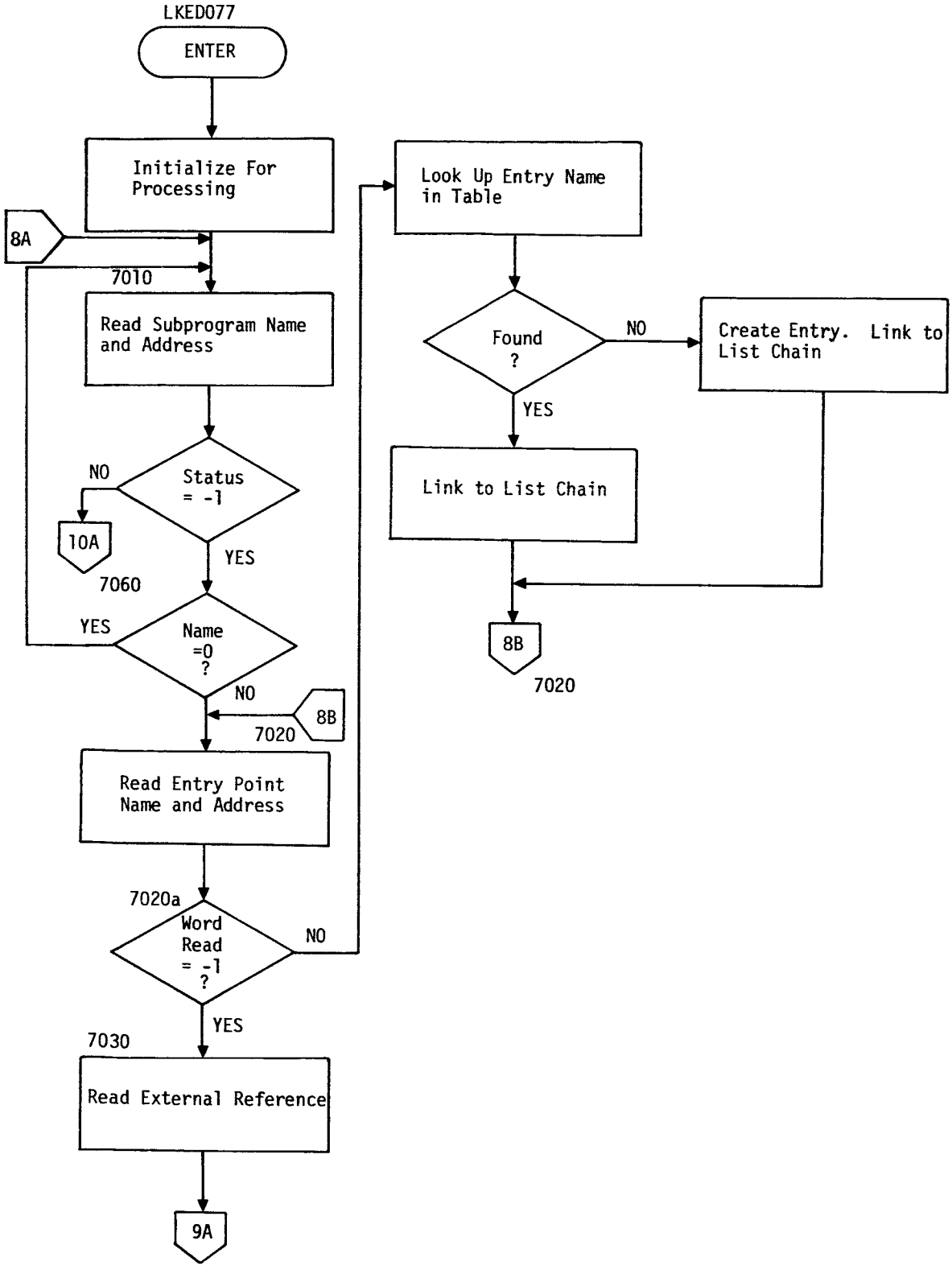


Figure 37(h). Flowchart for LKED075.

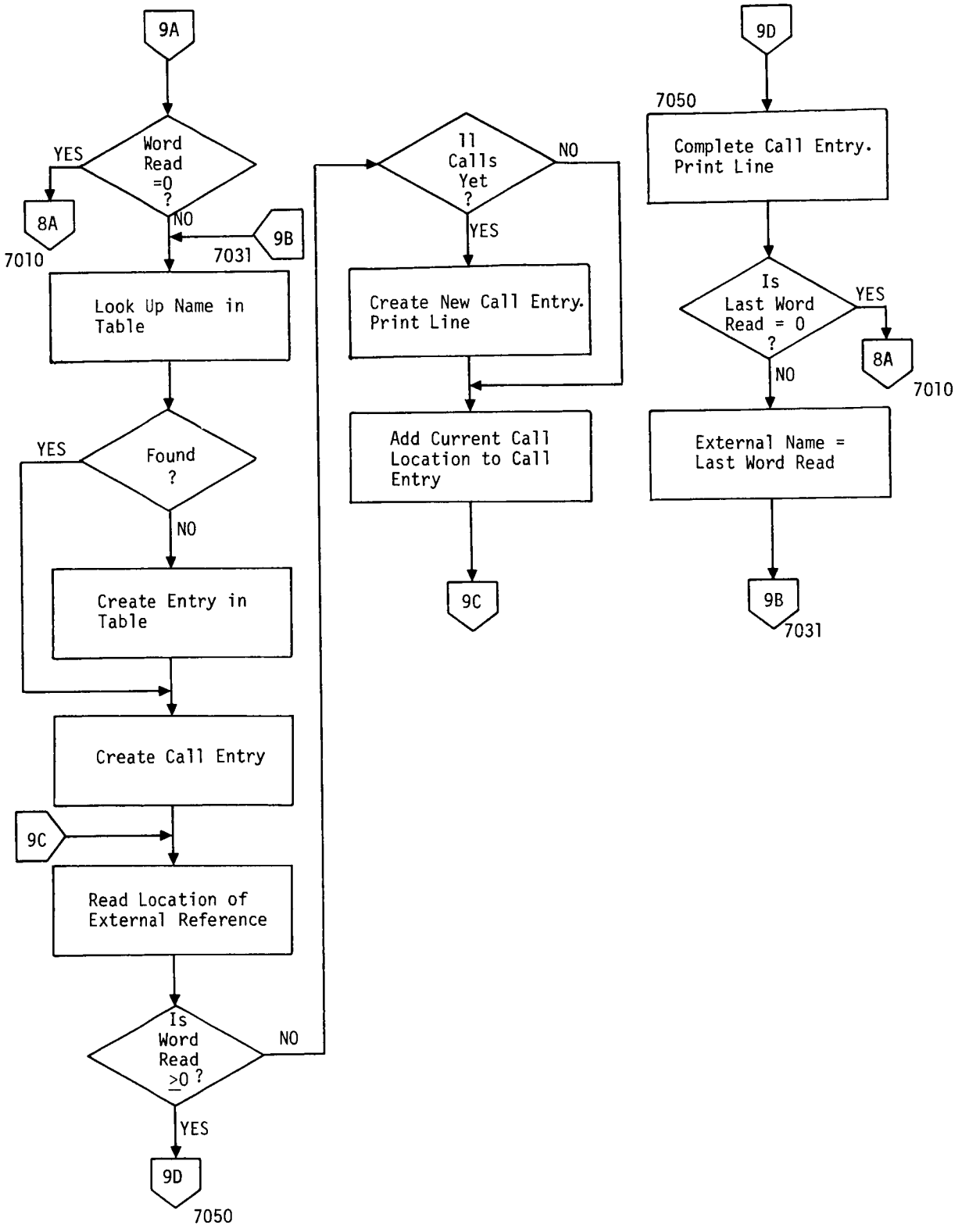


Figure 37(i). Flowchart for LKED075.

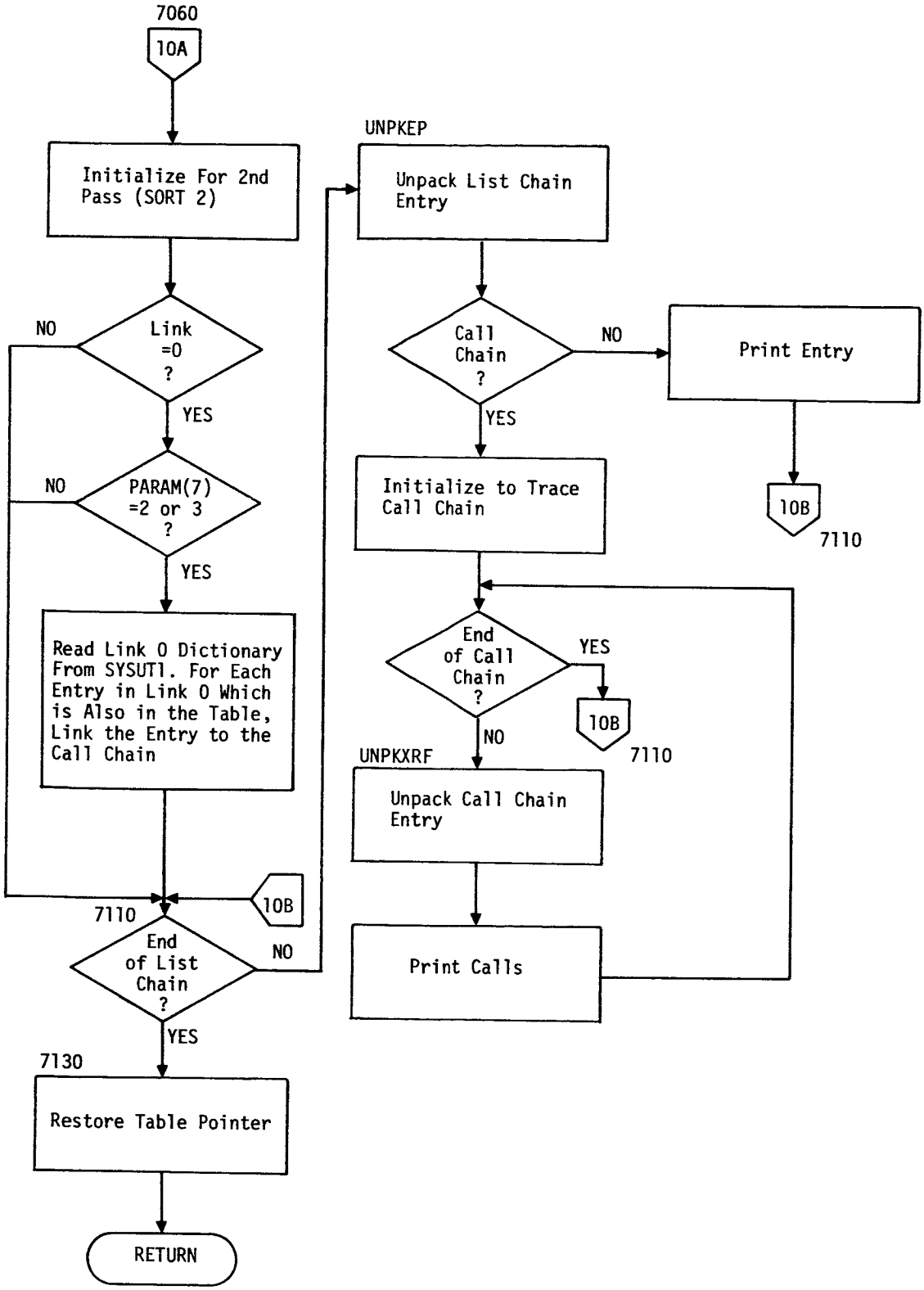


Figure 37(j). Flowchart for LKED075.

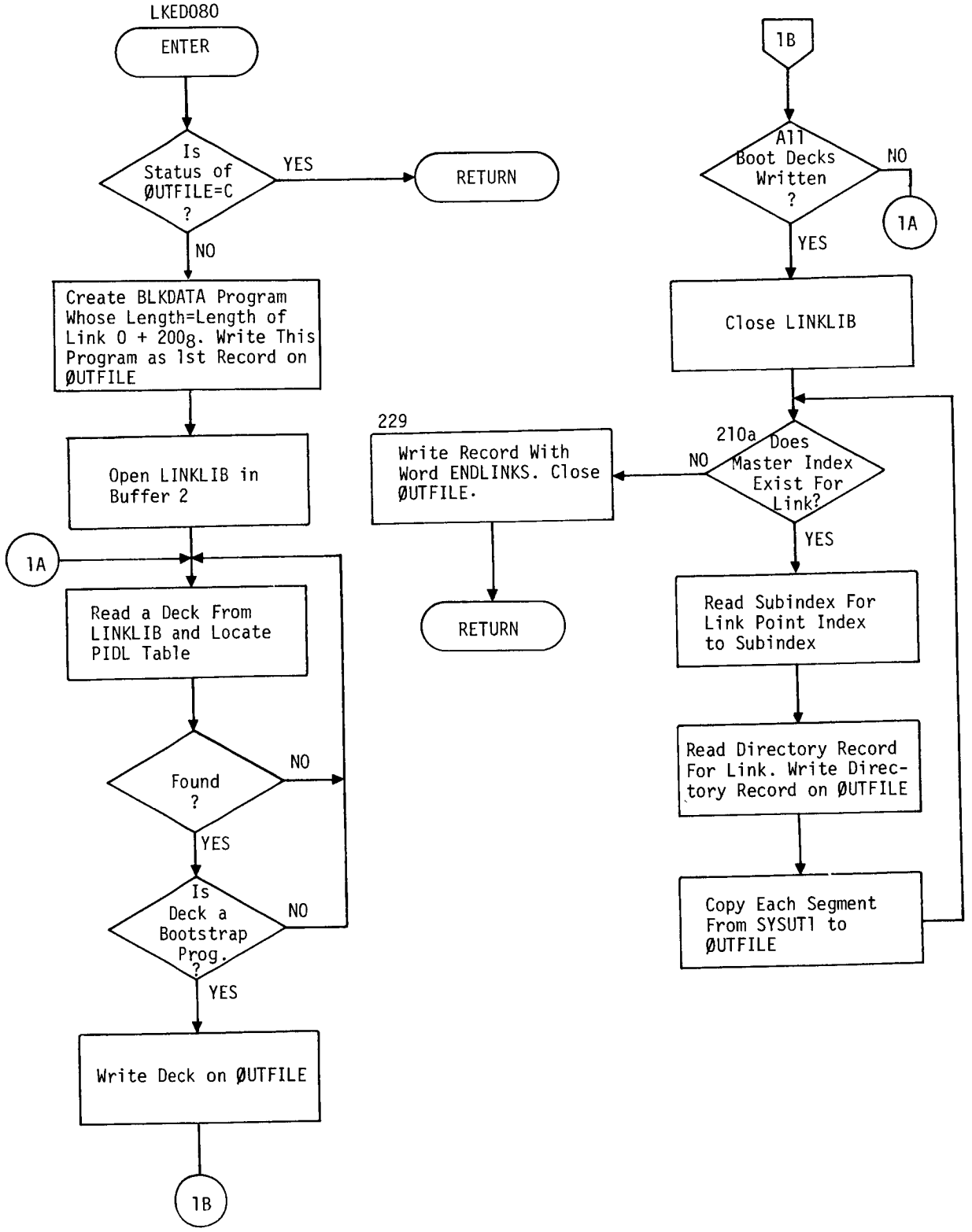


Figure 38. Flowchart for LKED080.

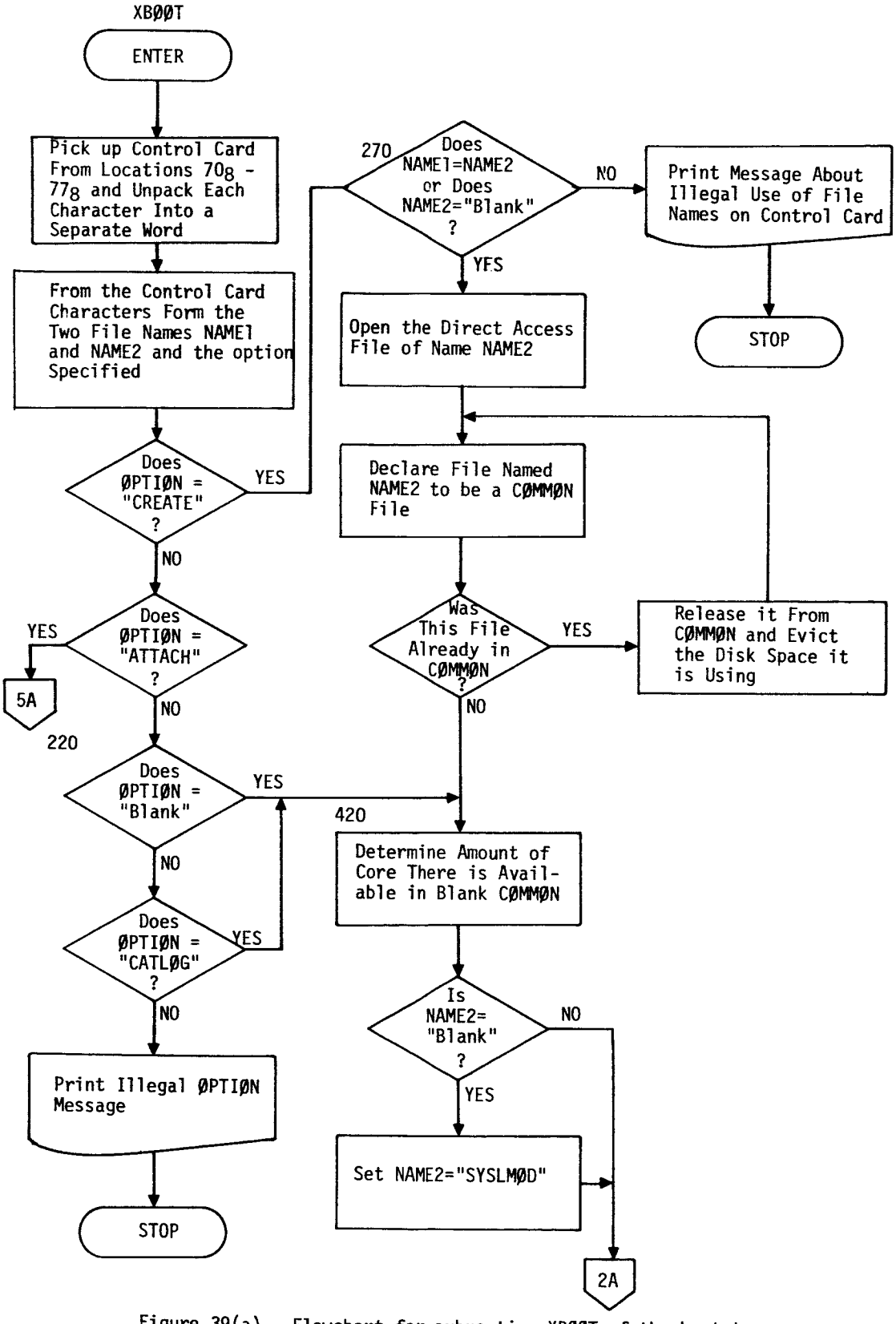


Figure 39(a). Flowchart for subroutine XBØØT of the bootstrap program.

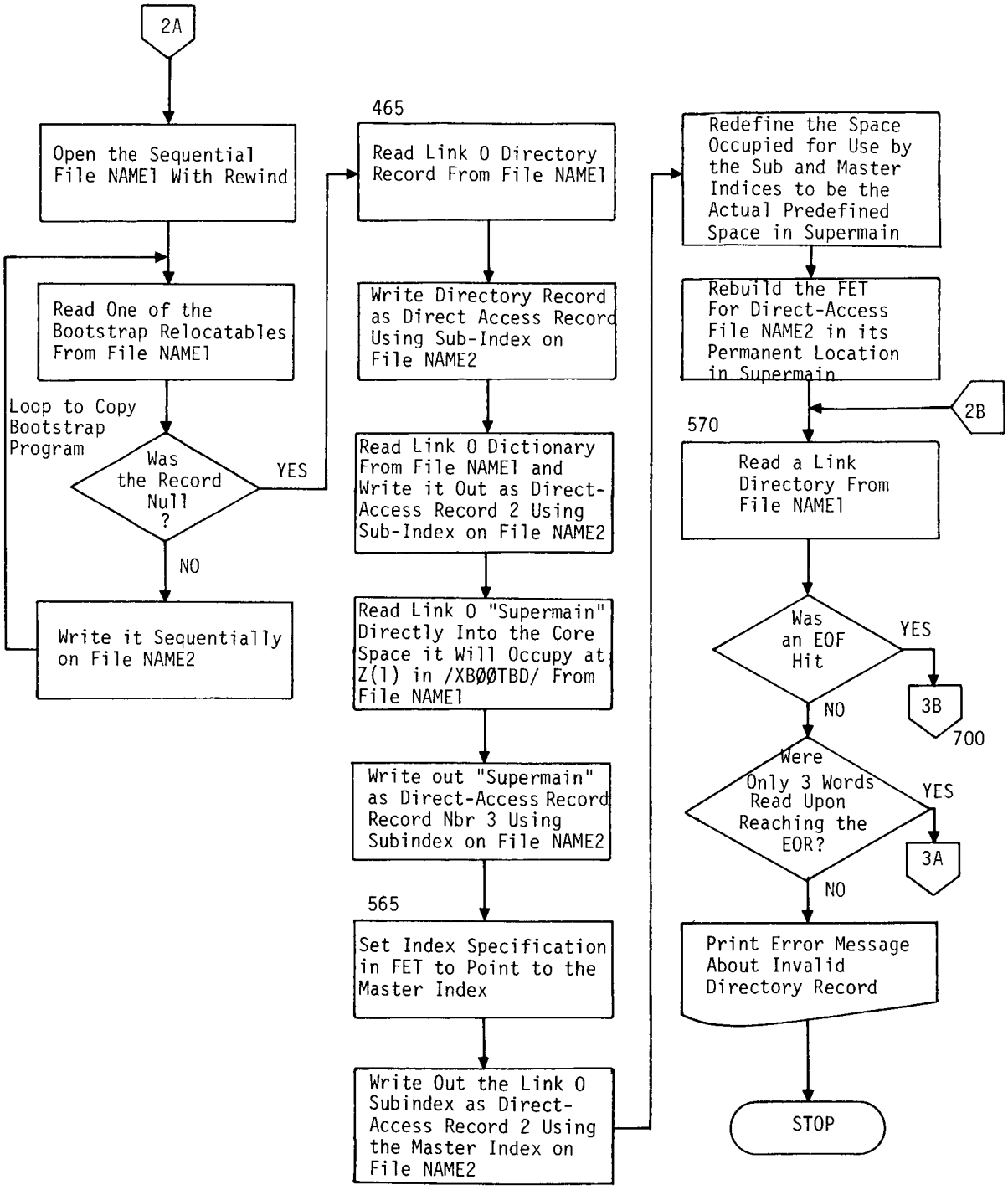


Figure 39(b). Flowchart for subroutine XBØØT of the bootstrap program.

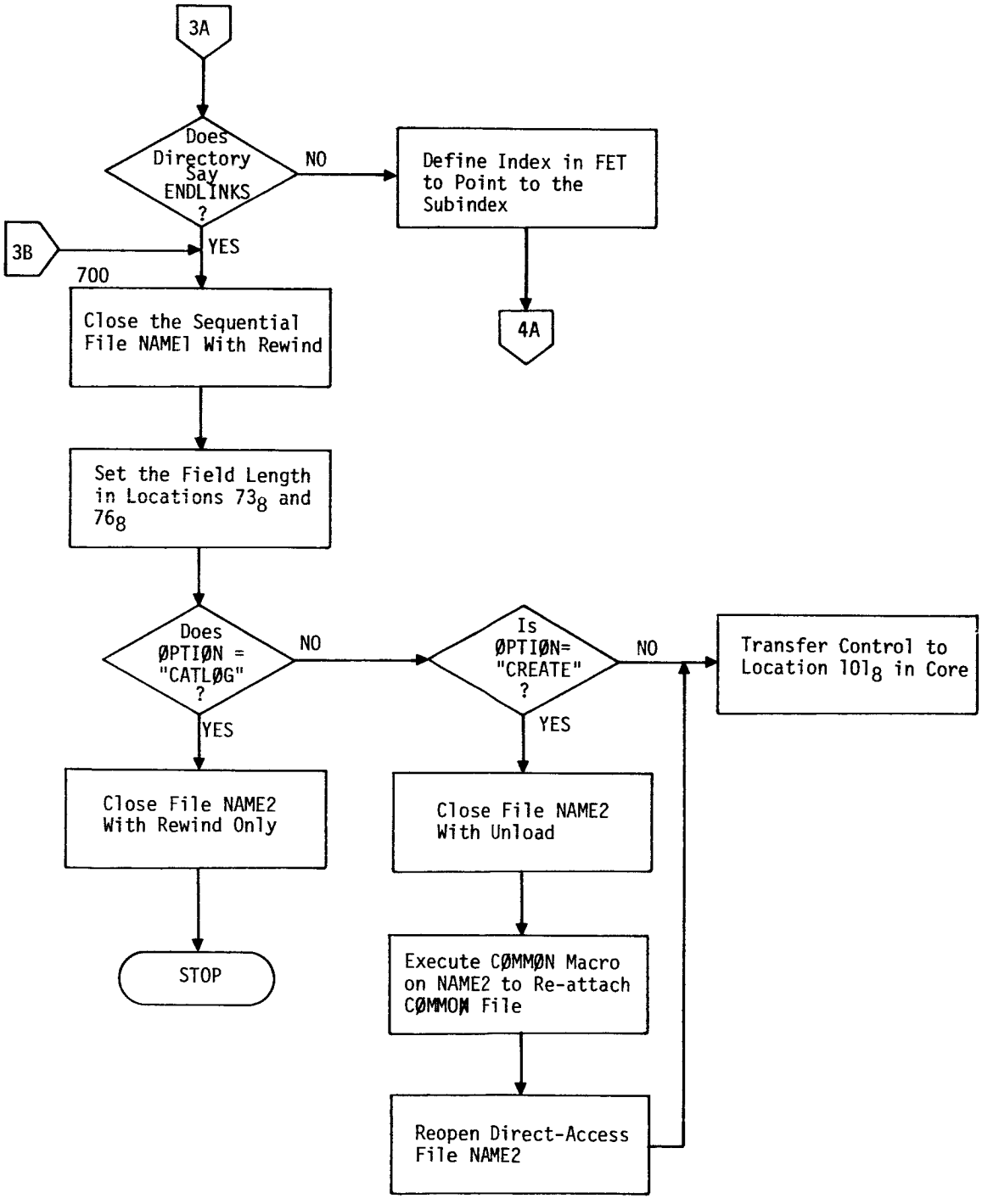


Figure 39(c). Flowchart for subroutine XBØØT of the bootstrap program.

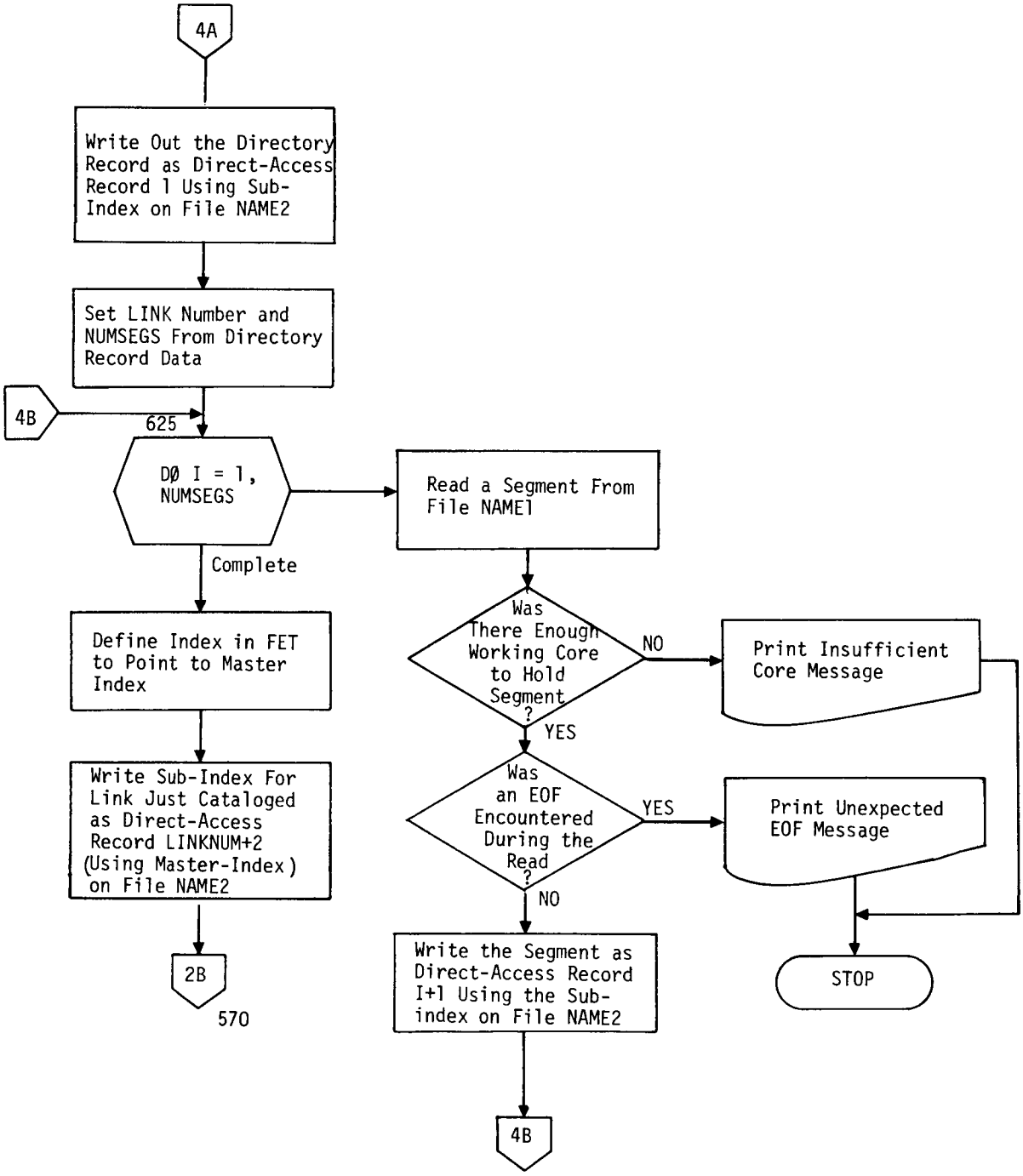


Figure 37(d). Flowchart for subroutine XBØØT of the bootstrap program.

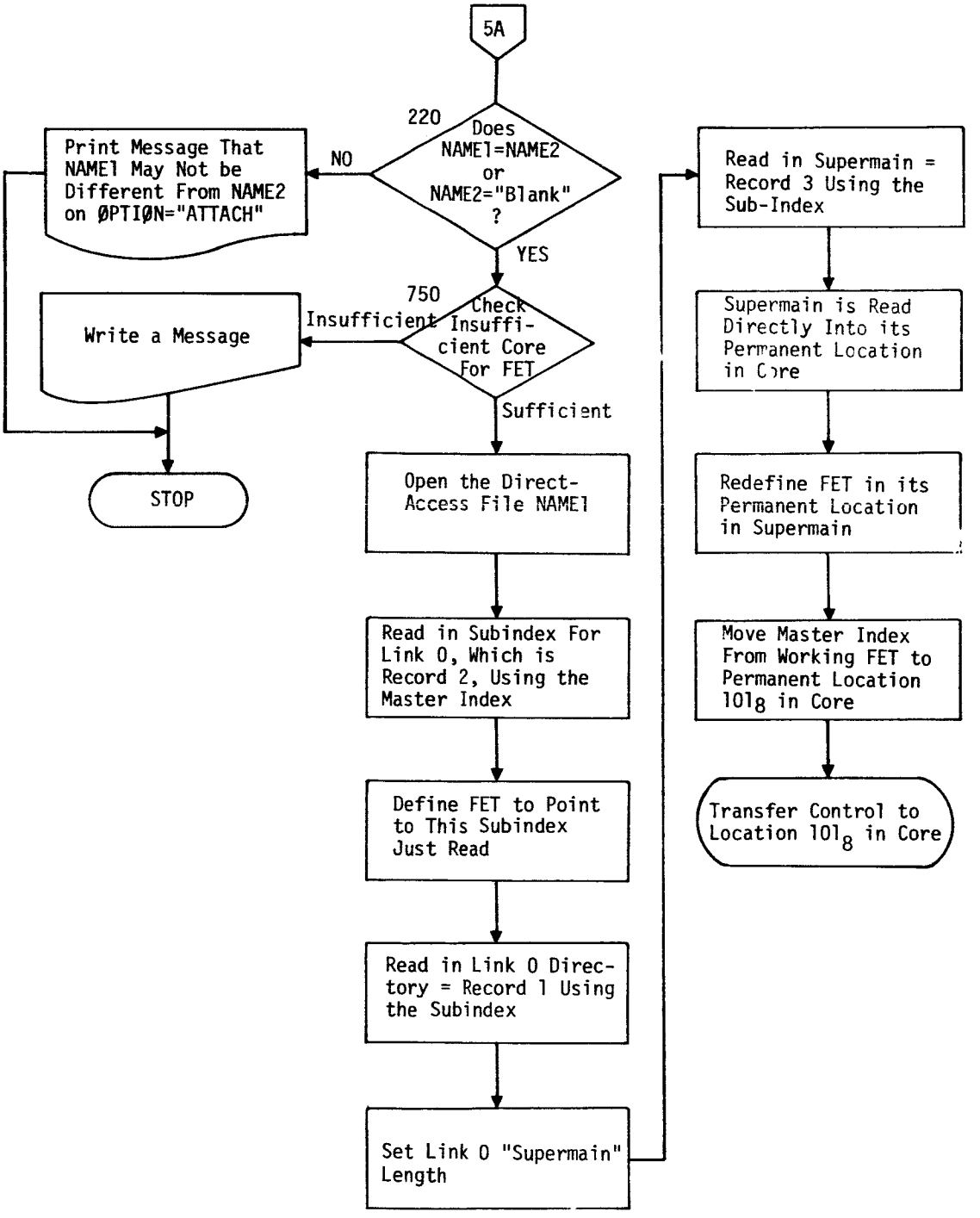


Figure 39(e). Flowchart for subroutine XBØØT of the bootstrap program.

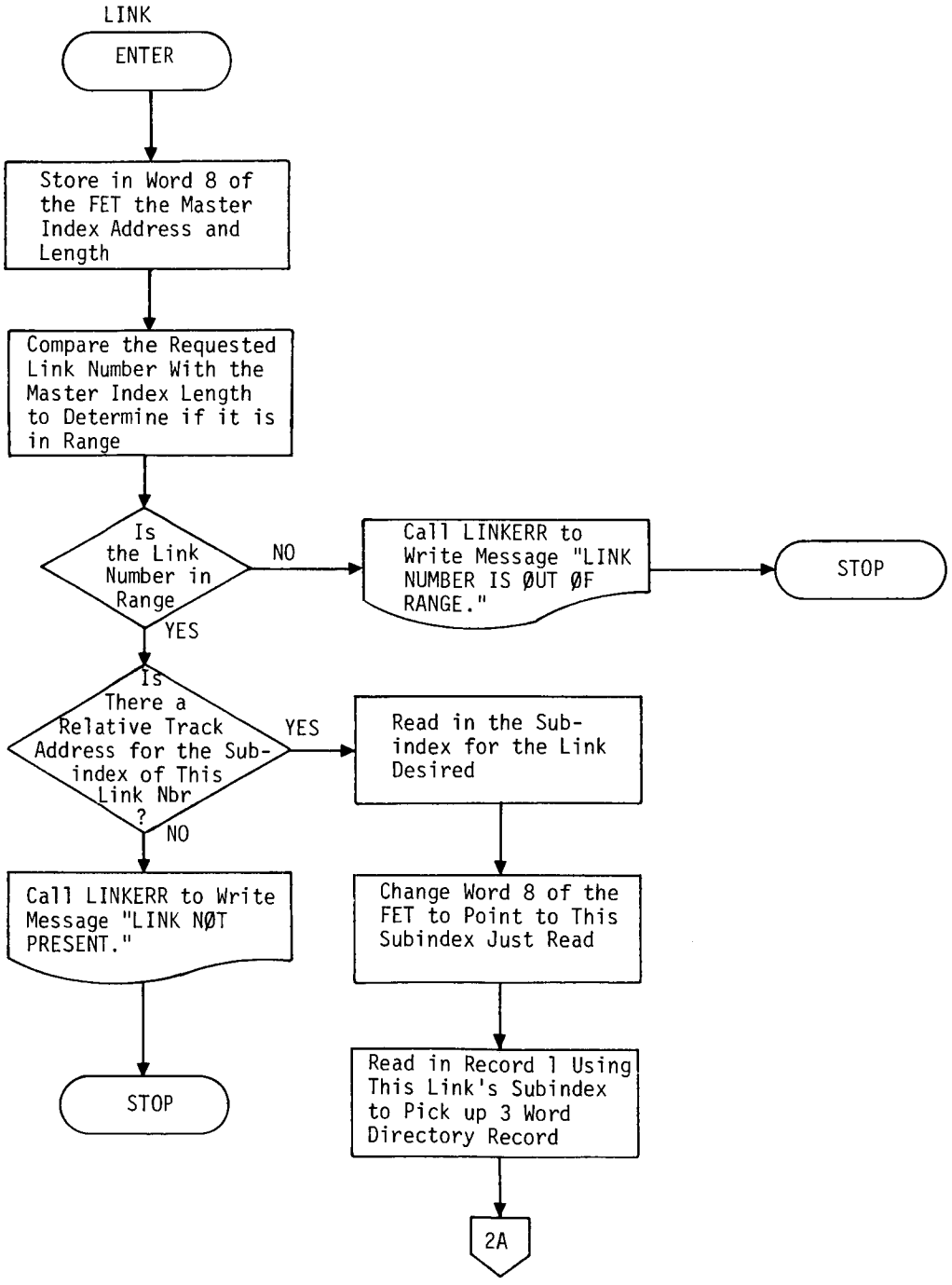


Figure 40(a). Flowchart for subroutine LINK of the segment loader.

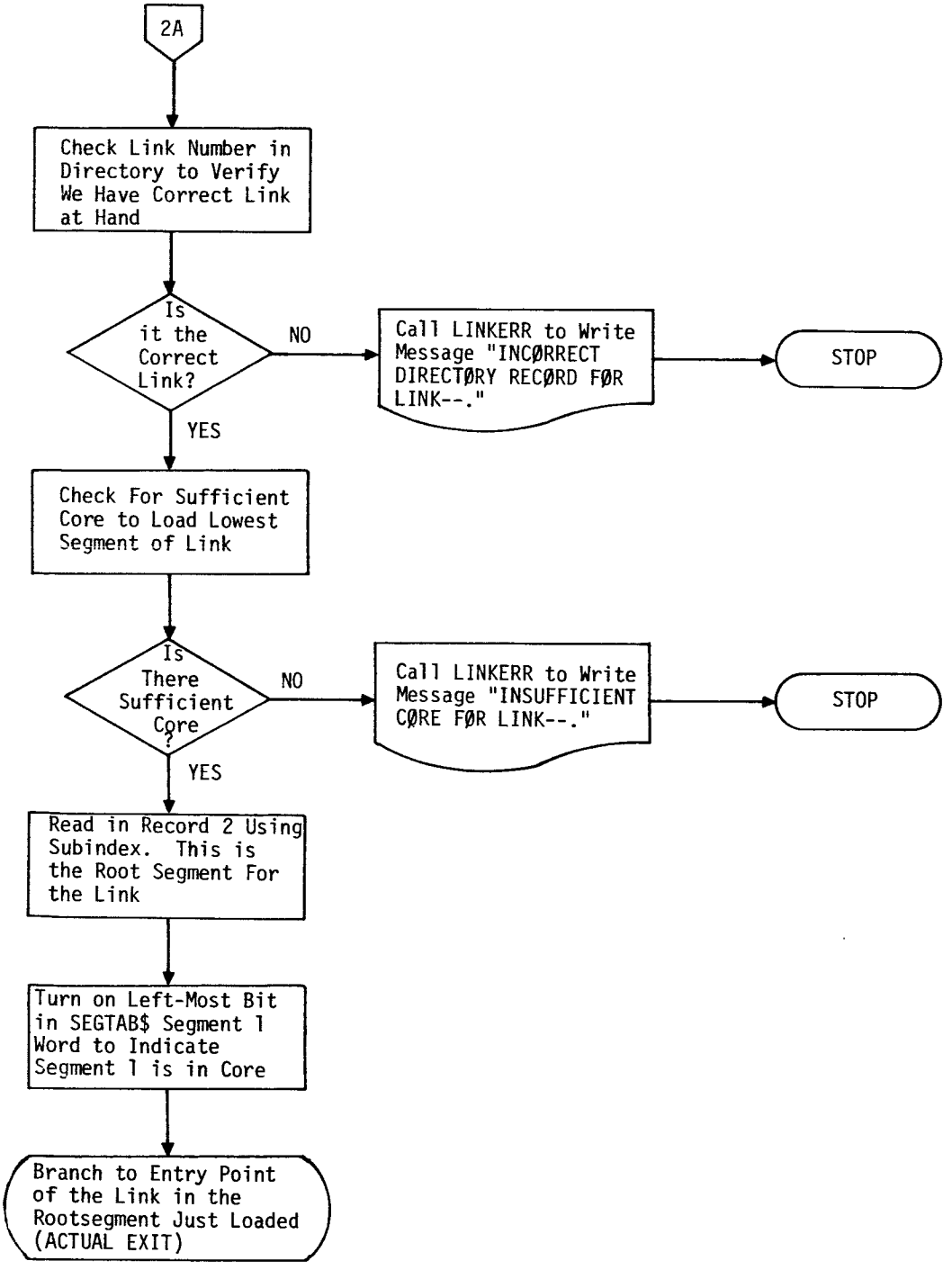


Figure 40(b). Flowchart for subroutine LINK of the segment loader.

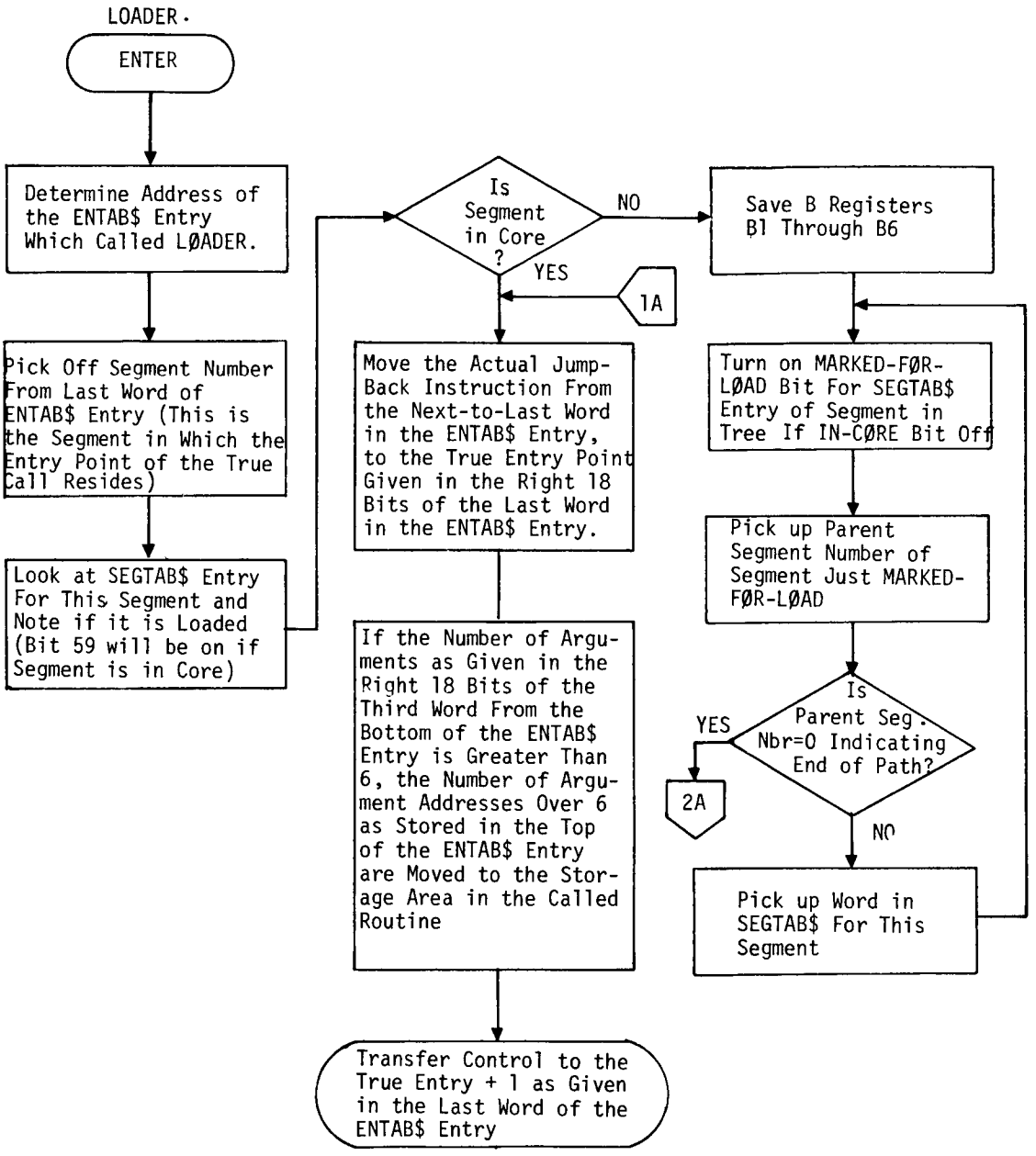


Figure 41(a). Flowchart for subroutine LØADER. of the segment loader.

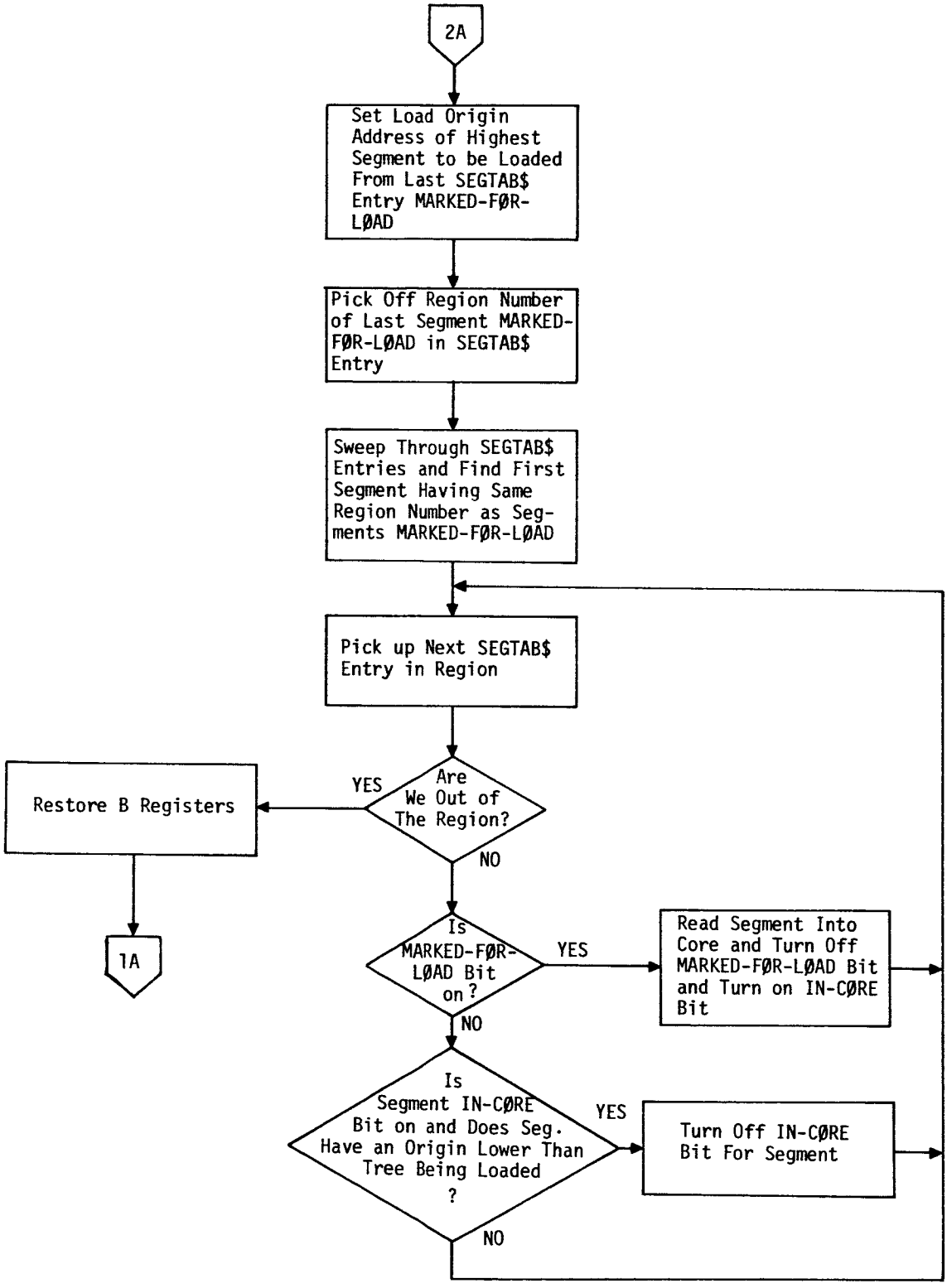


Figure 41(b). Flowchart for subroutine LØADER. of the segment loader.

7.2.4 Subroutine Descriptions

This section contains descriptions for linkage editor subroutines, which are classified in four categories:

1. Major subroutines. These are coded in FØRTRAN and are named LKEDxxx, where $100 \leq xxx \leq 299$. In general these subroutines operate on the linkage editor tables in working storage.

2. Linkage editor utilities. These are CØMPASS routines the names of which are related to the function they perform. They are all entry points in subprograms named LKEDxxx, where $300 \leq xxx \leq 399$. Most of these routines perform tasks directly related to the linkage editor such as field manipulation of table entries.

3. General utilities. These are CØMPASS and FØRTRAN routines the primary functions of which are general in nature and not limited to linkage editor applications. No naming convention exists for the general utilities. Several of these routines (e.g., XRCARD, MAPFNS) are used in the NASTRAN program.

4. Miscellaneous. These are written primarily in FØRTRAN and perform auxiliary tasks for the linkage editor. The naming convention is LKEDxxx, where $900 \leq xxx \leq 999$. An example is LKED990, a routine which abnormally terminates the linkage editor in the event of an error in the logic.

Much of the communication among linkage editor subroutines is via seven named common blocks, LKEDCxx, where $01 \leq xx \leq 07$. Section 7.2.6 gives definitions of the principal variables in these common blocks.

Table 2 gives in alphabetical order the entry points described in section 7.2.4 along with the subsection numbers where the descriptions can be found.

Table 2. Entry Points Described in Section 7.2.4.

Entry Point	Section Number	Entry Point	Section Number
ABSENT.	7.2.4.3.5	REINDX	7.2.4.3.11
ANDF	7.2.4.3.21	REPLTAB	7.2.4.2.23
CALLCHN	7.2.4.2.8	RSHIFT	7.2.4.3.21
CHARTST	7.2.4.2.12	RSHIFTX	7.2.4.2.11
CØMPARE	7.2.4.3.4	SEGPATH	7.2.4.2.9
CØMPLF	7.2.4.3.21	STØEXT	7.2.4.2.18
CØNVERT	7.2.4.2.10	SYMHASH	7.2.4.2.7
CØRDUMP	7.2.4.3.6	TEXTTAB	7.2.4.2.20
CØRWDS	7.2.4.3.24	UNPK	7.2.4.2.4
FIELDLN	7.2.4.3.27	UNPK12	7.2.4.2.5
FILLTAB	7.2.4.2.21	UNPK30	7.2.4.2.24
GETEXT	7.2.4.2.17	UNPKCAL	7.2.4.2.15
HASH	7.2.4.2.30	UNPKEP	7.2.4.2.29
LINK20.	7.2.4.3.28	UNPKID	7.2.4.2.25
LINKERR	7.2.4.3.29	UNPKMSK	7.2.4.2.4
LINKTB1	7.2.4.2.22	UNPKSYM	7.2.4.2.1
LINKTB2	7.2.4.2.22	UNPKXRF	7.2.4.2.28
LKED100	7.2.4.1.1	UNPKXX	7.2.4.2.13
LKED150	7.2.4.1.2	WRITEX	7.2.4.3.14
LKED175	7.2.4.1.3	XBKPREC	7.2.4.3.19
LKED200	7.2.4.1.4	XBKREC	7.2.4.3.17
LKED201	7.2.4.1.4	XCLØSE	7.2.4.3.9
LKED900	7.2.4.4.1	XDUMP	7.2.4.3.3
LKED990	7.2.4.4.2	XEØF	7.2.4.3.7
LKED995	7.2.4.4.3	XEVICT	7.2.4.3.10
LSHIFT	7.2.4.3.21	XFETCH	7.2.4.3.22
LWØRDS	7.2.4.3.23	XFRDREC	7.2.4.3.18
NØW	7.2.4.2.19	XJUMP	7.2.4.3.25
ØRF	7.2.4.3.21	XØPEN	7.2.4.3.8
PACK	7.2.4.2.3	XRCARD	7.2.4.3.1
PACK12	7.2.4.2.6	XREAD	7.2.4.3.13
PACKCAL	7.2.4.2.16	XREQST	7.2.4.3.20
PACKDMP	7.2.4.2.26	XREWIND	7.2.4.3.16
PACKSYM	7.2.4.2.2	XSTØRE	7.2.4.3.22
PACKXRF	7.2.4.2.27	XTRACE	7.2.4.3.2
PACKXX	7.2.4.2.14	XWRITE	7.2.4.3.12
READX	7.2.4.3.15	ZAP	7.2.4.3.26

7.2.4.1 Major Subroutines

7.2.4.1.1 LKED100

Subprogram name: LKED100

Type of routine: Subroutine

Alternate entry points: None

Purpose: To locate an entry in the General Table. If no entry is found and an option is selected, a new entry in the GT is created.

Calling Sequence:

CALL LKED100(NAME,PØINTER,ZPØINT,SEGNØ,STATUS,FLAG)

NAME - (input) symbolic name, left justified, zero filled

PØINTER - (output) relative location of entry if found or created; zero if not found and not created

ZPØINT - (output) ITABO + PØINTER if found or created; undefined otherwise, where ITABO is a zero pointer to the GT

SEGNØ - (input) if entry is not found and FLAG $\neq$ 0 and SEGNØ $\neq$ 0, the newly created entry is chained to the segment defined by SEGNØ.

STATUS - (output) if entry was not found (whether created or not), STATUS = -1. Otherwise, STATUS = CLASS (see section 7.2.2.1.9) of entry ($0 \leq$ STATUS ≤ 7)

FLAG - (input). If entry is found, FLAG is ignored. If entry is not found and FLAG = 0, return is made with PØINTER = 0 and STATUS = -1. Otherwise, (i.e., FLAG $\neq$ 0), a new entry is created and PØINTER points to it while STATUS = -1 indicates this case.

Method: HASH (section 7.2.4.2.30) is called to obtain the hash number for NAME. SYMHASH (section 7.2.4.2.7) is called to locate the entry in the General Table. If the entry is in the table, then return is given with PØINTER pointing to the entry, ZPØINT = ITABO + PØINTER and STATUS = CLASS of the entry. If the entry is not in the table and FLAG = 0, return is given with PØINTER = 0 and STATUS = -1. Otherwise a new entry is created in the GT. If SEGNO $\neq$ 0, the new entry is chained to the segment chain defined by SEGNO. Return is given with PØINTER pointing to the new entry, ZPØINT = ITABO + PØINTER and STATUS = -1.

Language: FØRTRAN

7.2.4.1.2 LKED150

Subprogram name: LKED150

Type of routine: Subroutine

Alternate entry points: None

Purpose: To delink a symbol entry in the General Table from its posted segment chain and link the entry to a new segment chain.

Calling Sequence:

CALL LKED150(PØINTER,ZPØINT,SEGNBR)

PØINTER - (input) points to an entry in the GT.

ZPØINT - (input) = TABO + PØINTER, where ITABO is the zero pointer to the GT

SEGNBR -- (input) new segment number to which entry is now to be linked

Method: The posted segment number and segment chain pointers are obtained from the 3rd word of the GT entry by UNPKXX (section 7.2.4.2.13). The beginning and ending segment chain pointers are obtained from the SCT by UNPK12 (section 7.2.4.2.5). The entry is then delinked (removed) from the posted segment chain. Segment chain pointers for the new segment (defined by SEGNBR) are obtained from the SCT by UNPK12. The entry is now linked (added) to the end of the new segment chain. Updated chain pointers for both the old and new segment chains are stored in the SCT. An updated 3rd word of the GT entry is stored.

Language: FØRTRAN

7.2.4.1.3 LKED175

Subprogram name: LKED175

Type of routine: Subroutine

Alternate entry points: None

Purpose: To Perform the rename function (see section 5.6.4.9)

Calling Sequence:

CALL LKED175(NAME,DKNAME,NEWSTAT)

NAME - (input/output) name of the external reference to be tested for renaming. If the rename occurs, NAME is replaced by the new name.

DKNAME - (input) name of subprogram in which NAME is an external reference

NEWSTAT - (output) a logical variable set to .TRUE., if a rename occurred; .FALSE., otherwise.

Method: NEWSTAT is set to .FALSE.. If the Rename Table is empty, return is given. Otherwise, HASH (section 7.2.4.2.29) and SYMHASH (section 7.2.4.2.7) are called to locate the entry in the Rename Table. If the entry is not in the table, return is given. Otherwise, NAME is set to the new name, NEWSTAT is set to .TRUE., and return is given.

Language: FØRTRAN

7.2.4.1.4 LKED200

Subprogram name: LKED200

Type of routine: Subroutine

Alternate entry points: LKED201

Purpose: To determine if a call (external reference) is in the path of the subprogram making the call. If the call is not in the path, an entry is added to the call chain of the current subprogram and linked to the ENTAB$ chain of the calling segment. LKED201 performs all the logic as LKED200 does except the path test.

Calling Sequence:

CALL $\begin{Bmatrix}\text{LKED200}\\\text{LKED201}\end{Bmatrix}$ (TØPTR,TØSEG,FRØMSEG)

TØPTR - (input) pointer in GT to entry defining the symbol called (external reference).

TØSEG - (input) segment number of external reference

FRØMSEG - (input) segment number from which call originates.

Method: If entry comes through a call to LKED200, then SEGPATH (section 7.2.4.2.9) is called to determine if the call is in the path. If it is, return is given. Otherwise, code common with LKED201 is executed. CALLCHN (section 7.2.4.2.8) is called to determine if any entry is already in the call chain. If so, return is given. If not, an entry in the call chain is created. The entry is linked to the ENTAB$ chain for the segment defined by FRØMSEG. The fields of the entry are completed and return is given.

Language: FØRTRAN

7.2.4.2 Linkage Editor Utilities

7.2.4.2.1 UNPKSYM

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack into 11 words the 11 fields of a 3-word symbol entry in the General Table (see section 7.2.2.1.9)

Calling Sequence:

CALL UNPKSYM(Z(ZPØINT),ITEMS)

Z(ZPØINT) - (input) address of the 1st word of the symbol entry

ITEMS - (output) address of an array of dimension 11 where the fields of the entry will be stored as follows:

(1) Symbol name

(2) CLASS

(3) P_1

(4) INDEX

(5) L

(6) P_C

(7) P_N

(8) SEG

(9) A

(10) PREV

(11) NEXT

Note: the ARG bit is not unpacked

Method: Fields are extracted using bit masks constructed by the MXi instruction shifts and logical products.

Language: CØMPASS

7.2.4.2.2 PACKSYM

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To store the 11 fields of a 3-word symbol entry in the General Table from an 11-word array (see section 7.2.2.1.9)

Calling Sequence:

```
CALL PACKSYM(Z(ZPØINT),ITEMS)
```

The arguments are defined as in UNPKSYM (see section 7.2.4.2.1)

Method: Each word of the 3-word entry is constructed using shift and logical sum instructions. Fields are not examined for maximum size.

Language: CØMPASS

7.2.4.2.3 PACK

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: PACKMSK

Purpose: To store a single item in a word which contains more than one item.

Calling Sequence:

```
CALL PACK(ENTRY,ITEM,BIT,WIDTH)
CALL PACKMSK(ENTRY,ITEM,BIT,MASK)
```

ENTRY - (output) address of word where ITEM is to be stored

ITEM - (input) item to be stored

BIT - (input) position of the low-order bit in the field in ENTRY where ITEM is to be stored (numbering convention is that the high order bit in a word is 59 and the low order bit is 0. Bits are numbered from left to right).

WIDTH - (input) width of the field in bit positions

MASK - (input) a mask of 1-bits in the low order position of the word, the number of 1-bits is the width of the field where ITEM is stored. The remainder of MASK must be zero-filled.

Method: IF PACK is called, a mask of "1" bits specified by WIDTH is constructed in the low-order part of a word, with the remainder of the word zero-filled. If PACKMSK is called, this step is not necessary. The word specified by ENTRYiis fetched, shifted according to BIT, the requested field is cleared using alogical product with the complement of MASK, ITEM is entered using a logical sum, the word is shifted to its original position, and stored back in memory.

Language: CØMPASS

7.2.4.2.4 UNPK

Subprogram name: LKED300

Type of routine: Integer function

Alternate entry points: UNPKMSK

Purpose: To extract a single item from a word which contains more than one item.

Calling Sequence:

ITEM = UNPK(ENTRY,BIT,WIDTH)

ITEM = UNPKMSK(ENTRY,BIT,MASK)

Where the arguments are defined as in PACK and PACKMSK (see section 7.2.4.2.3)

Method: If UNPK is called, a mask of "1" bits specified by WIDTH is constructed in the low-order part of the word, with the remainder of the word zero-filled. If UNPKMSK is called, this step is unnecessary. The word specified by ENTRY is fetched, shifted according to BIT and the item is extracted using a logical product. ENTRY remains unchanged in memory.

Language: CØMPASS

7.2.4.2.5 UNPK12

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack four 15-bit items from a one-word entry or eight 15-bit items from a two-word entry.

Calling Sequence:

CALL UNPK12(ENTRY,ITEMS,K)

ENTRY - (input) address of the 1st word of a one-word or two-word entry.

ITEMS - (output) address of the 1st word of a 4-word or 8-word array where the unpacked items will be stored, right-adjusted, zero-filled

K - (input) 1 or 2 specifying the number of words to be unpacked

Method: Items are extracted using a 15-bit mask, logical product and 15-bit shift instructions.

Language: CØMPASS

7.2.4.2.6 PACK12

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To pack four 15-bit items into a one-word entry or eight 15-bit items into a two-word entry.

Calling Sequence:

CALL PACK12(ENTRY,ITEMS,K)

where the arguments are defined as in UNPK12 (see section 7.2.4.2.5)

Method: Using a shift and logical sum, the items are packed together.

Note: Items are not examined for maximum size ($\leq$ 15 bits)

Language: CØMPASS

7.2.4.2.7 SYMHASH

Subprogram name: LKED300

Type of routine: Integer Function

Alternate entry points: None

Purpose: To locate a symbol entry in a table

Calling Sequence:

PØINTER = SYMHASH(TABLE,NAME,HASHNBR,STATUS)

TABLE - (input) address of the 0th word in the table (i.e., address of the 1st word minus one)

NAME - (input) symbol to be located, left-justified, zero filled

HASHNBR - (input) hash number of the symbol

PØINTER and STATUS - (output) if entry for symbol is not in table:

PØINTER = 0

STATUS points to last entry in symbol chain.

if entry is in table:

PØINTER points to entry

STATUS = CLASS of entry

Method: Beginning with the entry to which HASHNBR points, the symbol chain is searched for a match. If found, PØINTER and STATUS are set as defined above. If the end of chain is encountered before a match occurs, PØINTER is set to zero and STATUS is set to point to the last entry in the symbol chain.

Language: CØMPASS

7.2.4.2.8 CALLCHN

Subprogram name: LKED300

Type of routine: Integer Function

Alternate entry points: None

Purpose: To trace the chain of calls to a symbol.

Calling Sequence:

PØINTER = CALLCHN(TABLE,CALLPTR,FRØMSEG,STATUS)

TABLE - (input) address of 0th word in table

CALLPTR - (input) pointer to entry of symbol called

FRØMSEG - (input) segment number from which call originates

PØINTER and STATUS - (output) if no chain exists:

PØINTER = STATUS = 0

if call is already in chain:

PØINTER = 0, STATUS $\neq$ 0

if call is not in chain:

PØINTER points to last entry in call chain

STATUS $\neq$ 0

Method: A call chain exists if the ARG bit = 0 and $P_c \neq 0$. This situation is tested. If not true, return is made with PØINTER = STATUS = 0. A call is defined to be already in the chain if the segment number from which the call originates matches the FRØM field of the call entry. The chain is searched for this condition. If found, PØINTER and STATUS are set as defined above. Otherwise, PØINTER points to the last entry in the chain and STATUS is set to nonzero.

Language: CØMPASS

7.2.4.2.9 SEGPATH

Subprogram name: LKED300

Type of routine: Logical Function

Alternate entry points: None

Purpose: To determine if the segment called is in the path of the segment from which the call is made.

Calling Sequence:

LVAR = SEGPATH(Z(ISEGD0),TØSEG,FRØMSEG)

LVAR - (output) logical variable which is .TRUE. if call is in the path; .FALSE. otherwise

Z(ISEGD0) - (input) address of the 0th word of the Segment Definition Table

TØSEG - (input) segment number to which call is made

FRØMSEG - (input) segment number from which call is made

Method: Starting with the entry in the SDT to which FRØMSEG points, the parent of the segment is checked. If it maches TØSEG, LVAR is set to .TRUE. and SEGPATH returns. If the parent is zero, LVAR is set to .FALSE. and return is given. Otherwise, the segment to which the parent points is fetched and the tests repeated.

Language: CØMPASS

7.2.4.2.10 CØNVERT

Subprogram name: LKED300

Type of routine: Integer Function

Alternate entry Points: None

Purpose: To convert a symbol stored in a 2-word array of 4 characters per word, left justified, blank filled (NASTRAN format) to a single word, left-justified, zero filled.

Calling Sequence:

NEWNAME = CØNVERT(ØLDNAME)

ØLDNAME - (input) 2-word array of 4 characters per word, left justified, blank filled

NEWNAME - (output) one word, left justified, zero filled

Method: Each character of ØLDNAME is tested until a blank character is found or 8 characters have been examined. Character positions starting with the blank and those succeeding are set to zero.

Language: CØMPASS

7.2.4.2.11 RSHIFTX

Subprogram name: LKED300

Type of routine: Integer Function

Alternate entry points: None

Purpose: To shift a computer word to the right a specified number of bit positions.

Calling Sequence:

SHIFTED = RSHIFTX(NUMBER,N)

SHIFTED - (output) shifted word

NUMBER - (input) computer word to be shifted

N - (input) number of bit positions to shift

Method: The number is assumed to have the high order bit equal to zero (this is not tested). The AXi instruction is used.

Language: CØMPASS

7.2.4.2.12 CHARTST

Subprogram name: LKED300

Type of routine: Logical Function

Alternate entry points: None

Purpose: To test a position in a XRCARD output buffer (see section 3.4.19) for a specific delimiter.

Calling Sequence:

LVAR = CHARTST(ØUTBUF(K),CHAR)

LVAR - (output) logical variable which is .TRUE. if ØUTBUF(K) and ØUTBUF(K+1) contain the specified delimiter; .FALSE. otherwise

ØUTBUF(K) - (input) address of a 2-word array of characters stored 4 characters per word, left justified, blank filled

CHAR - (input) address of a character stored in 1H format (i.e., left justified, blank filled)

Method: Let the character be C and a blank be b. Then the two words at ØUTBUF(K) and ØUTBUF(K+1) must be Cbbbbbbbbb and bbbbbbbbbb. The words are tested for that condition. If the condition is satisfied, LVAR is set to .TRUE.. If not, LVAR is set to .FALSE..

Language: CØMPASS

7.2.4.2.13 UNPKXX

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack the 2nd or 3rd word of a symbol entry in the General Table (see section 7.2.2.1.9).

Calling Sequence:

CALL UNPKXX(Z(I),ITEMS)

Z(I) - (input) address of the word to be unpacked (2nd or 3rd word of a GT entry)

ITEMS - (output) address of a 4-word array where the four items will be stored.

Method: Using appropriate bit masks, shifts, and logical products, the fields of the word are extracted and stored.

Language: CØMPASS

7.2.4.2.14 PACKXX

Subprogram name: LKED300

Type of routine: Subroutine

Alternate entry points: None

Purpose: To pack 4 items into the 2nd or 3rd word of a symbol entry in the General Table (see section 7.2.2.1.9)

Calling Sequence:

CALL PACKXX(Z(I),ITEMS)

where the arguments are defined in UNPKXX (see section 7.2.4.2.13)

Method: Using appropriate shifts and logical sums, the items are packed into a single word and stored in the table. The items are not checked for being within the specified field width.

Language: CØMPASS

7.2.4.2.15 UNPKCAL

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack the items in the first two words of a call entry in the General Table (see section 7.2.2.1.9)

Calling Sequence:

CALL UNPKCAL(Z(I),ITEMS)

Z(I) - (input) address of call entry in GT

ITEMS - (output) a 9-word array where the items from the first two words of the call entry are stored as follows:

(1) PREV

(2) NEXT

(3) NBRARG

(4) CLASS = 6

(5) P_1

(6) FRØM

(7) $P_{FRØM}$

(8) P_{NEXT}

(9) P_{SYM}

Method: The items are extracted using appropriate bit masks, shifts, and logical products.

Language: CØMPASS

7.2.4.2.16 PACKCAL

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To pack the items comprising the first two words of a call entry in the General Table (see section 7.2.2.1.9)

Calling Sequence:

CALL PACKCAL(Z(I),ITEMS)

where the arguments are defined as in UNPKCAL (see section 7.2.4.2.15)

Method: The items are packed using shifts and logical sums. Field width sizes are not checked.

Language: CØMPASS

7.2.4.2.17 GETEXT

Subprogram name: LKED320

Type of routine: Integer Function

Alternate entry points: None

Purpose: To convert a single word an external reference in the LINK Table (see section 7.2.5) when it is split between two words.

Calling Sequence:

EXTNAME = GETEXT(Z(J))

EXTNAME - (output) external reference

Z(J) - (input) address of the first of two words where the external reference is stored in the right half of Z(J) and the left half of Z(J+1)

Method: Using a 30-bit mask, shifts, and logical products, the external reference is constructed from the two words.

Language: CØMPASS

7.2.4.2.18 STØEXT

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To store an external name in the LINK Table (see section 7.2.5) when the name is split between two words. STØEXT is the inverse of GETEXT (section 7.2.4.2.17)

Calling Sequence:

CALL STØEXT(Z(J),EXTNAME)

where the arguments are defined as in GETEXT

Method: Using masks and shifts, EXTNAME is split into two halves and stored in the right half of Z(J) and left half of Z(J+1).

Language: CØMPASS

7.2.4.2.19 NØW

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To return the date and time of day

Calling Sequence:

CALL NØW(A)

A - (output) address of a two-word array where

A(1) = time of day (BCD)

A(2) = date

Method: The time of day is found using the SCØPE CLØCK macro, and the date is found using the DATE macro.

Language: CØMPASS

7.2.4.2.20 TEXTTAB

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To perform relocation of text words in a TEXT Table (see section 7.2.5)

Calling Sequence:

CALL TEXTTAB(Z(LØC),Z(I),N,ADDRESS)

Z(LØC) - (output) address where the first word of relocated text will be stored

Z(I) - (input) address of first word of TEXT Table.

N - (input) number of words in TEXT Table

ADDRESS - (input) relocation address (i.e., address of subprogram or common block to which text refers)

Method: See section 7.2.5 for a description of the TEXT Table of a subprogram. The first word of a TEXT Table is a relocation indicator word. It is used to determine what kind of relocation applies to each of the address fields in the remaining words of the TEXT Table.

Language: CØMPASS

7.2.4.2.21 FILLTAB

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To perform relocation of address specified by the FILL Table

Calling Sequence:

CALL FILLTAB(Z(ITEXT),Z(JLCTO),Z(J),N,LR)

Z(ITEXT) - (output) address of the 1st word of text for the control section currently being constructed

Z(JLCTO) - (input) address of the 0th word of the Local Common Table (LCT) (see section 7.2.5)

Z(J) - (input) address of the 1st word of the FILL Table

N - (input) number of words in the FILL Table

LR - (input) pointer in the LCT to the control section currently being constructed.

Method: See section 7.2.5 for a description of the FILL Table of a subprogram. A 30-bit byte is extracted from the FILL Table. If it is a control byte, the relocated address is fetched from the LCT. If it is a data byte, the text word containing the reference to be relocated is fetched, the relocation is performed (upper, middle or lower depending on P), and the relocated word is stored back in the text area. This process is repeated for each 30-bit byte until the end of the table is encountered.

Language: CØMPASS

7.2.4.2.22 LINKTB1

Subprogram name: LKED320

Type of routine: Function

Alternate entry points: LINKTB2

Purpose: LINKTB1 returns an external name from the LINK Table (see section 7.2.5), and LINKTB2 performs relocation of all references to the external name.

Calling Sequences:

EXTNAME = LINKTB1(Z(IO),J,SWITCH)

LVAR = LINKTB2(ADDRESS,Z(ITEXT),LØC)

EXTNAME - (output) name of external reference

J - (input/output) current pointer in LINK Table (starting with 1)

SWITCH - (input) current byte pointer (- = high order, + = low order)

Z(IO) - (input) address of 0th word in LINK Table

LVAR - (output) logical variable which if .TRUE. means the next call must be to LINKTB2 and if .FALSE. means the next call must be to LINKTB1. Note:

LINKTB1 is always called first at the beginning of the analysis of the LINK Table.

ADDRESS - (input) address of the external name returned from last LINKTB1 call.

Z(ITEXT) - (input/output) address of first word of text being constructed.

LØC - (input) relative address in text of external reference to be relocated.

Method: See section 7.2.5 for a description of the LINK Table of a subprogram. LINKTB1 extracts the name of the external reference. If the byte switch is plus, the name is split between two words. The addresses of the arguments of the LINKTB1 call are saved and restored at entry to LINKTB2. Actual relocation of references to the external name are performed by the alternate entry. Depending on the relocation bits, the word located at Z(ITEXT + LØC) is relocated and returned to memory. The byte switch, LINK Table pointer, and logical variable are set and return is made.

Language: CØMPASS

7.2.4.2.23 REPLTAB

Subprogram name: LKED32O

Type of routine: Subroutine

Alternate entry points: None

Purpose: To perform relocation specified by a REPL Table (see section 7.2.5) of a subprogram

Calling Sequence:

CALL REPLTAB(Z(J),Z(ITEXT),N,LR)

Z(J) - (input) address of the 0th word of the REPL Table (i.e., the ID word)

Z(ITEXT) - (input/output) address of the first word of text being constructed

N - (input) number of words in REPL Table

LR - (input) pointer in LCT to the control section currently being constructed.

Method: See section 7.2.5 for a description of the REPL Table of a subprogram. Data items are built, relocated, and stored in the text area as a function of the parameter in the REPL Table.

Language: CØMPASS

7.2.4.2.24 UNPK30

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry point: None

Purpose: To unpack two 30-bit bytes from a FILL Table (see section 7.2.5) or LINK Table (see section 7.2.5).

Calling Sequence:

CALL UNPK30(ENTRY,ITEMS)

ENTRY - (input) address of word in FILL or LINK Table to be unpacked

ITEMS - (output) an 8-word array as follows:

(1) = high-byte control, 0 or 1

(2) = high-byte relocation bits or 0 if (1) = 0

(3) = high-byte RL or 0 if (1) = 0

(4) = high-byte LØC or AR if (1) = 0

(5)-(8)= same for low byte

Method: The items are unpacked using shifts and logical products with appropriate masks.

Language: CØMPASS

7.2.4.2.25 UNPKID

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack a table identification word (see section 7.2.5)

Calling Sequence:

CALL UNPKID(WØRD,ITEMS)

WØRD - (input) ID word to be unpacked

ITEMS - (output) a 4-word array as follows:

(1)=CN
(2)=WC
(3)=LR
(4)=L

} See section 7.2.5

Method: The items are unpacked using shifts and logical products with appropriate masks.

Language: CØMPASS

7.2.4.2.26 PACKDMP

Subprogram name: LKED32O

Type of routine: Integer Function

Alternate entry points: None

Purpose: To format the dump control word which is stored at the beginning of each control section.

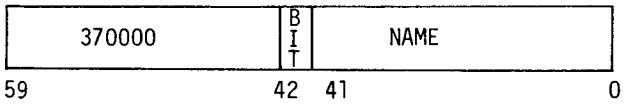
Calling Sequence:

WØRD = PACKDMP(NAME)

WØRD - (output) formatted dump control word

NAME - (input) control section name, left justified, zero filled

Method: The dump control word is constructed to look as follows:



where

BIT = {1 for a common block
{0 otherwise

Language: CØMPASS

7.2.4.2.27 PACKXRF

Subprogram name: LKED35O

Type of routine: Subroutine

Alternate entry points: None

Purpose: To pack the items of the XREF entry into the XREF Table (see section 7.2.2.1.10).

Calling Sequence:

CALL PACKXRF(Z(ZPØINT),ITEMS)

Z(ZPØINT) - (output) address of first word of 6-word XREF entry in XREF Table.

ITEMS - (input) a 19-word array containing the items to be packed into the XREF entry as follows:

(1)	Subprogram name	See section 7.2.2.1.10
(2)	CLASS = 2	
(3)	P_1	
(4)	0 (not used)	
(5)	N	
(6)	PREV	
(7)	NEXT	
(8)-(18)	C_i	
(19)	0 (not used)	

Method: The items are packed using appropriate shifts and logical sums.

Language: CØMPASS

7.2.4.2.28 UNPKXRF

Subprogram name: LKED350

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack the items of an XREF entry in the XREF Table (see section 7.2.2.1.10).

Calling Sequence:

```
CALL UNPKXRF(Z(ZPØINT),ITEMS)
```

where the arguments are defined as in PACKXRF (see section 7.2.4.2.27)

Method: Using appropriate masks, shifts, and logical products each of the fields in Z(ZPØINT) is extracted and stored in the ITEMS array.

Language: CØMPASS

7.2.4.2.29 UNPKEP

Subprogram name: LKED350

Type of routine: Subroutine

Alternate entry points: None

Purpose: To unpack the items of an entry-point entry in the XREF Table (see section 7.2.2.1.10).

Calling Sequence:

CALL UNPKEP(Z(ZPØINT),ITEMS)

Z(ZPØINT) - (input) address of the first word of a 3-word entry-point entry in the XREF Table

ITEMS - (output) an 11-word array where the items are stored as follows:

(1) Entry point name
(2) CLASS = 1
(3) P_1
(4) 0 (not used)
(5) A
(6) 0 (not used)
(7) P_N
(8) PC_1
(9) PC_N
(10) PREV
(11) NEXT

} See section 7.2.2.1.10

Method: Using appropriate masks, shifts, and logical products, each of the fields is extracted and stored in the ITEMS array.

Language: CØMPASS

7.2.4.2.30 HASH

Subprogram name: HASH

Type of routine: Integer Function

Alternate entry points: None

Purpose: To compute the hash number of a symbolic name

Calling Sequence:

HASHNBR = HASH(NAME,NBRENTR)

HASHNBR - (output) hash number of the symbolic name

NAME - (input) symbolic name, left justified, zero filled.

NBRENTR - (number of entries (not words) in table

Method: The following equation is evaluated:

HASHNBR = MØD(RSHIFTX(NAME,18),NBRENTR)*3+1

where RSHIFTX is described in section 7.2.4.2.11 and MØD is the standard MØD function of the FØRTRAN language. It is assumed that the number of words per table entry is three.

Language: FØRTRAN

7.2.4.3 General Utilities

7.2.4.3.1 XRCARD

Subprogram name: XRCARD

Type of routine: Subroutine

Alternate entry points: None

Purpose: To interpret and convert free-field card images.

Calling Sequence:

CALL XRCARD(ØUTBUF,N,INBUF)

ØUTBUF - (output) address of anyarray where the converted card image is stored

N - (input) number of words in ØUTBUF

INBUF - (input) address of an 20-word array containing the card image.

Method: See section 3.4.19.

Language: FØRTRAN

7.2.4.3.2 XTRACE

Subprogram name: XLØADER

Type of routine: Subroutine

Alternate entry points: None

Purpose: XTRACE when called gives a traceback from itself to the program which called XTRACE and from that program to the one calling it and so forth. Note following sample output.

XTRACE	CALLED	FROM	LOCATION	023351	IN CONTROL SECTION	CORDUMP
CORDUMP	CALLED	FROM	LOCATION	022122	IN CONTROL SECTION	XDUMP
XDUMP	CALLED	FROM	LOCATION	012025	IN CONTROL SECTION	DUMP
DUMP	CALLED	FROM	LOCATION	012511	IN CONTROL SECTION	MESAGE
MESAGE	CALLED	FROM	LOCATION	003050	IN CONTROL SECTION	GINO
GINO	CALLED	FROM	LOCATION	042047	IN CONTROL SECTION	SDR2F
SDR2F	CALLED	FROM	LOCATION	040301	IN CONTROL SECTION	SDR2D
SDR2D	CALLED	FROM	LOCATION	035553	IN CONTROL SECTION	SDR2
SDR2	CALLED	FROM	LOCATION	030414	IN CONTROL SECTION	XSEM13

Calling Sequence:

```
CALL XTRACE
```

Method: From the entry point of XTRACE, XTRACE picks up the address + 1 of where the call to XTRACE was made from. Stored at the address of that call is the address of that program's entry point - 1. From there a trace can be made to the next called routine in the same fashion.

Language: CØMPASS

7.2.4.3.3 XDUMP

Subprogram name: XLØADER

Type of routine: Subroutine

Alternate entry points: None

Purpose: XDUMP is called to dump an area of core storage. XDUMP does not actually perform the dumping. It uses the utility routine CØRDUMP (section 7.2.4.3.6) to actually format the dump.

Calling Sequence:

```
CALL XDUMP(ADD1,ADD2,ØP)
```

ADD1 - Variable containing first address desired in dump

ADD2 - Variable containing last address desired in dump (If it is greater than field length, XDUMP will use the field length - 1 as the last address in dump.

ØP - { 0 if only an octal dump is desired
     { 1 if octal and BCD are desired

Method: XDUMP determines the number of words to be dumped. It then sets up a call to CØRDUMP which performs the actual dumping, CØRDUMP receives the address of the array and dumps it in the prescribed format.

Language: CØMPASS

7.2.4.3.4 CØMPARE

Subprogram name: XLØADER

Type of routine: Integer Function

Alternate entry points: None

Purpose: CØMPARE compares two words of core memory and returns a count (0 to 60) of the number of bits that do not match in the two words.

Calling Sequence:

CØUNT = CØMPARE(WØRD1,WØRD2)

Method: An logical difference is performed and the number of bits in the result is returned.

Language: CØMPASS

7.2.4.3.5 ABSENT.

Subprogram name: XLØADER

Type of routine: Subroutine

Alternate entry points: None

Purpose: The linkage editor automatically inserts a call to ABSENT. for calls to unsatisfied externals. ABSENT. will be called if these unsatisfied externals are ever called. Then ABSENT. will call XTRACE to inform the user whence the unsatisfied external was called.

Calling Sequence:

CALL ABSENT.

Usually called in assembly language or implicitly via a RENAME card in the linkage editor control card language.

Method: ABSENT. calls XTRACE and then executes a return jump to EXIT to halt the job.

Language: CØMPASS

7.2.4.3.6 CØRDUMP

Subprogram name: CØRDUMP

Type of routine: Subroutine

Alternate entry points: None

Purpose: CØRDUMP performs the actual dumping of an area of core. Normally CØRDUMP is called via the driver XDUMP since a FØRTRAN program normally cannot define any area of core directly.

Calling Sequence:

CALL CØRDUMP(BUF,LBUF,ØP,NBUFF)

BUF - Array to be dumped.

LBUF - Length of the array BUF

ØP - {0 for octal dump only; 1 for octal and BCD dump.}

NBUFF - Variable containing the address of the last word of the segment loader's buffer. (NBUFF is used to eliminate the formatting of IØ buffer into control sections)

Method: CØRDUMP creates a normal dump of core storage giving absolute addresses and core storage four words per line. CØRDUMP also looks for the "control section ID word" which starts each common block or subprogram and outputs relative addresses based on this word. Figure 42 gives an example of a core storage dump.

Language: FØRTRAN

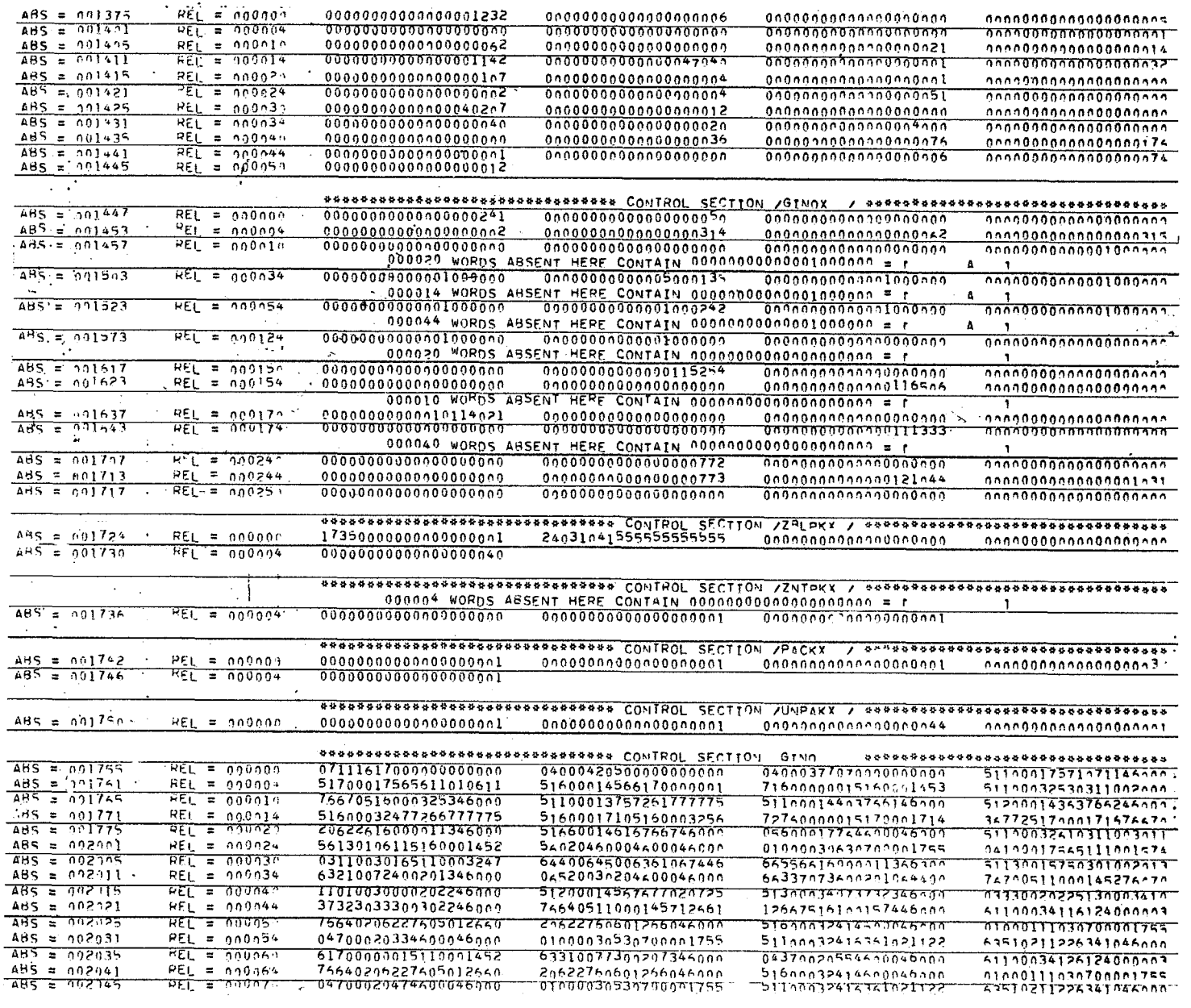


Figure 42(a). Example of a core dump output by CØRDUMP.

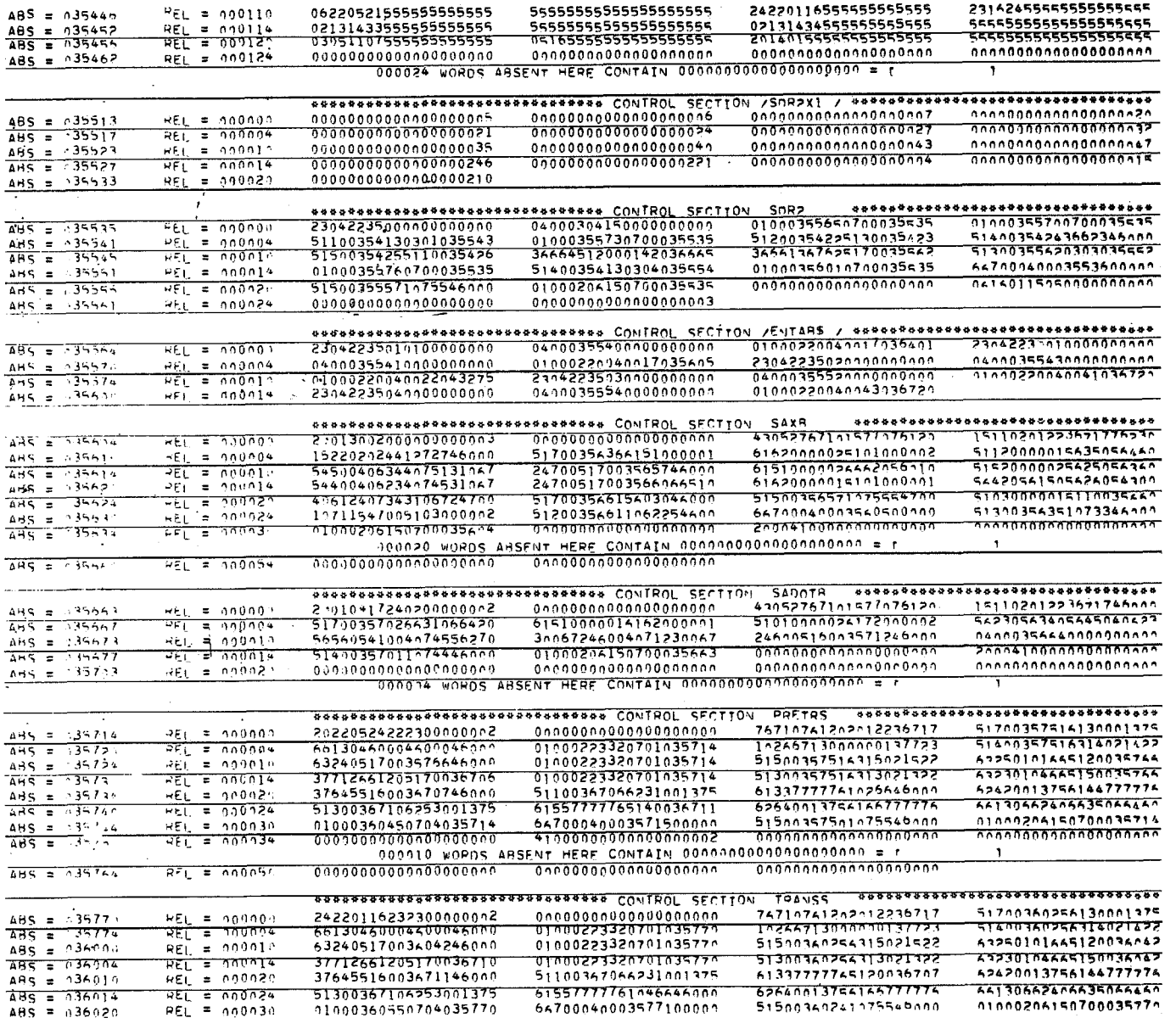


Figure 42(b). Example of a core dump output by CØRDUMP.

7.2.4.3.7 XEØF

Subprogram name: XEØP

Type of routine: Subroutine

Alternate entry points: None

Purpose: To write an end-of-file on a storage device (tape or disk).

Calling Sequence:

CALL XEØF(FET)

FET - Address of the FET

Method: XEØF executes the SCØPE WRITEF macro via the SCØPE routine CPC to write the end-of-file.

Language: CØMPASS

7.2.4.3.8 XØPEN

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: XØPEN generates the File Environment Table (FET) for a file based on data in the calling sequence.

Calling Sequence:

CALL XØPEN(FET,LFET,INDEX,LINDEX,ØP)

FET - (output) array where the FET is to be built. (First word of FET should have file name left adjusted and zero filled.)

LFET - (input) length of FET plus the length of the circular buffer

INDEX - Variable array where relative track addresses for direct access records will be stored.

LINDEX - Length of INDEX. (If 0, then no index is implied and file will be sequential.)

ØP -
- 0 Open to read/rewind
- 1 Open to read/no rewind
- 2 Open to write/rewind
- 3 Open to write/no rewind
- 4 Open for direct access-alter/rewind (see SCØPE manual)
- 5 Open for direct access-alter/no rewind (see SCØPE manual)
- -1 Construct FET but do not open file.

Method: XØPEN builds the FET as described in the SCØPE 3.1 reference manual, chapter 3. The FET length is made 15 words long, and the balance of the space sent to XØPEN and used as the circular buffer. The circular buffer is never used if only READX (section 7.2.4.3.15) and WRITEX (section 7.2.4.3.14) are to be used, and in that case LFET may be set to 30 on calls to XØPEN.

Language: CØMPASS

7.2.4.3.9 XCLØSE

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: XCLØSE closes a file but does not return it to the system.

Calling Sequence:

```
CALL XCLØSE(FET,ØP)
```

FET - Address of the FET

ØP -
- 0 Close/no rewind
- 1 Close/rewind
- 2 Close/unload

Method: XCLØSE executes the SCØPE CLØSE macro which performs differently on the many versions of SCØPE 3 in the field. Consult with your systems programmer to determine exact results for your installation. Refer also to the SCØPE 3.1 reference manual, chapter 3.

Language: CØMPASS

7.2.4.3.10 XEVICT

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: XEVICT releases all space occupied by a file on the disk. The logical file name is preserved.

Calling Sequence:

```
CALL XEVICT(FET)

FET - Address of the FET
```

Method: XEVICT executes the SCØPE 3 EVICT macro.

Language: CØMPASS

7.2.4.3.11 REINDX

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

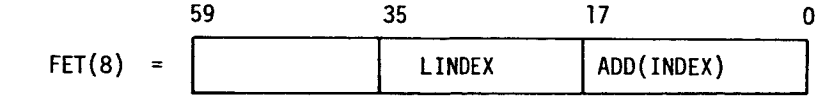
Purpose: REINDX redefines the index pointer field for the FET.

Calling Sequence:

```
CALL REINDX(FET,INDEX,LINDEX)

FET    - Address of the FET
INDEX  - Array where new index is to be defined
LINDEX - Length of INDEX
```

Method: REINDX places the index address and index length in word 8 of the FET in the following format



where ADD = address

Language: CØMPASS

7.2.4.3.12 XWRITE

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To start writing, continue writing, or complete writing a logical record on tape or disk either sequentially or randomly.

Calling Sequence:

```
CALL XWRITE(FET,RECØRD,BUF,LBUF,FLAG)
```

FET - Array where FET is stored.

RECØRD - 0 if sequential writing is to begin or continue.

> 0 implies RECØRD is the record number of a direct-access record.

Used only when starting to write the record

BUF - Array of information to be written

LBUF - Length of BUF

FLAG - { 0 if record is not to be completed.
{ 1 if record is to be completed with end-of-record mark.

Method: XWRITE stores the address of BUF in the FET. It then begins or continues writing the record either sequentially using IØWRITE or direct access using IØRW (both are SCØPE utilities). If FLAG is nonzero, the record is then completed sequentially using the SCØPE WRITER macro. All data are processed through the circular buffer.

Language: CØMPASS

7.2.4.3.13 XREAD

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To start reading, continue reading, or complete reading a logical record on tape or disk either sequentially or randomly.

Calling Sequence:

```
CALL XREAD(FET,RECØRD,BUF,LBUF,FLAG,CØUNT)
```

FET - Array where FET for file is stored.

RECØRD - 0 if sequential reading is to begin or continue.

> 0 implies RECØRD is the record number of a direct-access record.

Used only when starting to read the record

BUF - Array where data read are to be placed

LBUF - Length of BUF

FLAG -
- 0 to read LBUF words or to read to the end of record, which ever occurs first.
- 1 if up to LBUF words are to be read and positioning to next record is to occur.

CØUNT -
- -2 on return if end-of-file was encountered.
- -1 on return if end of record was not hit and LBUF words were read.
- A count $\geq$ 0 on return is the number of words that were read if an end of record was hit before LBUF words were read.

Method: XREAD defines where BUF is located in the FET. It then begins or continues reading the record either sequentially using IØREAD or randomly using IØRR (both are SCØPE utilites). If FLAG is nonzero and the end of record was not encountered, a record is skipped to bypass any remaining data. This is accomplished by using the SCØPE SKIPF macro.

Language: CØMPASS

7.2.4.3.14 WRITEX

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To write an entire logical record either sequentially or randomly without using the circular buffer.

Calling Sequence:

Identical to XWRITE except FLAG is not interpreted (see section 7.2.4.3.12)

Method: The pointers FIRST, IN, ØUT, and LIMIT are set to reflect the actual output buffer BUF, which in turn becomes the circular buffer. A direct call is made to the PP routine CIØ.

Language: CØMPASS

7.2.4.3.15 READX

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To read an entire logical reocrd either sequentially or randomly without using the circular buffer.

Calling Sequence:

Identical to XREAD except FLAG is not interpreted (see section 7.2.4.3.13).

Method: The pointers FIRST, IN, ØUT, and LIMIT are set to reflect the actual input buffer BUF, which in turn becomes the circular buffer. A direct call is made to the PP routine CIØ.

Language: CØMPASS

7.2.4.3.16 XREWIND

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To rewind a disk or tape file and place it at the beginning of information.

Calling Sequence:

CALL XREWIND(FET)

FET - Address of the FET

Method: XREWIND executes the SCØPE REWIND macro.

Language: CØMPASS

7.2.4.3.17 XBKREC

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: XBKREC backspaces a tape or disk file one logical record.

Calling Sequence:

CALL XBKREC(FET)

FET - Address of the FET

Method: XBKREC executes the SCØPE BKSP macro.

Language: CØMPASS

7.2.4.3.18 XFRDREC

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To position a file forward to the beginning of the next logical record crossing only one end-of-record mark.

Calling Sequence:

CALL XFRDREC(FET)

FET - Address of the FET

Method: XFRDREC executes the SCØPE SKIPF macro.

Language: CØMPASS

7.2.4.3.19 XBKPREC

Subprogram name: XIØRTNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To position a file backwards one physical record.

Calling Sequence:

CALL XBKPREC(FET)

FET - Address of the FET

Method: XBKPREC executes the SCØPE BKSPHRU macro.

Language: CØMPASS

7.2.4.3.20 XREQST

Subprogram name: XIØRTNS

Type of routine: Subroutine

Purpose: To execute the standard SCØPE request macro.

Calling Sequence:

CALL XREQST(FET,PYQX,DC,DT)

FET - Address of the FET

PYQX, DC, DT } See SCØPE 3.1 reference manual, section 3.5

Method: XREQST executes the SCØPE REQUEST macro. This may be installation dependent.

Language: CØMPASS

7.2.4.3.21 ANDF, ØRF, CØMPLF, RSHIFT, LSHIFT

Subprogram name: MAPFNS

Type of routines: All Integer Functions.

Purpose: To perform a logical and, or, complement, right shift, or left shift.

Calling Sequence:

RESULT = ANDF(WØRD1,WØRD2)

RESULT = ØRF(WØRD1,WØRD2)

RESULT = CØMPLF(WØRD1)

RESULT = RSHIFT(WØRD1,CØUNT)

RESULT = LSHIFT(WØRD1,CØUNT)

where WØRD1 and WØRD2 are words being operated on and are unchanged after the execution.

CØUNT is the number of bits WØRD1 is to be shifted right or left.

In RSHIFT and LSHIFT bits shifted outside of the word boundary are lost while the others are zero filled.

Method: Direct assembly language logical instructions are used.

Language: CØMPASS

7.2.4.3.22 XFETCH, XSTØRE

Subprogram name: MAPFNS

Type of routines: Subroutines

Alternate entry points: None

Purpose: To fetch (store) an array of data from (to) anywhere in the job's core.

Calling Sequence:

CALL XSTØRE(BUF,LBUF,LØCADD)

CALL XFETCH(BUF,LBUF,LØCADD)

BUF - Receiving array (XFETCH); transmitting array (XSTØRE)

LBUF - Length of BUF

LØCADD - Variable containing the address from which data is fetched (XFETCH); or address into which data is stored (XSTØRE)

Method: A direct move of data is made in such a way that it does not matter if the array from which data are moved overlaps the array to which the data are moved.

Language: CØMPASS

7.2.4.3.23 LWØRDS

Subprogram name: MAPFNS

Type of routine: Integer Function

Alternate entry points: None

Purpose: To determine how many words of core there are from the argument to the field length

Calling Sequence:

RESULT = LWØRDS(ARG)

ARG - Variable from which the number of words to the field length is computed.

Method: The field length, stored in location 76_8 of the job's core, is used to make the computation.

7.2.4.3.24 CØRWDS

Subprogram name: MAPFNS

Type of routine: Integer Function

Alternate entry points: None

Purpose: To determine an inclusive distance in words between two arguments in core.

Calling Sequence:

RESULT = CØRWDS(ARG1,ARG2)

ARG1 and ARG2 are the two arguments for which the inclusive difference is desired.

Method: RESULT = Absolute value of the differences between the two addresses plus one.

Language: CØMPASS

7.2.4.3.25 XJUMP

Subprogram name: MAPFNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To make an absolute jump to code anywhere in core.

Calling Sequence:

CALL XJUMP(LØCAT)

LØCAT = Variable where an absolute location is stored.

Method: A jump is executed to whatever address is in the location LØCAT.

Language: CØMPASS

7.2.4.3.26 ZAP

Subprogram name: MAPFNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To zero core from whatever location is specified in core location 101_8 to the field length as specified in location 63_8.

Calling Sequence:

CALL ZAP

Method: Store zeros in all locations desired.

Language: CØMPASS

7.2.4.3.27 FIELDLN

Subprogram name: MAPFNS

Type of routine: Subroutine

Alternate entry points: None

Purpose: To obtain the field length of the job, or to change the field length and to store the field length in locations 63_8 and 76_8.

Calling Sequence:

CALL FIELDLN(LENGTH)

LENGTH = 0 if field length is to be returned in LENGTH.

= Value > 0 if the field length is to be changed. The field length is changed to LENGTH.

Method: The SCØPE memory macro (MEM) is executed.

Language: CØMPASS

7.2.4.3.28 LINK2O.

Subprogram name: MAPFNS

Type of routine: Subroutine

Alternate entry point: None

Purpose: LINK2O. makes a call to Link 20. Through the use of a RENAME, a particular routine when called can result in a switch to Link 20. (e.g., RENAME PEXIT=LINK2O.)

Calling Sequence:

CALL LINK2O.

Method: A call to Link 20 is made directly.

Language: CØMPASS

7.2.4.3.29 LINKERR

Subprogram name: LINKERR

Type of routine: Subroutine

Purpose: To output message when called by subroutine LINK in XLØADER.

Calling Sequence:

CALL LINKERR(LINK,ERRØR)

LINK - A link number

ERRØR - Number of an error message

Method: Writes the error message specified by ERRØR.

Language: FØRTRAN

7.2.4.4 MISCELLANEOUS

7.2.4.4.1 LKED900

Subprogram name: LKED900

Type of routine: Subroutine

Alternate entry points: None

Purpose: To abnormally terminate execution of the linkage editor with an error message in case of table overflow.

Calling Sequence:

CALL LKED900(CØDE)

CØDE - (input) number which defines the type of overflow which has occurred.

Method: A fatal error message is printed and the linkage editor stops.

Language: FØRTRAN

7.2.4.4.2 LKED990

Subprogram name: LKED320

Type of routine: Subroutine

Alternate entry points: None

Purpose: To abort the linkage editor in the event an unexpected condition (logic error) is encountered.

Calling Sequence:

CALL LKED990

Method: LKED990 passes the address from which the call occurs to LKED995 which prints the fatal message.

Language: CØMPASS

7.2.4.4.3 LKED995

Subprogram name: LKED995

Type of routine: Subroutine

Alternate entry points: None

Purpose: To abort the linkage editor abnormally

Calling Sequence:

CALL LKED995(LØC)

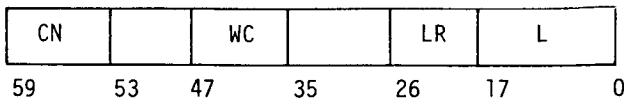
LØC - (input) location at which logic error was detected.

Method: LKED995 prints a message indicating that a logic error has been detected and the location of the error. The contents of the linkage editor tables are then printed by LKED999. Finally, a mode error is forced so that, if the user has included a DMP control card, a storage dump will be taken.

Language: FØRTRAN

7.2.5 Object Deck Format

The object deck of a subprogram as it is output from the assembler or the compiler comprises one logical record. Each logical record is made up of an indefinite number of tables. Each table is proceeded by an identification word which has the format:



where

CN = code number identifying the type of table

WC = Word count of the table excluding identification word

LR = Code defining the method of relocation of the relative address L

L = Relative address, 18 bits defined differently for each type of table

7.2.5.1 PIDL Table

The Program Identification and Length (PIDL) Table contains the subprogram identification and names of each of the common blocks referenced by the subprogram.

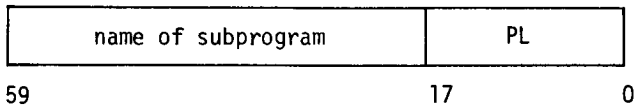
identification word

CN = 34_8

LR = ignored

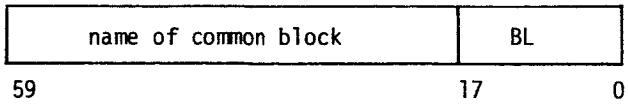
L = 0

word 1



PL = length of subprogram

words 2-WC



where

BL = length of common block

If WC = 1, no references to common blocks appear in the subprogram. The linkage editor is prepared to process only one PIDL table in an object deck. Additional PIDL tables are ignored with a warning message. The list of common block names is called the Local Common Table (LCT). Since relocation of addresses relative to common blocks is designated by positions in the LCT, the order of common block names is significant.

7.2.5.2 ENTR Table

The ENTRy Point Table (ENTR Table) contains a list of all named entry points to the subprogram and to associated common blocks (note: an entry point to a common block is ignored by the linkage editor and a warning message is issued). The ENTR Table must immediately follow the PIDL Table.

identification word

CN = 36_8

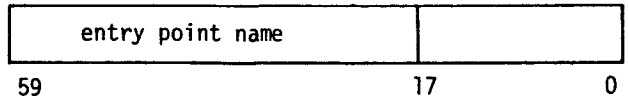
LR = ignored

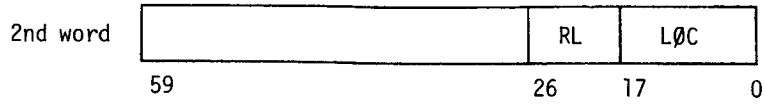
L = ignored

words 1-WC

Each entry in the ENTR table consists of two words. The first word contains the name of the entry point. The second word contains the relative address of the entry point and its method of relocation.

1st word





RL = code defining the relocation specified by LØC:

0 = absolute (therefore the Table is ignored by the linkage editor)

1 = relative to subprogram origin

$3\text{-}77_8$ = relative to common block M, where M is in position RL-2 of the LCT (ignored by linkage editor)

LØC = relative address of the entry point

7.2.5.3 TEXT Table

Text and data tables (TEXT tables) contain data comprising the subprogram and information necessary for relocating the data. The TEXT Table consists of an origin for the data, the data itself, and indicators describing relocation (if any) of the three possible locations in a data word which may have relative storage addresses. TEXT Tables may appear in any order and any numbers in the object deck.

identification word

CN = 40_8

WC satisfies: $2 \leq WC \leq 20_8$

LR
- 0 = absolute (therefore the Table is ignored by the linkage editor)
- 1 = relative to subprogram origin
- $2\text{-}77_8$ = relative to common block M, where M is in the position LR-2 of LCT (see section 7.2.5.1)

L = relative address of first word of data

First word

This relocation word consists of a series up to 15 of 4-bit bytes describing the relocation of each of the three possible address references in a 60-bit data word. The first byte (bits 56-59) describes the relocation for the data word in the second word of the TEXT Table, etc. The number of relevant bytes and data words is determined by WC. Relocation is relative to program origin or the complement of program origin (negative relocation). The value and relocation for each byte follows:

000x	no relocation
10xx	upper address, program relocation
11xx	upper address, negative relocation
010x	middle address, program relocation
011x	middle address, negative relocation
1x10	lower address, program relocation
1x11	lower address, negative relocation
0010	same as 1x10
0011	same as 1x11

words 2 through WC

Data words are relocated consecutively relative to L. All addresses are relocated relative to subprogram origin, never relative to a common block. Relocation of addresses relative to common blocks is accomplished through FILL Tables (see section 7.2.5.4).

7.2.5.4 FILL Table

The FILL Table contains information to relocate previously defined address fields. References to common blocks are relocated through this table.

identification word

CN = 42_8

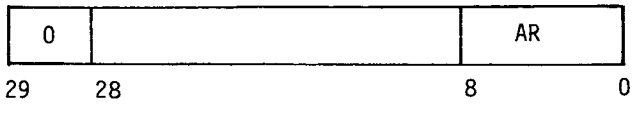
LR = 0

L = 0

words 1 through WC

All FILL Table words are partitioned into sets of contiguous 30-bit bytes. Each set is headed by one control byte and followed by an arbitrary number of data bytes. The last data byte may be zero. The control byte contains information about each of the subsequent data bytes until another control byte is encountered.

control byte



AR is the relocation code pertaining to the succeeding data bytes. AR may assume

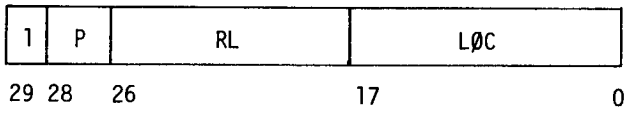
0 = absolute relocation (i.e., no relocation takes place)

1 = program relocation

2 = negative relocation

$3\text{-}77_8$ = relative to common block M where M is in position AR-2 of LCT (see section 7.2.5.1)

data byte



P = position within word of address

10 = upper

01 = middle

00 = lower

RL = code pertaining to the relocation of the address specified by LØC. RL has the same range as AR (see above) except RL $\neq$ 2

LØC = relative address of the data word to be modified. The contents of the address field position (F) at location LØC relative to RL is added to the origin as specified by AR in the control byte.

7.2.5.5 LINK Table

The LINK Table specifies external references within the subprogram. Each reference to an external symbol must appear as an entry in the LINK Table.

identification word

CN = 44_8

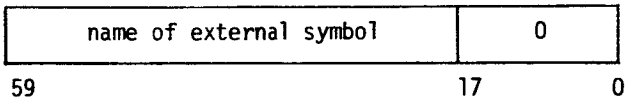
LR = ignored

L = 0

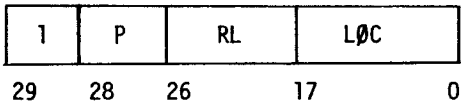
words 1 through WC

All remaining words are partitioned into sets, each consisting of one 60-bit name and a series of contiguous 30-bit data bytes indicating address positions which refer to the external symbol described in the 60-bit name. It is possible for the 60-bit name to be split between two computer words. Names of external symbols must begin with a character for which the display code representation has the high order bit equal to zero.

name word



data byte



P = position within the word of the reference to the external symbol

10 = upper

01 = middle

00 = lower

RL = code pertaining to the relocation of the address specified by LØC

0 = absolute (ignored by linkage editor)

1 = program relocation

$3\text{-}77_8$ = relative to common block M, where M is in position RL-2 of the LCT.

LØC = relative address of the word containing the external symbol

7.2.5.6 REPL Table

The REPL Table provides an efficient means for repetition of a block of data.

identification word

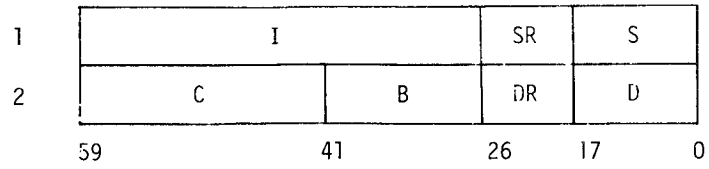
CN = 43_8

LR = ignored

L = ignored

words 1 through WC

Each entry in the table consists of two words in the format



S = initial relative address of source data

SR = code for the relocation of the address specified by S

- 0 = absolute (ignored by linkage editor)
- 1 = program relocation
- $3\text{-}77_8$ = relocation relative to common block M, where M is in position SR-2 of LCT (see section 7.2.5.1)

D = initial relative address of destination of data

DR = code for the relocation of the address specified by D; same range of value as SR

B = size of data block in words

C = number of times data block is to be repeated;

I = increment to be added to D before each data block is repeated; first repetition of block is at D, second at D + I, etc.

If C = 0, C is interpreted as 1

If B = 0, B is interpreted as 1

If I = 0, I is interpreted as B

If D = 0, D is interpreted as S + B

7.2.6 Principal Linkage Editor Variables

Table 3 describes principal linkage editor variables in common blocks LKEDCxx, where $01 \leq xx \leq 07$. The following conventions apply:

1. In the description column, a pointer, if not defined further, is assumed to point to the 1st word rather the 0th word of a table
2. Twenty character symbols in the default value column imply octal representation
3. The letter "b" in the default value column implies a blank character
4. Ten character symbols in the default value column imply character string representations. Note these are left-adjusted in the word and zero-filled.
5. Integers (less than ten digits) in the default value column are decimal numbers.
6. A blank in the default value column implies the entry has no default value.

Table 3(a). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
ARGBIT	LKEDC04	1	ARG bit in symbol entry of GT	0000400000000000000
ASTRSK	LKEDC04	1	the character *	*bbbbbbbbb
BLANK	LKEDC04	1	a blank character	bbbbbbbbbb
BLKDATA	LKEDC04	1	the name BLKDATA	BLKDATA000
BØØTDK3	LKEDC07	3	names of subprograms on LINKLIB required for bootstrap program	XBØØT00000 XIØRTNS000 MAPFNS0000
C	LKEDC03	1	the character C	Cbbbbbbbbb
CARD	LKEDC02	20	scratch storage (initially to hold card image)	
CARGBIT	LKEDC04	1	complement of ARG bit	77773777777777777777
CHAINS	LKEDC02	4	scratch storage (primarily for chain pointers from the SCT)	
DIRECTY	LKEDC03	1	.TRUE. if, for Link ≠ 0, Link 0 directory is present; .FALSE. otherwise	
DKLENTH	LKEDC01	1	number of words available to store an object deck	
DKSIZE	LKEDC01	1	number of words in the longest table of an INCLUDEd deck	
DUMMY	LKEDC05	15	Block Data subprogram for bootstrap program	
			PIDL Table	34000002000000000000 BLKDATA000 XBØØTBD000
			ENTR Table	36000002000000000000 BLKDATA000 00000000000001000000
			TEXT Table	40000003000001000000 00000000000000000000 BLKDATA000 00000000000000000000

(1) Lower case "b" denotes a blank character

Table 3(b). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
			TEXT Table	4000000200000300000 0000000000000000000 XBØØTBD000
ENDMSK	LKEDC04	1	mask signifying end-of-card (output from XRCARD)	3777777777777777777
ENTAB	LKEDC04	1	the name ENTAB$	ENTAB$000
ENTRY	LKEDC03	1	before LKED050, name of entry point to Link; address of entry point thereafter	
EQUAL	LKEDC04	1	the character =	=bbbbbbbbb
HIBIT	LKEDC04	1	the leftmost bit in a word	4000000000000000000
IBUF1	LKEDC01	1	pointer to third buffer	
IDECK	LKEDC01	1	pointer to object deck storage table	
IEPS	LKEDC01	1	pointer to Entry Point Table	
IINDEX	LKEDC01	1	pointer to object deck index	
ILIB	LKEDC01	1	pointer to Library Table (LT)	
IMASTER	LKEDC01	1	pointer to master index	
INAMES	LKEDC01	1	pointer to Subprogram Names Table (SNT)	
INDXLN	LKEDC01	1	number of words in object deck index	
INFILE	LKEDC03	1	name of INFILE	-1
INSTAT	LKEDC03	1	status of INFILE (T or C)	Tbbbbbbbbb
IREGO	LKEDC01	1	pointer to Oth word of Region Definition Table (RDT)	
IREGDEF	LKEDC01	1	pointer to 1st word of Region Definition Table	
IRENMO	LKEDC01	1	pointer to Oth word of Rename Table (RT)	
ISEGCO	LKEDC01	1	pointer to Oth word of Segment Chains Table (SCT)	

Table 3(c). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
ISEGCHN	LKEDC01	1	pointer to 1st word of Segment Chains Table	
ISEGDO	LKEDC01	1	pointer to 0th word of Segment Definition Table (SDT)	
ISEGDEF	LKEDC01	1	pointer to 1st word of Segment Definition Table	
ISEGNDX	LKEDC01	1	pointer to segment index	
ISYSUT1	LKEDC01	1	pointer to first buffer	
ISYSUT2	LKEDC01	1	pointer to second buffer	
ITAB0	LKEDC01	1	pointer to 0th word of General Table (GT)	
ITEMS	LKEDC02	11	scratch storage (usually to hold items of a symbol entry of the GT)	
ITEXT	LKEDC01	1	pointer to 1st word of text building storage	
JUMP	LKEDC05	1	an EQ B0,B0,0 instruction	04000000000000000000
LASTENT	LKEDC01	1	pointer to last entry in the GT	
LDR	LKEDC04	1	the name LØADER.	LØADER.000
LET	LKEDC03	1	option to neglect the effect of certain errors	.FALSE.
LIBTOTL	LKEDC01	1	number of subprograms named on INCLUDE statements in Link	
LINK	LKEDC03	1	current Link number (from LINK statement)	
LINKLIB	LKEDC04	1	the name LINKLIB	LINKLIB000
LINK0	LKEDC05	10	not used in Level 2.0 Linkage Editor	
LINK0D	LKEDC04	1	the name LINK0$	LINK0$0000
LINKZ	LKEDC03	3	storage for the 3-word directory for Link 0	
LIST	LKEDC03	1	option to list control statements	.TRUE.

Table 3(d). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
LKEDCC	LKEDC03	14	list of legal verbs in linkage editor statements	INCLUDE000 INC0000000 REGIØN0000 ØVERLAY000 ØVR0000000 INSERT0000 INS0000000 RENAME0000 END0000000 LINK000000 ENDLINKS00 ENTRY00000 0 0
LKEDIT	LKEDC03	1	the name LINKEDIT	LINKEDIT00
LKEDKEY	LKEDC03	8	list of legal keywords on the LINKEDIT control statement	LET0000000 NØLIST0000 NØMAP00000 INFILE0000 ØUTFILE000 PARAM00000 XREF000000 0
LØUTBUF	LKEDC02	1	number of words in ØUTBUF array	99
LPAREN	LKEDC04	1	the character (	(bbbbbbbbb
MAP	LKEDC03	1	option to list storage map	.TRUE.
MIDBIT	LKEDC03	1	high order bit of low-order 30-bit byte	000000000040000000000
NBRBØØT	LKEDC07	1	number of subprograms required for bootstrap program	3
NBRCC	LKEDC03	1	number of legal verbs in linkage editor control statements	12
NBRENTR	LKEDC01	1	number of entries in the GT	

Table 3(e). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
NBRKEY	LKEDC03	1	number of legal keywords on the LINKEDIT control statement	7
NBRPARM	LKEDC03	1	number of words in the PARAM array	8
NBRREG	LKEDC01	1	number of regions in current link	
NBRRNAM	LKEDC01	1	number of RENAME statements in current link	
NBRSEG	LKEDC01	1	number of segments in current link	
NBRSEG1	LKEDC01	1	NBRSEG + 1	
NDXMSK	LKEDC0	1	mask to extract INDEX field of symbol entry in the GT	77770000000000000000
NEXTENT	LKEDC01	1	next available entry in the GT	
NEXTRNM	LKEDC01	1	next available entry in the RT	
NLIB	LKEDC01	1	pointer to last entry in the LT	
NØGØ	LKEDC03	1	current error code setting	0
NREGDEF	LKEDC01	1	pointer to last entry in the RDT	
NSEGCHN	LKEDC01	1	pointer to last entry in the SCT	
NSEGDEF	LKEDC01	1	pointer to last entry in the SDT	
ØUTBUF	LKEDC02	99	scratch array (initially used for storage of converted card image)	
ØUTFILE	LKEDC03	1	name of ØUTFILE	
ØUTSTAT	LKEDC03	1	status of ØUTFILE (T or C)	
PARAM	LKEDC03	8	length of FET + circular buffer	530
			maximum number of object decks in all libraries	1000
			maximum size of any table in an object deck	500

Table 3(f). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
			maximum number of links	32
			maximum number of segments in any link	128
			maximum length of any control section for which text is defined	5000
			additional options if XREF is selected	0
			intermediate print switch (see Appendix E)	0
PLUS	LKEDC04	1	the character +	+bbbbbbbbb
RJLDR	LKEDC05	1	the instruction RJ LØADER.	01000000000000000000
SEGTAB	LKEDC04	1	the name SEGTAB$	SEGTAB$000
SYMASK	LKEDC04	1	a mask to extract a symbolic name	37777777777777000000
SYSLMØD	LKEDC04	1	the name SYSLMØD	SYSLMØD000
SYSUT1	LKEDC04	1	the name SYSUT1	SYSUT10000
SYSUT2	LKEDC04	1	the name SYSUT2	SYSUT20000
SYSUT3	LKEDC04	1	the name SYSUT3	SYSUT30000
T	LKEDC03	1	the character T	Tbbbbbbbbb
TØTLENG	LKEDC03	1	last address in current link	
TXTBIT	LKEDC04	1	bit set in the LCT to indicate text for common blocks	00000000000000400000
TXTLEN	LKEDC01	1	maximum length of a control section with text defined	
WRITØUT	LKEDC03	1	.TRUE. if link is to be written; .FALSE. otherwise	
XREF	LKEDC03	1	option to produce listing of cross references in the link	.FALSE.

Table 3(g). Description of Principal Linkage Editor Variables.

Variable Name	Common Block	Number of Words	Description	Default Value
Z	blank	6144	open-ended working storage	
ZEND	LKEDC01	1	pointer to last word in working storage	

7.2.7 Linkage Editor Output and Diagnostic Messages

Figure 43 shows control statements and output of a link edit of the linkage editor.

7.2.7.1 Diagnostic Messages

Figures 31 through 38 show how diagnostic (or intermediate) output which may be obtained from the linkage editor. This output is intended primarily for test or maintenance of the linkage editor. The output is selected by setting PARAM(8) to an appropriate value on the LINKEDIT control statement (see section 5.6.4.2). PARAM(8) acts similarly to a sense switch, i.e., each defined bit triggers a certain type of output independently of the other bit settings. The decimal values (all powers of two) for PARAM(8) and their functions are as follows:

Value	Type of Output Obtained
1	Contents of the GT after each INCLUDE and INSERT statement
2	Contents of each object deck as it is processed in LKED025
4	All tables after processing each deck in LKED025
8	Text for each segment after construction in LKED075
16	Contents of all tables after control statement processing
32	Contents of all tables after object deck processing
64	Contents of all tables after address assignment processing
128	Contents of each link as it is written in LKED080

These values may be combined in any desired manner (e.g., PARAM(8) = 52 which is 4 + 16 + 32).

7.2.7.2 LINKLIB Subprograms

Table 4 gives a list of subprograms in LINKLIB.

```
                    L E V E L   2 . 0   C D C   6 6 0 0   L I N K A G E   E D I T O R    20.41.29.   09/17/69

                LINKEDIT LET, OUTFILE=LNKEDIT(T), XREF
                LIBRARY  LINKEDT

                LINK     0
SEGMENT    1    RENAME   SYSTEM = SYSTEM.
                RENAME   LKEDOCO = LINK
                INCLUDE  LINKEDT( LKED, BLKDATA(LKEDCO1) )
                ENTRY    LKED
                END

                                S T O R A G E   M A P   F O R   L I N K    0   20.41.29.   09/17/69

SEGMENT   NAME       ADDRESS   LENGTH   ENTRY-PT   ADDRESS   ENTRY-PT   ADDRESS   ENTRY-PT   ADDRESS   ENTRY-PT   ADDRESS   ENTRY-PT   ADDRESS

    1   /LINKO$ /    000101    001273
    1    LKED        001375    000476   LKED       001376
    1   /LKEDCO1/    002074    000045
    1   /LKEDCO2/    002142    000207
    1   /LKEDCO3/    002352    000065
    1   /LKEDCO4/    002440    000027
    1   /LKEDCO5/    002470    000031
    1   /LKEDCO7/    002522    000004
    1    SYSTEM.     002527    001006   Q8NTRY     002530    SYSTEM.    002727    SYSTEMC    002674    SYSTEMP    002722    END        002615
                                        STOP       002646    EXIT       002640    ABNORML    002656
    1    MAPFNS      003536    000237   ANDF       003550    ORF        003554    COMPLF     003560    XORF       003537    RSHIFT     003575
                                        LSHIFT     003563    CORSZ      003543    CORWDS     003632    XSTORE     003607    XFETCH     003614
                                        LWORDS     003626    XJUMP      003637    ZAP        003642    LOCF       003651    FIELDLN    003654
                                        FLUSH      003670    RECOVRY    003673    TDATE      003713    DAYTIME    003733    KLOCK      003751
                                        LINK20.    003772    XCOMMON    003762
    1    XLCADER     003776    000300   LOADER.    004064    LINK       003777    XTRACE     004213    XDUMP      004170    COMPARE    004207
                                        ABSENT.    004273
    1    XIORTNS     004277    000176   XOPEN      004307    XCLOSE     004344    XEVICT     004353    REINDX     004360    XWRITE     004366
                                        XREAD      004407    XREWIND    004436    XBKREC     004443    XFRDREC    004455    XBKPREC    004450
                                        XREQST     004462
    1    OUTPTC      004476    000142   OUTPTC     004500
    1    LINKERR     004641    000040   LINKERR    004642
    1    CORDUMP     004702    000452   CORDUMP    004703
    1    CPC         005355    000237   CPC        005423    CPC02      005477    CPC03      005355    CPC04      005374    CPC999     005604
    1    IORANDM     005615    000136   IORR       005615    IORW       005632
    1    IO          005754    000152   IOREAD     006004    IOWRITE    006007    IOIO       006012    IOSAV      005765
    1    SION        006127    000675   BKSPRU.    006473    FIZBAK.    006504    POSFIL.    006542    RDPRU.     006552    DAT.       006574
                                        CIO1.      006412    OPEN.      006133    SIO.       006274
    1    GETBA       007025    000017   GETBA      007025
    1    KODER       007045    001176   KODER      007046

LAST ADDRESS IN LINK = 010242
```

Figure 43(a). Linkage editor output.

```
                    R E F E R E N C E S   T O   E A C H   E N T R Y   P O I N T   I N   L I N K   0   20.41.29.   09/17/69

ENTRY-PT   ADDRESS  CALL FROM LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION LOCATION

 LKED      001376 ---NONE---

 Q8NTRY    002530   LKED      000002

 SYSTEM.   002727   MAPFNS    000132
                    OUTPTC    000021
                    KCDER     001006

 SYSTEMC   002674 ---NONE---

 SYSTEMP   002722 ---NONE---

 END       002615   LKED      000014
                    LINKERR   000021
                    CCRDUMP   000331

 STOP      002646   LKED      000012
                    LINKERR   000017

 EXIT      002640   MAPFNS    000147
                    XLOADER   000277

 ABNORML   002656   OUTPTC    000022
                    KCDER     001007

 ANDF      003550 ---NONE---

 ORF       003554 ---NONE---

 COMPLF    003540 ---NONE---

 XORF      003537 ---NONE---

 RSHIFT    003575 ---NONE---

 LSHIFT    003563 ---NONE---

 CORSZ     003543 ---NONE---

 CORWDS    003632 ---NONE---

 XSTORE    003607 ---NONE---

 XFETCH    003614 ---NONE---

 LWORDS    003626 ---NONE---
```

Figure 43(b). Linkage editor output.

```
XJUMP       003637 ---NONE---
ZAP         003642 ---NONE---
LOCF        003651   CORDUMP   000025   000043
FIELDLN     003654    LKED      000005
FLUSH       003670 ---NONE---
RECOVRY     003673    LKED      000006
TDATE       003713 ---NONE---
DAYTIME     003733 ---NONE---
KLOCK       003751 ---NONE---
LINK20.     003772 ---NONE---
XCOMMON     003762 ---NONE---
LOADER.     004064 ---NONE---
LINK        003777    LKED      000010
                      MAPFNS    000235
XTRACE      004213    CORDUMP   000011
XDUMP       004170    SYSTEM.   000323
                      MAPFNS    000146
                      LINKERR   000015
COMPARE     004207    CORDUMP   000070
ABSENT.     004273 ---NONE---
XOPEN       004307 ---NONE---
XCLOSE      004344 ---NONE---
XEVICT      004353 ---NONE---
REINDX      004360 ---NONE---
XWRITE      004366 ---NONE---
XREAD       004407    XLOADER   000016   000027   000042   000137
XREWIND     004436 ---NONE---
```

Figure 43(c). Linkage editor output.

```
XBKREC    004443 ---NONE---

XFRDREC   004455 ---NONE---

XBKPREC   004450 ---NONE---

XREQST    004462 ---NONE---

OUTPTC    004500   XLOADER  000221  000222  000245  000247  000250
                   LINKERR  000005  000007  000011  000012
                   CORDUMP  000007  000010  000014  000015  000114  000116  000120  000122  000123  000132  000134
                            000136  000142  000146  000154  000160  000164  000212  000214  000216  000220  000221
                            000231  000233  000235  000241  000245  000253  000257  000263  000301  000303  000304
                            000321  000323  000324

LINKERR   004642   XLOADER  000061

CORDUMP   004703   XLOADER  000204

CPC       005423   MAPFNS   000121  000136  000157  000177  000215  000226
                   XLOADER  000174
                   XIORTNS  000034  000050  000055  000104  000140  000145  000152  000157  000170
                   IORANDM  000022  000130
                   IO       000112

CPC02     005477   IORANDM  000051

CPC03     005355   IO       000012

CPC04     005374   IC       000145

CPC999    0056C4   IORANDM  000077  000103  000110  000114  000120  000124  000134  000135
                   IO       000024

IORR      005615   XIORTNS  000115

IORW      005632   XIORTNS  000074

IOREAD    006004   XIORTNS  000122

IOWRITE   006007   XIORTNS  000101

IOIO      006012   IORANDM  000014

IOSAV     005765   IORANDM  000001  000016

BKSPRU.   006473 ---NONE---

FIZBAK.   006504 ---NONE---
```

Figure 43(d). Linkage editor output.

```
POSFIL.     006542   OUTPTC    000037

RDPRU.      006552 ---NONE---

DAT.        006574   OUTPTC    000042   000061   000075

CIO1.       006412 ---NONE---

OPEN.       006133   SYSTEM.   000464
                     OUTPTC    000027

SIO.        006274   OUTPTC    000074

GETBA       007025   OUTPTC    000010

KODER       007046   OUTPTC    000004   000045
```

```
                    L E V E L   2 . 0   C D C   6 6 0 0   L I N K A G E   E D I T O R    20.41.29.   09/17/69

            LINK      1
SEGMENT  1  RENAME    SYSTEM = SYSTEM.
            INCLUDE   LINKEDT( LKED000, LKED100, LKED150, LKED175, LKED200 )
            INCLUDE   LINKEDT( LKED900, LKED995, LKED999, LKED300, LKED320 )
            INCLUDE   LINKEDT( HASH )
            OVERLAY   A
SEGMENT  2  INCLUDE   LINKEDT( LKED010 )
            OVERLAY   A
SEGMENT  3  INCLUDE   LINKEDT( LKED015 )
            INCLUDE   LINKEDT( XRCARD )
            OVERLAY   A
SEGMENT  4  INCLUDE   LINKEDT( LKED025 )
            INCLUDE   LINKEDT( LKED964 )
            OVERLAY   A
SEGMENT  5  INCLUDE   LINKEDT( LKED050 )
            OVERLAY   A
SEGMENT  6  INCLUDE   LINKEDT( LKED075 )
            INCLUDE   LINKEDT( LKED077, LKED350 )
            INCLUDE   LINKEDT( RECDUMP )
            REGION
            OVERLAY   B
SEGMENT  7  INSERT    BLANK..
            ENTRY     LKED000
            END
```

Figure 43(e). Linkage editor output.

STORAGE MAP FOR LINK 1 20.41.29. 09/17/69

SEGMENT	NAME	ADDRESS	LENGTH	ENTRY-PT	ADDRESS	ENTRY-PT	ADDRESS	ENTRY-PT	ADDRESS	ENTRY-PT	ADDRESS	ENTRY-PT	ADDRESS
1	/SEGTAB$/	010244	000011										
1	LKED000	010256	002400	LKED000	010257								
1	LKED100	012657	000213	LKED100	012660								
1	LKED150	013073	000160	LKED150	013074								
1	LKED175	013254	000070	LKED175	013255								
1	LKED200	013345	000235	LKED200	013346	LKED201	013363						
1	LKED900	013603	000037	LKED900	013604								
1	LKED995	013643	000042	LKED995	013644								
1	LKED999	013706	001114	LKED999	013707								
1	LKED300	015023	000200	UNPKSYM	015024	PACKSYM	015040	PACK	015052	PACKMSK	015057	UNPK	015066
				UNPKMSK	015073	UNPK12	015101	PACK12	015111	SYMHASH	015123	CALLCHN	015135
				SEGPATH	015152	CONVERT	015162	RSHIFTX	015174	CHARTST	015200	UNPKXX	015206
				PACKXX	015216								
1	LKED320	015224	000312	UNPKCAL	015225	PACKCAL	015240	GETEXT	015252	STDEXT	015257	LKED990	015265
				NOW	015275	TEXTTAB	015313	FILLTAB	015345	LINKTB1	015404	LINKTB2	015420
				REPLTAB	015454	UNPK30	015503	UNPKID	015522	PACKDMP	015532		
1	HASH	015537	000031	HASH	015540								
1	/LKEDCOM/	015571	000135										
1	INPUTC	015727	000110	INPUTC	015731								
1	INPUTS	016040	000305	INPUTS	016042								
1	REMARK	016346	000021	REMARK	016347								
1	ACGOER	016370	000012	ACGOER	016371								
1	IBAIEX	016403	000031	IBAIEX	016404								
1	DBLE	016435	000004	DBLE	016436								
1	DBAIEX	016442	000056	DBAIEX	016443								
1	KRAKER	016521	000777	KRAKER	016522								
1	XRCL	017521	000005	XRCL	017521								
1	/ENTAB$	017527	000025										
2	LKED010	017555	000757	LKED010	017556	LKED080	020015						
3	LKED015	017555	000610	LKED015	017556								
3	XRCARD	020366	001715	XRCARD	020367								
4	LKED025	017555	002412	LKED025	017556								
4	LKED964	022170	001133	LKED964	022171								
5	LKED050	017555	000503	LKED050	017556								
6	LKED075	017555	002223	LKED075	017556								
6	LKED077	022001	001115	LKED077	022002								
6	LKED350	023117	000047	PACKXRF	023120	UNPKXRF	023134	UNPKEP	023152				
6	RECDUMP	023167	000144	RECDUMP	023170								
					REGION 2								
7	/BLANK../	023334	014000										

LAST ADDRESS IN LINK = 037333

Figure 43(f). Linkage editor output.

R E F E R E N C E S T O E A C H E N T R Y P O I N T I N L I N K 1 20.41.29. 09/17/69

ENTRY-PT	ADDRESS	CALL FROM LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION	LOCATION
LKED000	010257	---NONE---										
LKED100	012660	LKED000	001032	001227	001623	001707	001727					
		LKED025	000047	000245	000467	001016	001075	001301				
		LKED050	000345	000412								
		LKED075	000226	000644	000726	001300						
LKED150	013074	LKED000	001246									
		LKED025	000575	001114	001321							
LKED175	013255	LKED025	001012									
		LKED075	001266									
LKED200	013346	LKED025	001133									
LKED201	013363	LKED025	001045									
LKED900	013604	LKED000	000364	001442								
		LKED100	000037									
		LKED200	000045									
		LKED015	000150	000320	000336	000401						
		LKED025	001760									
LKED995	013644	LKED320	000045									
LKED999	013707	LKED000	001050	001242	001253	001757	001765	001773				
		LKED995	000012									
		LKED025	001213									
UNPKSYM	015024	LKED999	000354	000451								
		LKED025	000134	001363								
		LKED050	000021	000235								
		LKED075	000153	000333	001306							
PACKSYM	015040	LKED000	001043	001235	001634	001717	001742					
		LKED025	000154	000276	000517	001040	001104	001310	002003			
PACK	015052	LKED000	001057	001115	001123							
PACKMSK	015057	LKED000	001376	001752								
		LKED100	000062	000151								
		LKED150	000036	000047	000056	000062	000120					
		LKED200	000076	000117	000143							
		LKED010	000265	000272								
		LKED025	000312	000324	000337	000545	000601	000605	000611	000710	000725	001120	001124
			001165	001220	001224	001325	001331	001511	001536	001664	001672	001677	001703

Figure 43(g). Linkage editor output.

```
                                 002010
                    LKED050      000037  000106  000126  000175  000203  000256  000267  000311  000370  000423
                    LKED075      000051  000056  000161  000371  000400  000455  000461  000562  000657  001543
                    LKED077      000107  000123  000130  000137  000176  000246  000552  000557  000564  000603  000607

UNPK        015066  ---NONE---

UNPKMSK     015073  LKED000      001161  001204
                    LKED200      000065  000112
                    LKED999      000210  000215  000333
                    LKED025      000063  000315  000445  000554  000673  000716  000731  001130  001443  001603  001607
                                 001640
                    LKED964      000151
                    LKED050      000064  000162  000224  000303  000333  000357  000364  000417
                    LKED075      000235  000276  000302  000435  000442  000652  000742  001326  001333  001531  001535

UNPK12      015101  LKED100      000116
                    LKED150      000015  000101
                    LKED200      000127
                    LKED999      000067  000137  000420
                    LKED025      001241  001345  001547  001616
                    LKED050      000011  000050  000141  000220
                    LKED075      000141  000311
                    LKED077      000220

PACK12      015111  LKED100      000136
                    LKED150      000071  000125
                    LKED200      000152
                    LKED025      002016
                    LKED077      000375  000443

SYMPASH     015123  LKED000      001347
                    LKED100      000022
                    LKED175      000017
                    LKED077      000066  000155  000544

CALLCHN     015135  LKED200      000027

SEGPATH     015152  LKED200      000007
                    LKED025      001531  001644  001730
                    LKED075      001314

CONVERT     015162  LKED000      000101  000176  000262  000601  000717  000760  001002  001020  001151  001222  001323
                                 001332  001337  001420
                    LKED015      000041  000113

RSHIFTX     015174  HASH         000004

CHARTST     015200  LKED000      000242  000245  000306  000326  000714  000764  001310  001317

UNPKXX      015206  LKED150      000007
```

Figure 43(h). Linkage editor output.

PACKXX	015216	LKED150	000133										
UNPKCAL	015225	LKED999	000532										
		LKED025	001522	001627									
		LKED075	001513										
PACKCAL	015240	LKED200	000170										
GETEXT	015252	LKED025	001001										
		LKED964	000640										
STOEXT	015257	LKED025	001152										
LKED990	015265	LKED000	001014	001413	001626	001712	001732						
		LKED010	000322										
		LKED025	000356	000510	000541	000551	000614	000701	000721	001157	001446	001501	001525
			001632										
		LKED050	000300	000313	000317	000414							
		LKED075	000343	000417	000526	000536	000620	000647	000701	000737	001043	001303	001317
			001336	001345									
NOW	015275	LKED000	000003										
TEXTTAB	015313	---NONE---											
FILLTAB	015345	LKED075	001246										
LINKTB1	015404	LKED075	001263										
LINKTB2	015420	LKED075	001402										
REPLTAB	015454	LKED075	001423										
UNPK30	015503	LKED964	000324	000566	000633								
UNPKID	015522	LKED010	000331										
		LKED015	000234	000353									
		LKED025	000111	000201	000377	000641	000746	001176					
		LKED964	000015										
		LKED075	000533	000676	001207								
PACKDMP	015532	LKED075	000356	000423	001061	001151	001452						
HASH	015540	LKED000	001342										
		LKED100	000010										
		LKED175	000010										
		LKED077	000061	000150	000537								
INPUTC	015731	LKED000	000015	000021	000025	000117	000123	000127	000523	000527	000533		
		LKED015	000012	000014	000015	000063	000065	000066					

Figure 43(i). Linkage editor output.

INPUTS	016042	LKED000	000051 000565	000054	000056	000057	000145	000150	000152	000153	000557	000562	000564
REMARK	016347	LKED000	000065	000067	000650								
ACCDER	016371	LKED000 LKED025 LKED050	000206 000252 000242	000625 000474	001470 001023	001370							
IBAIEX	016404	XRCARD	000023										
DBLF	016436	XRCARD	000772	001014									
DBAIEX	016443	XRCARD	001020	001070									
KRAKER	016522	INPUTC INPUTS	000030 000005	000004 000022									
XRCL	017521	REMARK	000012										
LKED010	017556	LKED000	000460										
LKED080	020015	LKED000	001777										
LKED015	017556	LKED000	000461										
XRCARD	020367	LKED000 LKED015	000062 000026	000156 000077	000570								
LKED025	017556	LKED000	001760										
LKED964	022171	LKED025	000163										
LKED050	017556	LKED000	001766										
LKED075	017556	LKED000	001774										
LKED077	022002	LKED075	001662										
PACKXRF	023120	LKED077	000306	000372									
UNPKXRF	023134	LKED077	000641										
UNPKEP	023152	LKED077	000615										
RECDUMP	023170	LKED075	001642										

L E V E L 2 . 0 C D C 6 6 0 0 L I N K A G E E D I T O R 20.41.29. 09/17/69

ENDLINKS

LINK 0 HAS BEEN WRITTEN ON LNKEDIT

LINK 1 HAS BEEN WRITTEN ON LNKEDIT

Figure 43(j). Linkage editor output.

Table 4(a). List of Subprograms in LINKLIB.

RECORD NO.	LEVEL NO. OCTAL	LENGTH DECIMAL	LENGTH OCTAL(B)	PACKAGE	CHKSUM	CREATION DATE
1	0	1778	3362	XBOOT	6661	UNKNOWN
2	0	283	433	XLOADER	571	12/15/70
3	0	290	442	XIORTNS	5116	05/07/70
4	0	30	36	XEOF	4620	UNKNOWN
5	0	75	113	DUMP	6137	UNKNOWN
6	0	257	401	MAPFNS	3617	03/16/70
7	0	671	1237	SYSTEM.	2533	05/07/70
8	0	684	1254	SIO$	6554	UNKNOWN
9	0	90	132	OUTPTC	2273	UNKNOWN
10	0	15	17	LOCF	600	UNKNOWN
11	0	27	33	GETBA	2146	UNKNOWN
12	0	183	267	IO	6603	UNKNOWN
13	0	182	266	IORANDM	6671	UNKNOWN
14	0	191	277	CPC	4017	UNKNOWN
15	0	42	52	XDUMP	3461	UNKNOWN
16	0	349	535	CORDUMP	1410	UNKNOWN
17	0	179	263	LINKERR	5332	UNKNOWN
18	0	719	1317	KODER	4652	UNKNOWN
19	0	599	1127	KRAKER	7405	UNKNOWN
20	0	14	16	XRCL	2040	UNKNOWN
21	0	25	31	ACGOER	4374	UNKNOWN
22	0	14	16	DBLE	1360	UNKNOWN
23	0	86	126	SINCOS	6150	UNKNOWN
24	0	61	75	DBAIEX	6445	UNKNOWN
25	0	40	50	IBAIEX	1210	UNKNOWN
26	0	213	325	INPUTB	6664	UNKNOWN
27	0	97	141	INPUTC	2116	UNKNOWN
28	0	73	111	OUTPTS	2374	UNKNOWN
29	0	35	43	REMARK	4750	UNKNOWN
30	0	33	41	SECOND	2220	UNKNOWN
31	0	67	103	DSQRT	534	UNKNOWN
32	0	26	32	DABS	4357	UNKNOWN
33	0	52	64	SQRT	2347	UNKNOWN
34	0	71	107	INPUTS	3664	UNKNOWN
35	0	66	102	EXP	5003	UNKNOWN
36	0	55	67	DMOD	4530	UNKNOWN
37	0	14	16	LEGVAR	7325	UNKNOWN
38	0	13	15	SNGL	3431	UNKNOWN
39	0	94	136	TAN	4044	UNKNOWN
40	0	76	114	ALNLOG	6537	UNKNOWN
41	0	121	171	ASINCOS	1047	UNKNOWN
42	0	79	117	ATAN	5326	UNKNOWN
43	0	96	140	ATAN2	4315	UNKNOWN
44	0	284	434	BACKSP	2205	UNKNOWN
45	0	97	141	BUFFEI	570	UNKNOWN
46	0	96	140	BUFFEO	3750	UNKNOWN
47	0	45	55	CABS	1510	UNKNOWN
48	0	53	65	CBAIEX	7066	UNKNOWN
49	0	60	74	CCOS	4042	UNKNOWN
50	0	48	60	CEXP	576	UNKNOWN
51	0	45	55	CLOG	6455	UNKNOWN
52	0	60	74	CSIN	1417	UNKNOWN

Table 4(b). List of Subprograms in LINKLIB.

RECORD NO.	LEVEL NO. OCTAL	LENGTH DECIMAL	LENGTH OCTAL(B)	PACKAGE	CHKSUM	CREATION DATE
53	0	48	60	CSQRT	2672	UNKNOWN
54	0	161	241	DATAN	3135	UNKNOWN
55	0	90	132	DBADEX	4624	UNKNOWN
56	0	120	170	DEXP	3071	UNKNOWN
57	0	200	310	DISPLA	1756	UNKNOWN
58	0	157	235	DLNLOG	2776	UNKNOWN
59	0	31	37	DSIGN	5611	UNKNOWN
60	0	154	232	DSINCOS	5324	UNKNOWN
61	0	16	20	DVCHK	26	UNKNOWN
62	0	71	107	ENDFIL	5332	UNKNOWN
63	0	36	44	IDINT	4143	UNKNOWN
64	0	75	113	IFENDF	4500	UNKNOWN
65	0	66	102	IOCHEK	4642	UNKNOWN
66	0	13	15	IOCHEC	165	UNKNOWN
67	0	34	42	LENGTH	6311	UNKNOWN
68	0	216	330	OUTPTB	5516	UNKNOWN
69	0	15	17	OVERFL	3300	UNKNOWN
70	0	30	36	PAUSE	1666	UNKNOWN
71	0	21	25	RANF	6147	UNKNOWN
72	0	51	63	RBAIEX	233	UNKNOWN
73	0	65	101	RBAREX	5424	UNKNOWN
74	0	76	114	REWINM	1563	UNKNOWN
75	0	26	32	SLITE	2535	UNKNOWN
76	0	31	37	SLITET	2201	UNKNOWN
77	0	68	104	TANH	6543	UNKNOWN
78	0	72	110	SINH	146	UNKNOWN
79	0	72	110	COSH	1302	UNKNOWN
80	0	28	34	SSWTCH	457	UNKNOWN
81	0	17	21	START	1111	UNKNOWN
82	0	31	37	TIME	4360	UNKNOWN
83	0	45	55	WRITEC	5100	UNKNOWN
84	0	87	127	WRITMS	1727	UNKNOWN
85	0	588	1114	INPUTN	2671	UNKNOWN
86	0	351	537	OUTPTN	1422	UNKNOWN
87	0	74	112	READEC	4432	UNKNOWN
88	0	39	47	FTNBIN	4666	UNKNOWN
89	0	96	140	INITMS	6535	UNKNOWN
90	0	118	166	READMS	1	UNKNOWN
91	0	25	31	MBYTE	5571	UNKNOWN
92	0	14	16	MXIFT	7004	UNKNOWN
93	0	32	40	MXGET	5675	UNKNOWN
94	0	19	23	MXCALL	1315	UNKNOWN
95	0	32	40	MBPUT	7236	UNKNOWN
96	0	32	40	MXPUT	4577	UNKNOWN
97	0	347	533	PLOT	6730	UNKNOWN
98	0	325	505	SYMBOL	3664	UNKNOWN
99	0	184	270	SCALE	702	UNKNOWN
100	0	299	453	AXIS	2356	UNKNOWN
101	0	167	247	LINE	4512	UNKNOWN
102	0	236	354	NUMBER	6167	UNKNOWN
103	17	0	0		0	
	LEVEL 17GROUP LENGTH IS		14154 33512			

7.2.8 Recommended Improvements to the Level 2.0 Version

More and more CDC 6000 series installations are installing "private" disk packs thus providing a user mountable/demountable direct access storage device. The increasing use of these packs suggests two areas of improvement in the Level 2.0 version (the current version) of the linkage editor.

1. Provide for the case where the individual links which comprise the executable program reside in more than one direct access file (presumably on different packs). Large programs such as NASTRAN will not fit on a single disk pack.

2. Provide for object deck libraries in direct access format on the packs. Again, for a large program such as NASTRAN, considerable elapsed time is spent in initial processing in creating the single direct access file SYSUT2 from each of the sequential libraries.

The first area could be implemented by modifying XBØØT and XLØADER. Perhaps input could be supplied to XBØØT which specifies a destination file for the link. XBØØT could then modify the master index in LINKO$ with this information. XLØADER could be modified to accept the new format in LINKO$.

The second area could be implemented by changing the format of the LIBRARY control statement to the following:

$$\text{LIBRARY} \quad \text{name}_1(a), \text{name}_2(a) \ \ldots$$

where

a = T or C as in the LINKEDIT statement. Files which are coded C are assumed to be already in direct access format (probably with a name index). Files coded T are sequential and are converted to direct access formation on SYSUT2 as now. This would imply changes to LKED015, LKED025 and LKED075.

7.2.9 Linkage Editor Glossary

control section	Consists of all instructions and data defined for a subprogram or common block.
delink	to delete from
ENTR Table	Object deck table containing a list of all named entry points and common blocks. See section 7.2.5.2
EPT	Entry Point Table. See section 7.2.2.1.4
FET	File Environment Table. See SCØPE reference manual.
FILL Table	Object deck table containing information to relocate previously defined address fields. See section 7.2.5.4
GT	General Table. See section 7.2.2.1.9
ID	Identification
LCT	Local Common Table, See section 7.2.5.1
link	when used as a verb, "to link" means "to add to."
link	Collection of one or more segments which comprise a logical subdivision of the program. Link 0 (consisting of one segment only) is in main storage at all times. It is the first link to receive control when execution of the program is initiated. The root segment of any other link resides in main storage at all times that the link is being executed. An overlay program must consist of at least one link other than Link 0.
LINK Table	Object deck table specifying external references with the subprogram. See section 7.2.5.5
LKED000	Main program. See Figure 31.
LT	Library Table. See section 7.2.2.1.2
nbr	abbreviation for "number"
path	Consists of a segment, A say, and all segments in the same region between A and the root segment (first segment). The root segment is a part of every path in every region. When a segment is in main storage, all segments in its path are also in main storage.
PIDL Table	Program Identification and Length Table. Object deck table containing the subprogram identification and names of each of the common blocks referenced by the subprogram. See section 7.2.5.1.

reg.	abbreviation for "region"
region	Contiguous area of main storage within which segments can be loaded independently of paths in other regions. An overlay program can be designed in a single or multiple regions.
RDT	Region Definition Table. See section 7.2.2.1.5.
REPL Table	Object deck table that provides for an efficient means for repeating a block of data.
RT	Rename Table. See section 7.2.2.1.8.
SCT	Segment Chains Table. See section 7.2.2.1.6.
SDT	Segment Definition Table. See section 7.2.2.1.7.
seg.	abbreviation for "segment."
segment	Smallest functional unit (one or more control sections) that can be loaded as one logical entity during program execution.
SNT	Subprogram Names Table. See section 7.2.2.1.3.
TEXT Table	Object deck table containing instructions and data. See section 7.2.5.3
tree	The graphic representation that shows how segments can use main storage at different times. It does not imply the order of execution.
XREF Table	See section 7.2.2.1.10.

7.3 THE SOURCE CONVERSION PROGRAM (SCP)

7.3.1 Purpose of the Source Conversion Program

The Source Conversion Program (SCP) translates the NASTRAN FORTRAN code that compiles on the UNIVAC 1108 and IBM S/360 to a form acceptable to the NASA Langley Research Center (LRC) CDC 6000 series RUN compiler.

The SCP is primarily concerned with two major differences between the FORTRAN acceptable to the LRC RUN compiler and the FORTRAN acceptable to the compilers of the three other computers initially selected for NASTRAN's execution: IBM System/360 (ØS); UNIVAC 1108 (EXEC 8); and IBM 7094-7044 Direct Couple System (IBSYS). These two differences are: a) nonstandard returns from called subroutines, and b) subroutines with multiple entry points.

7.3.2 Conversion Performed

Figure 1 shows a subroutine containing special cases of the types of FORTRAN statements on which the SCP operates. This subroutine was generated merely for illustrative purposes; it clearly violates many of the NASTRAN FORTRAN rules set down in section 6.2.

Figures 2, 3, 4, and 5 show the FORTRAN statements generated by the SCP from the code shown in Figure 1. These statements will compile on the LRC RUN compiler and will produce object code equivalent to that produced by the other compilers.

7.3.2.1 The Nonstandard Return (NSR)

The NSR affects three types of FORTRAN statements: a) the RETURN statement; b) the CALL statement; and c) the SUBROUTINE or ENTRY statement.

1. The RETURN statement.

   SCP Input (e.g., see lines 0033 and 0015 in Figure 1)

   RETURN

   or

   RETURNi

   where i is an alphanumeric constant.

```
      SUBROUTINE SUB1(*,A,*)                                          0001
C*****                                                                0002
C  THIS SAMPLE SUBROUTINE ILLUSTRATES PARTICULAR CASES OF ALL THE     0003
C  STATEMENT TYPES CONVERTED BY THE SOURCE CONVERSION PROGRAM.        0004
C                                                                     0005
C     1) MULTIPLE ENTRIES,                                            0006
C     2) MULTIPLE ENTRIES WITH NON-STANDARD RETURNS,                  0007
C     3) DUMMY ARGUMENT -A- APPEARING ON MORE THAN ONE ENTRY,         0008
C     4) DIMENSION STATEMENTS AFTER AN ALTERNATE ENTRY,               0009
C     5) NON-STANDARD RETURNS AS IN A CALLING PROGRAM,                0010
C     6) NON-STANDARD RETURNS AS IN THE CALLED PROGRAM,               0011
C     7) NON-STANDARD RETURNS ON LOGICAL IF STATEMENTS,               0012
C*****                                                                0013
      IF( A * 3,5) 40,50,50                                           0014
   40 RETURN 1                                                        0015
   50 RETURN 2                                                        0016
C*****                                                                0017
C  SECOND ENTRY POINT                                                 0018
C*****                                                                0019
      ENTRY SUB2                                                      0020
      CALL FUNC1(A,$100)                                              0021
  100 CALL FUNC2($100,  $200,  1,0,  D)                               0022
  200 CALL FUNC3($100)                                                0023
      RETURN                                                          0024
C*****                                                                0025
C  THIRD ENTRY POINT                                                  0026
C*****                                                                0027
      ENTRY SUB3(A,BC,DEF,*)                                          0028
      INTEGER BC(3)                                                   0029
      IF( D .EQ. 1 ) CALL FUNC2($100,$300,2,0D0,D)                    0030
      RETURN 1                                                        0031
  300 IF( D .EQ. 2.0 ) RETURN 1                                       0032
      RETURN                                                          0033
      END                                                             0034
```

Figure 1. Subroutine acceptable to the UNIVAC 1108, IBM System/360, and IBM 7094-7044 Direct Couple System FORTRANs, but not to the CDC 6000 series FORTRAN.

```
      SUBROUTINE SUB1(*,*),RETURNS(RETURN1,RETURN2)                   SUB1    1
      COMMON/SYSTEM /IIIIIII(1)                                       SUB1    2
      COMMON/ZZZSUB1/IIIIII1,IIIII02,IIIII03                          SUB1    3
      UNNNOWN=LOCF(IIIIIII(1))-1                                      SUB1    4
      IIIIII1=LOCF(A)- UNNNOWN                                        SUB1    5
      CALL SUB1ZZZ(IIIIIII(IIIII01),IIIIIII(IIIII02),IIIIIII(IIIII03)),RSUB1    6
     1RETURNS(1,2)                                                    SUB1    7
      RETURN                                                          SUB1    8
    1 RETURN RETURN1                                                  SUB1    9
    2 RETURN RETURN2                                                  SUB1   10
      END                                                             SUB1   11
```

Figure 2. Driver deck generated for entry SUB1 of the sample subroutine.

```
      SUBROUTINE SUB2                                                    SUB2    1
      COMMON/SYSTEM /IIIIIII(1)                                          SUB2    2
      COMMON/ZZZSUB1/IIIII01,IIIII02,IIIII03                             SUB2    3
      NNNNNNN=LOCF(IIIIIII(1))-1                                         SUB2    4
      CALL SUB2ZZZ(IIIIIII(IIIII01),IIIIIII(IIIII02),IIIIIII(IIIII03))   SUB2    5
      RETURN                                                             SUB2    6
      END                                                                SUB2    7
```

Figure 3. Driver deck generated for entry SUB2 of the sample subroutine.

```
      SUBROUTINE SUB3(A,BC,DEF),RETURNS(RETURN1)                         SUB3    1
      COMMON/SYSTEM /IIIIIII(1)                                          SUB3    2
      COMMON/ZZZSUB1/IIIII01,IIIII02,IIIII03                             SUB3    3
      NNNNNNN=LOCF(IIIIIII(1))-1                                         SUB3    4
      IIIII01=LOCF(A)-NNNNNN                                             SUB3    5
      IIIII02=LOCF(BC)-NNNNNNN                                           SUB3    6
      IIIII03=LOCF(DEF)-NNNNNNN                                          SUB3    7
      CALL SUB3ZZZ(IIIIIII(IIIII01),IIIIIII(IIIII02),IIIIIII(IIIII03)),RSUB3    8
     1ETURNS(1)                                                          SUB3    9
      RETURN                                                             SUB3   10
    1 RETURN RETURN1                                                     SUB3   11
      END                                                                SUB3   12
```

Figure 4. Driver deck generated for entry SUB3 of the sample subroutine.

```
      SUBROUTINE SUB1ZZZ(A,BC,DEF),RETURNS(RETURN1,RETURN2)          SUB1    1
C     SUBROUTINE SUB1(*,A,*)                                         SUB1    2
C*****                                                               SUB1    3
C  THIS SAMPLE SUBROUTINE ILLUSTRATES PARTICULAR CASES OF ALL THE    SUB1    4
C  STATEMENT TYPES CONVERTED BY THE SOURCE CONVERSION PROGRAM.       SUB1    5
C                                                                    SUB1    6
C     1) MULTIPLE ENTRIES,                                           SUB1    7
C     2) MULTIPLE ENTRIES WITH NON-STANDARD RETURNS,                 SUB1    8
C     3) DUMMY ARGUMENT *A* APPEARING ON MORE THAN ONE ENTRY,        SUB1    9
C     4) DIMENSION STATEMENTS AFTER AN ALTERNATE ENTRY,              SUB1   10
C     5) NON-STANDARD RETURNS AS IN A CALLING PROGRAM,               SUB1   11
C     6) NON-STANDARD RETURNS AS IN THE CALLED PROGRAM,              SUB1   12
C     7) NON-STANDARD RETURNS ON LOGICAL IF STATEMENTS.              SUB1   13
C*****                                                               SUB1   14
C     ENTRY SUB3(A,BC,DEF,*)                                         SUB1   15
      INTEGER BC(3)                                                  SUB1   16
      IF( A = 3,5) 40,50,50                                          SUB1   17
   40 RETURN RETURN1                                                 SUB1   18
   50 RETURN RETURN2                                                 SUB1   19
C*****                                                               SUB1   20
C  SECOND ENTRY POINT                                                SUB1   21
C*****                                                               SUB1   22
      ENTRY SUB2ZZZ                                                  SUB1   23
C     ENTRY SUB2                                                     SUB1   24
      CALL FUNC1(A),RETURNS(100)                                     SUB1   25
  100 CALL FUNC2(1,0,D),RETURNS(100,200)                             SUB1   26
  200 CALL FUNC3,RETURNS(100)                                        SUB1   27
      RETURN                                                         SUB1   28
C*****                                                               SUB1   29
C  THIRD ENTRY POINT                                                 SUB1   30
C*****                                                               SUB1   31
      ENTRY SUB3ZZZ                                                  SUB1   32
      IF(D.EQ.1)CALL FUNC2(2.0D0,D),RETURNS(100,300)                 SUB1   33
      RETURN RETURN1                                                 SUB1   34
  300 IF(D.EQ.2.0)RETURN RETURN1                                     SUB1   35
      RETURN                                                         SUB1   36
      END                                                            SUB1   37
```

Figure 5. SCP output of the sample subroutine.

SCP Output (e.g., see line SUB1 36 and SUB1 18 in Figure 5)

If i is not present in the input then no conversion takes place.

RETURN RETURNi

where i is an alphanumeric constant identical to the i of the input.

2. The CALL statement having nonstandard return arguments.

SCP Input (e.g., see line 0022 in Figure 1)

CALL $s(\$n_1,\$n_2,\ldots,\$n_K,a_1,a_2,\ldots,a_J)$

where s is the SUBROUTINE or ENTRY name, the n_i are FORTRAN statement numbers associated with nonstandard returns, and the a_i are ordinary arguments.

SCP Output (e.g., see line SUB1 26 in Figure 5)

CALL $s(a_1,a_2,\ldots,a_J)$, RETURNS$(n_1,n_2,\ldots,n_K)$

where s, the a_i, and the n_i are as defined above. Note the "$'s" have been removed.

3. The SUBROUTINE or ENTRY statement.

SCP Input (e.g., see line 0001 in Figure 1)

SUBROUTINE $s(*_1,*_2,\ldots,*_K,a_1,a_2,\ldots,a_J)$

or

ENTRY $s(*_1,*_2,\ldots,*_K,a_1,a_2,\ldots,a_J)$

where s is the subroutine or entry name, the $*_i$ are arguments representing the nonstandard returns and the a_i are ordinary arguments.

SCP Output

SUBROUTINE $s(a_1,a_2,\ldots,a_J)$, RETURNS (RETURN1, RETURN2, ..., RETURNK)

where s and the a_i are as defined above.

Note: During the overall conversion process the nonstandard return s(*'s) in ENTRY statements are removed by the multiple-entry processor (see Figure 7) as described in section 7.3.2.2. This process is performed first, and thus the nonstandard return processor encounters only SUBROUTINE statements having nonstandard returns.

7.3.2.2 Subroutines Having Multiple Entries

Unlike nonstandard return processing, which is essentially a statement-for-statement conversion process, subroutines having multiple entries cannot be converted in a straightforward way for compilation on the LRC RUN compiler.

The problem of multiple-entry subroutines lies in the requirement that each argument must continue to represent the beginning of the same area in core that is assigned upon the first entry where it appears as an argument until it receives another core assignment at the same or another entry in which it appears in the same subroutine. Thus in Figure 1, if entry were made to SUB3 (line 0028) the dummy arguments A, BC, and DEF would receive core assignments. If the next entry to this subroutine were made at SUB1 (line 0001), the argument A would receive a new core assignment; however BC and DEF would retain the assignments received at the previous entry, SUB3.

The LRC version and all versions of the CDC 6000 series RUN compiler accept arguments only on the SUBROUTINE statement; ENTRY statements may not have arguments[1].

The list of arguments on any CALL statement, whether to an initial or secondary entry point, should agree with the argument list of the SUBROUTINE statement. In CDC 6000 series FORTRAN, for each argument in a CALL list, an address and not a variable, entire array, or external subroutine is passed to the called subroutine. The following paragraphs describe the technique used to convert subroutines having multiple entries.

1. If all the entries of a subroutine have precisely the same number of arguments, and these arguments have the same names and appear in the same order, then the SCP does nothing more than remove the argument lists from the ENTRY statements.

[1] Control Data 6400/6600 Computer Systems FORTRAN Reference Manual (CDC Pub. No. 60174900)

2. If the above condition is not met, then the SCP generates "drivers" as shown in Figures 2, 3, and 4.

3. To insure that a core assignment for an argument is maintained for future calls to a subroutine with multiple entries, all calls to that subroutine are trapped through small subroutines called "drivers." The SCP generates a driver for each entry point in a multiple-entry subroutine. The driver subroutine name is the same as the entry it represents. Its argument list is the same as the original, e.g., see the entries in Figures 1, 2, 3, and 4.

4. The driver's function is to preserve the core assignments of its arguments and to then call the entry originally intended with a list of all possible argument core assignments.

5. The argument list of the converted deck is comprised of the set-theoretic union of all argument names for all entries (see Figure 1, lines 0001 and 0028, and Figure 5, line SUB1 1).

6. The drivers do not preserve the actual core locations, but instead preserve, in labeled COMMON, indexes relative to a fixed location in core (/SYSTEM/--see section 2.4.1.8). See for example lines SUB3 5, SUB3 6, and SUB3 7 in Figure 4.

7. The entry point names of the original subroutine are filled to seven characters each, using "Z's." Seven-character names are in general unique since six is the maximum number of characters permitted for names in NASTRAN FORTRAN. The SCP does not consider the possibility of a multiple-entry subroutine having two entry names (such as SUBZ and SUBZZ) which, when filled with Zs to seven characters, would produce identical entry names. In this case, the code produced by the SCP will not compile, and it is up to the programmer using the SCP to solve the problem.

8. At execution time the drivers will produce correct results only when CALLs are made in a sequence that would be valid using the original subroutine on the UNIVAC 1108 and the IBM S/360.

7.3.3 Major Divisions in the Program

The following discussion is intended for the use by the programming analyst responsible for the use and maintenance of the SCP. Refer to the symbolic FORTRAN code, which is heavily commented, in addition to this discussion and the flowcharts given in section 7.3.5.

7.3.3.1 The Main Driving Routine CØNVSØU

The main driving routine CØNVSØU is a single subprogram that controls the conversion of FORTRAN subprograms it finds on the input file.

It does the following:

1. Reads a full subprogram into core.
2. Calls MULTEN, the multiple-entry processor, which will convert the deck for multiple entries.
3. Calls REØRDR, the delcarative statement reordering processor, which will rearrange into correct order any declaratives within the subprogram. REØRDR is called only if the subprogram has multiple entries.
4. Calls NSRETN, the nonstandard return processor, which will complete the conversion by translating all nonstandard return statements within the subprogram.
5. Outputs the converted deck via routine DKØUT.
6. Repeats steps 1 through 5 until no more subprograms remain on the input file.

The main driving routine contains blank CØMMØN which is loaded below (i.e., at a higher core location than) all object code of the SCP. It is thus used as open core. Within the main driving routine and the three processors, a subprogram being converted always lies in this open core from Z(IDK) to Z(NDK), where

Z = Open core array

IDK = Relative location in Z where the subprogram begins.

NDK = Relative location where the subprogram ends.

Each card image of the subprogram being converted occupies twelve words of core, each word having six left-adjusted characters. Consequently, the SCP is recommended for use only on a CDC 6000 series computer although it is theoretically capable of running on any machine having six-character words (e.g., UNIVAC 1108). This is reasonable since the SCP is designed to operate on CDC 6000 series format files.

7.3.3.2 The Multiple-Entry Processor MULTEN

The multiple-entry processor MULTEN operates on the original code one subprogram at a time. It scans the code for entry statements and, if found, calls utility routine NAMARG to form an argument list. After all entries have been found, the following takes place.

1. If only a primary entry was found, no action is taken and this processor returns to the main driving routine.
2. The argument lists of all entries are compared. If they are identical, then the only action taken is to remove the argument lists from all secondary entries.
3. If the argument lists are not identical, utility routine DRIVES is called to generate and output a driver deck for each entry point. The entry statements of the original program are then altered to appear as comment statements, new entries are inserted before them, and control is returned to the main driving routine.

MULTEN will in all cases set a flag if more than one entry is found to indicate that the declarative statement processor REØRDR is to be called.

7.3.3.3 The Delcarative Statement Reordering Processor REØRDR

The function of the declarative statement reordering processor REØRDR is to move all declarative statements to the top of a subprogram and also insure that they are in the following order (see section 6.2):

1. DØUBLE PRECISIØN
2. CØMPLEX
3. REAL
4. INTEGER

5. LØGICAL
6. EXTERNAL
7. DIMENSIØN
8. CØMMØN
9. EQUIVALENCE
10. DATA

REØRDR is called for subprograms with multiple entries because DIMENSIØN statements appearing after a secondary entry must be moved to the top of the program.

This processor originally was a stand-alone program, and still retains DIMENSIØN statements, while the other two processors use the open core concept.

REØRDR uses a shuttle-exchange sort considering all nondeclarative statements to be stored last. Comments appearing directly above, or embedded within, a declarative statement are moved along with the respective declarative in the sorting process.

7.3.3.4 The Nonstandard Return Processor NSRETN

The nonstandard return processor NSRETN analyzes each statement of the subprogram it receives for conversion. When it finds any of the following statement forms, it will branch to a section of code that will perform the conversion directly.

1. SUBROUTINE statement having nonstandard returns (*'s) in its argument list.
2. RETURNi, where i is an integer constant.
3. IF(----)RETURNi, as in (2).
4. CALL statement having nonstandard return FORTRAN statement numbers ($n) in its argument list.
5. IF(----)CALL statement as in (4).

7.3.3.5 Utility Subroutines

Described below are 25 small utility subroutines used by the SCP. All are written in FORTRAN except WRTEØR, ØRF, LSHIFT, RSHIFT, LØCF, and FIELDLN, which are written in CØMPASS. All of the exceptions save WRTEØR are part of the MAPFNS routine described in section 5.5.6.1.

7.3.3.5.1 WRTEØR

A CØMPASS assembly language routine to complete a logical record on the converted deck output file.

CALL WRTEØR

7.3.3.5.2 CDTYPE

When called by REØRDR, this routine will analyze one 72-column card image and return a value indicating what kind of FORTRAN statement or statement fragment it is.

CALL CDTYPE(TYPE,BUFF,ADD)

TYPE = Integer returned with one of the following

- -1 Comment statement
- -2 Continuation statement
- 0 Undefined statement
- 1 DØUBLE PRECISIØN statement
- 2 CØMPLEX statement
- 3 REAL statement
- 4 INTEGER statement
- 5 LØGICAL statement
- 6 EXTERNAL statement
- 7 DIMENSIØN statement
- 8 CØMMØN statement
- 9 EQUIVALENCE statement
- 10 DATA statement

BUFF = Eleven-word buffer containing card column characters 7 through 72, six characters to a word

ADD = BCD word containing columns 1 through 6 of the card image.

7.3.3.5.3 MØVE

MØVE moves a group of card images, when called by REØRDR, to a higher position in the deck. It performs a shuttle-exchange.

CALL MØVE(PØINT,BEGIN,END,CARD,ADD)

PØINT = Integer value pointing to the last card sorted into place, after which cards on the current move will go.

BEGIN = Integer card number of the first card in a group of cards to be moved.

END = Integer card number of the last card in group to be moved.

CARD = Buffer containing the card images for the subprogram.

ADD = Buffer containing the address field of each card image.

7.3.3.5.4 TØP

TØP, a small routine, determines where the first nonentry, noncomment statement of a subprogram begins.

CALL TØP(PØINT,CARD,ADD,TØTAL)

PØINT = Integer value of card number returned.

CARD = Array of card image statement fields.

ADD = Array of card image address fields.

TØTAL = Integer value of the total number of cards in subprogram.

7.3.3.5.5 MASK2

MASK2 unpacks a specific character from a specific word in core.

CALL MASK2(WØRD,CHAR,LETTER)

WØRD = Word of core where the character to be unpacked resides.

CHAR = Integer count counting from left of character desired.

LETTER = Word character is returned in. The character is left-justified and the word is filled with blank characters.

7.3.3.5.6 MASK3

MASK3 unpacks a character from a word in a string of words and increments string pointers appropriately.

CALL MASK3(WØRD,MWØRD,MCHAR,LETTER)

WØRD = Current word in string to unpack character from.

MWØRD = Word currently being operated on.

MCHAR = Character desired counting from left in the word.

LETTER = Word in which character is returned, left-justified filled with blanks.

MCHAR is incremented by 1. If it then exceeds 6, it is set to 1 and MWØRD is incremented by 1 before return is made.

7.3.3.5.7 MASK7

MASK7 analyzes a statement image buffer and returns the n-th nonblank character in the image; or if the image is exhausted, it returns a blank.

CALL MASK7(CARD,N,LET,NCARDS)

CARD = Statement image buffer

N = Number of the character desired, $N \geq 1$

LET = Word the character is returned in, left-justified filled with blanks

NCARDS = Number of cards in statement image.

7.3.3.5.8 GETNAME

GETNAME determines the name appearing on the entry statement of a subprogram.

CALL GETNAME(Z,NAME)

Z = Entry statement image buffer.

NAME = Word where the name is returned, left-justified filled with blanks.

7.3.3.5.9 NAMARG

NAMARG operates on any kind of an entry statement (SUBROUTINE or ENTRY) and returns a buffer of data about the entry.

CALL NAMARG(ARGBUF,IARG)

ARGBUF = General buffer where data is to be placed.

IARG = Next location of ARGBUF which may be filled.

On return the following values will have been placed in ARGBUF.

ARGBUF(IARG+0) = Location of entry

ARGBUF(IARG+1) = Entry name

ARGBUF(IARG+2) = Number of nonstandard returns in the entry statement

ARGBUF(IARG+3) = Number of arguments

ARGBUF(IARG+4) = BCD name of the first argument

⋮

ARGBUF(IARG+3+ARGBUF(IARG+3)) = BCD name of the last argument

7.3.3.5.10 PACKCD

PACKCD packs a character into the output card image. It will generate continuation cards as needed.

CALL PACKCD(CHAR,IØPT)

CHAR = Word with the left-justified character to be packed.

IØPT
- = 0 implies continue the current statement.
- = 1 implies start a new statement.
- = 2 implies start the first statement at Z(1), the open core array in blank common.
- = >2 implies start a new statement at Z(IØPT).

7.3.3.5.11 INSERT

INSERT inserts new entries into multiple-entry subroutines if required, and converts the old entries into comment statements.

CALL INSERT(IDK,NDK,ARGS,JARGS,ARGBUF,IARG,STARS)

IDK = Pointer to the first word of the subprogram in open core.

NDK = Pointer to the last word of the subprogram in open core.

ARGS = Array containing the union of argument names.

JARGS = Number of names in ARGS.

ARGBUF = Buffer produced by NAMARG containing entry argument data.

IARG = Length of ARGBUF.

STARS = Number of asterisks to be placed on main entry.

7.3.3.5.12 UNPKZ

UNPKZ unpacks the next character of a statement, automatically considering continuation cards.

CALL UNPKZ

CØMMØM/ZUNPKZ/ISTATE,JSTATE,LASTWD,ZWØRD,ZCHAR,CHAR

ISTATE = Pointer to the first word of a statement.

JSTATE = Pointer to the tentative last word of a statement.

LASTWD = Pointer to the actual last word of a statement.

ZWØRD = Pointer to the current word of open core being work on.

ZCHAR = Last character position unpacked, $0 \leq$ ZCHAR ≤ 6.

CHAR = Character unpacked.

7.3.3.5.13 PACKZ

PACKZ packs a character into a string.

CALL PACKZ(IBUMP,CH)

CØMMØN/ZUNPKZ/ISTATE,JSTATE,LASTWD,ZWØRD,ZCHAR,CHAR

ISTATE, JSTATE, LASTWD, ZWØRD, ZCHAR, CHAR = See UNPKZ, section 7.3.3.5.12

IBUMP = { 0 if pointers are not to be altered.
{ ≠ 0 if automatic pointers are used.

CH = Character to be packed.

7.3.3.5.14 PACK1

PACK1 packs a specific character into a specific word of core.

CALL PACK1(WØRD,J,CHAR)

WØRD = Word where character will be placed.

J = Character position, 1 to 6, counting from left where the character will be placed in WØRD.

CHAR = BCD character left-justified.

7.3.3.5.15 UNPK (function)

UNPK unpacks a specific character from a specific word of core.

CHAR = UNPK(WØRD,J)

WØRD = Word of core where character to be unpacked resides.

J = Character position, 1 to 6, counting from left.

CHAR = Character returned, left-justified and filled with blanks.

7.3.3.5.16 ZWØRD

ZWØRD unpacks the next one to six characters from a statement, ignoring blanks, and packs them into a single word, left-justified and filled with blanks.

```
CALL ZWØRD(NAME,JCHARS)
CØMMØN/ZUNPKZ/ISTATE,JSTATE,LASTWD,ZWØRD,ZCHAR,CHAR
```

ISTATE, JSTATE, LASTWD, ZWØRD, ZCHAR, CHAR = See UNPKZ section 7.3.3.5.12

NAME = Word where the characters are returned.

JCHARS = Number of characters desired.

7.3.3.5.17 NAMEZ

NAMEZ fills out a name to seven characters with "Z's" on the right.

```
CALL NAMEZ(NAME,NEWNAME)
```

NAME = Single word with name in it.

NEWNAME = Seven word buffer where the seven characters of the new name will be returned, each left-justified and filled with blanks.

7.3.3.5.18 ZNAME

ZNAME is the same as NAMEZ (7.3.3.5.17) except that the name is filled with "Z's" on the left.

7.3.3.5.19 ØRF (function)

ØRF performs the logical sum of two words.

RESULT = ØRF(WØRD1,WØRD2)

7.3.3.5.20 LSHIFT (function)

LSHIFT performs logical shift of a word n-bits to the left. High-order bits shifted out are last; vacated low-order bit positions are zero-filled.

RESULT = LSHIFT(WØRD,N)

WØRD = Word to be shifted. (Its not altered)

N = Number of bits to shift left.

RESULT = Returned value of shifted word.

7.3.3.5.21 RSHIFT (function)

RSHIFT performs a right shift with the dual characteristics of LSHIFT. See section 7.3.3.5.20.

7.3.3.5.22 LØCF (function)

LØCF determines the absolute location of a variable address.

RESULT = LØCF(WØRD)

WØRD = Varaible whose address is desired.

RESULT = Returned address of WØRD.

7.3.3.5.23 FIELDLN

FIELDLN returns the number of words of core available for code and data storage.

CALL FIELDLN(L)

L = Number of words of core available L must be set to zero before call is made to FIELDLN.

7.3.3.5.24 DKØUT

DKØUT outputs the converted deck. It places the name and sequence numbers in columns 73 through 80 of each card image.

CALL DKØUT(IDK,NDK)

IDK = Pointer to the first word of the converted deck in open core.

NDK = Pointer to the last word of the converted deck in open core.

7.3.3.5.25 DRIVES

DRIVES generates a driver deck for each entry point of the subprograms that have multiple entries.

CALL DRIVES(ARGBUF,IARG,ARGS,JARG)

ARGBUF = Buffer of names and argument lists for all the entries as prepared by NAMARG. See section 7.3.3.5.9.

IARG = Length of ARGBUF

ARGS = Buffer where DRIVES will place the union of all arguments found in ARGBUF.

JARG = Length of ARGS.

7.3.4 Use of the SCP

The SCP operates on an input file of subprograms to be converted. This input file need only consist of FORTRAN card images in a form capable of being read by CDC 6000 series formatted READ statements. These card images, thus, must be in CDC 6000 series display code. The file may be constructed such that each deck is a logical record, or the card images of all decks may be continuous. The FORTRAN code of the routines to be converted are assumed to be "correct," i.e., compilable on the UNIVAC 1108 or the IBM S/360.

To execute the program, compile all routines of the SCP placing the object decks on some file, e.g., SCPR. Then execute the program using the control card:

SCPR(ØUTFILE,INFILE).

where INFILE is the file name where the code to be converted is to be found, and ØUTFILE is where the output code is to be placed. The output will be one CDC 6000 series logical record per output

subroutine or driver deck.

The program should be executed with approximately $130{,}000_8$ words of core. This amount will allow the handling of the largest subprogram within NASTRAN. Figure 6 shows a sample deck setup for an SCP run.

7.3.5 SCP Flowcharts

This section contains flowcharts for the routines comprising the SCP. The figure numbers and the corresponding routines are:

Figure Number	Routine	No. of Sheets
7	CØNVSØU	1
8	MULTEN	2
9	NAMARG	1
10	DRIVES	2
11	REØRDR	3
12	NSRETN	4

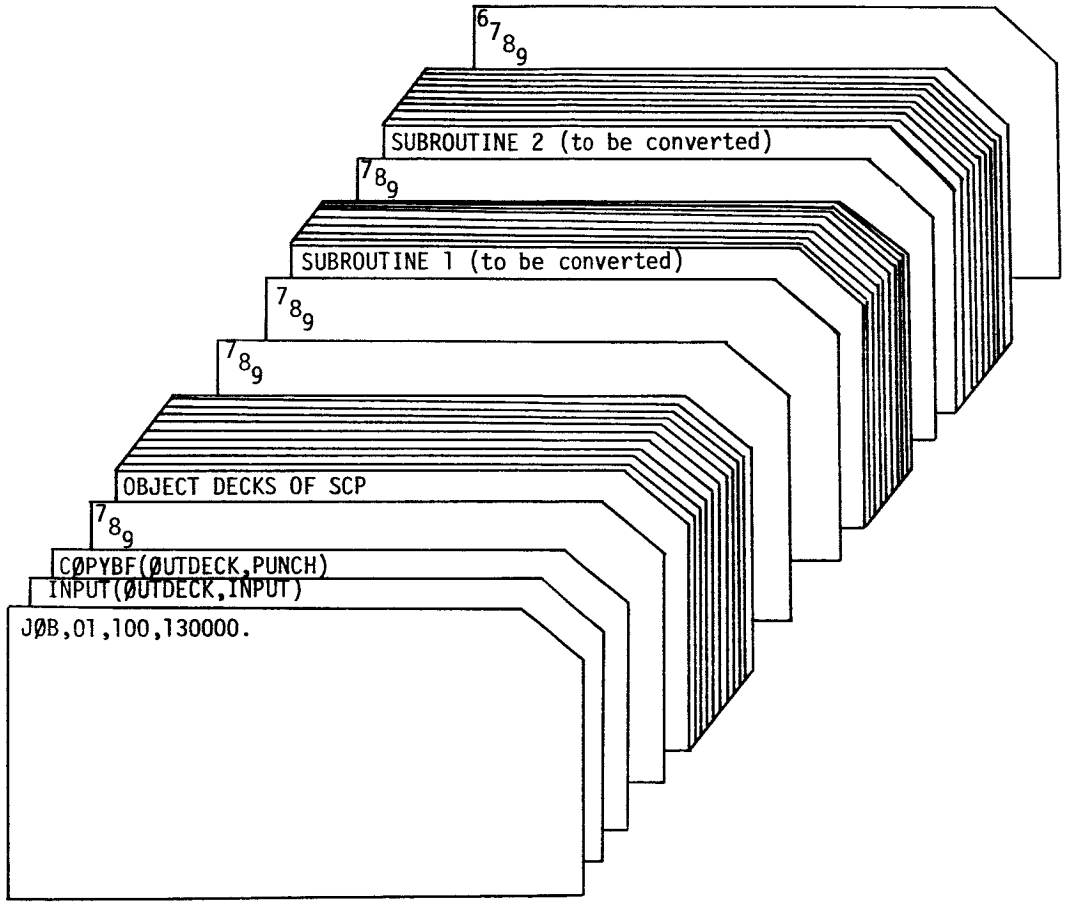


Figure 6. Sample deck setup for an SCP run.

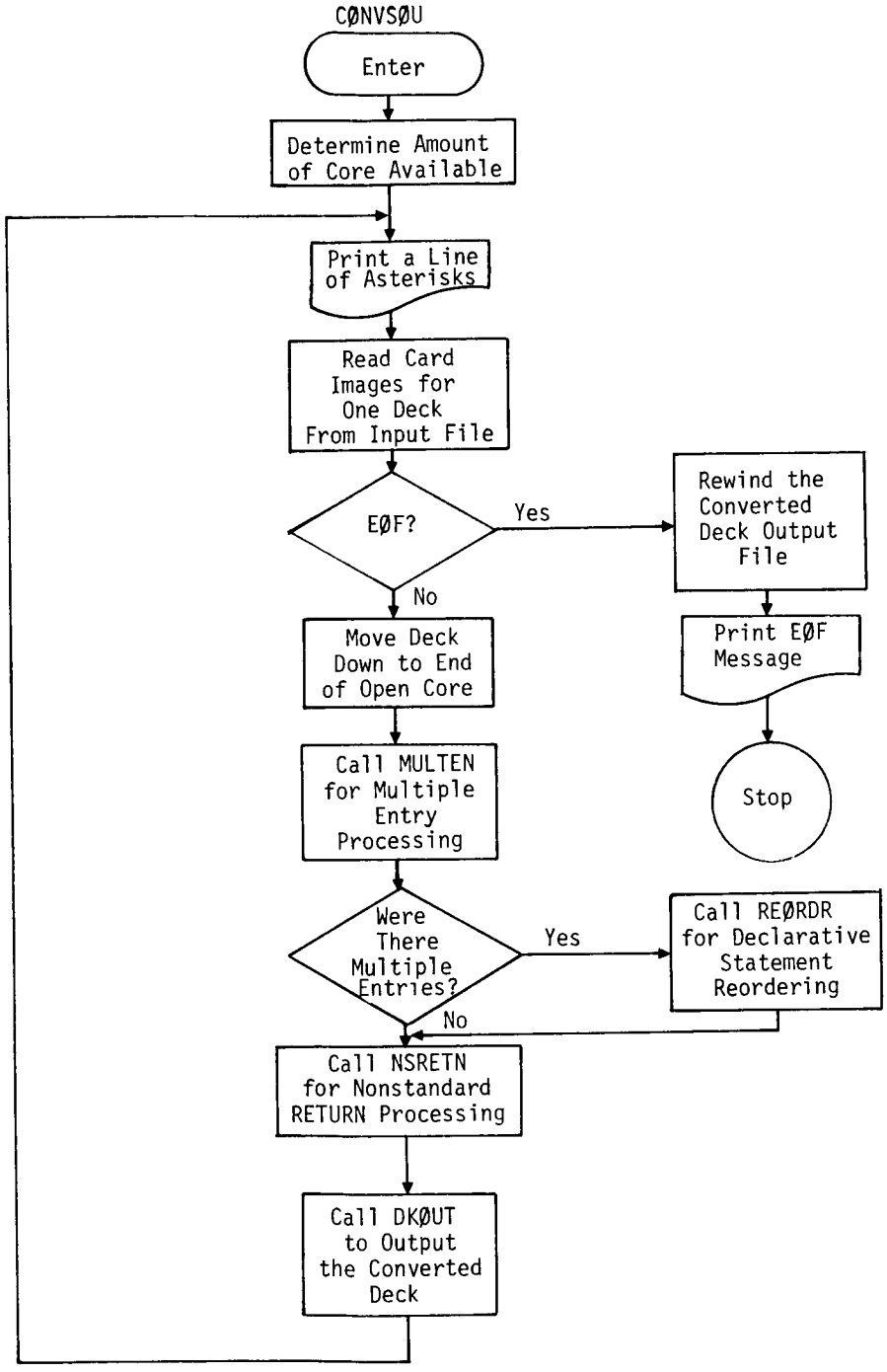


Figure 7. Flowchart for CØNVSØU.

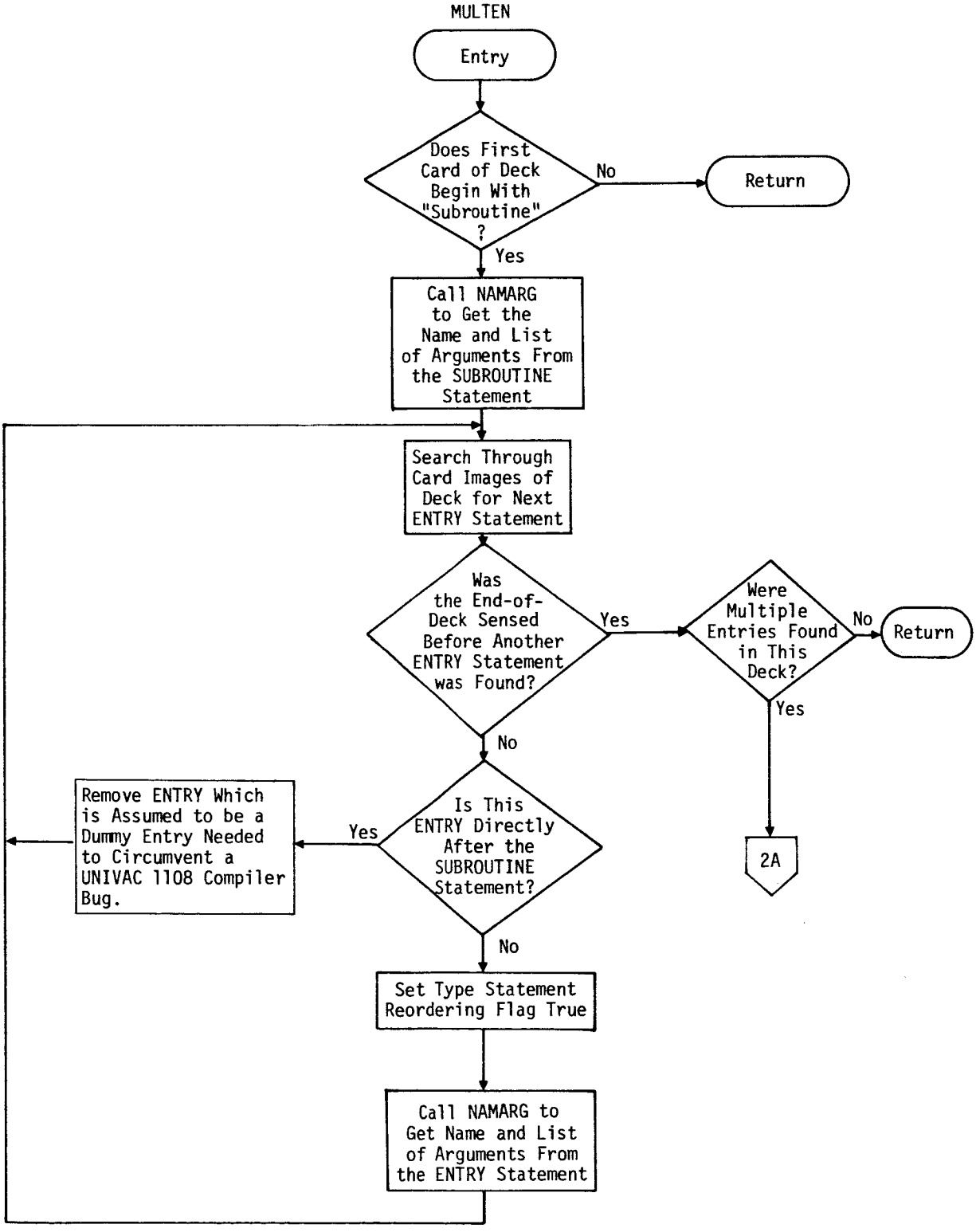


Figure 8(a). Flowchart for MULTEN.

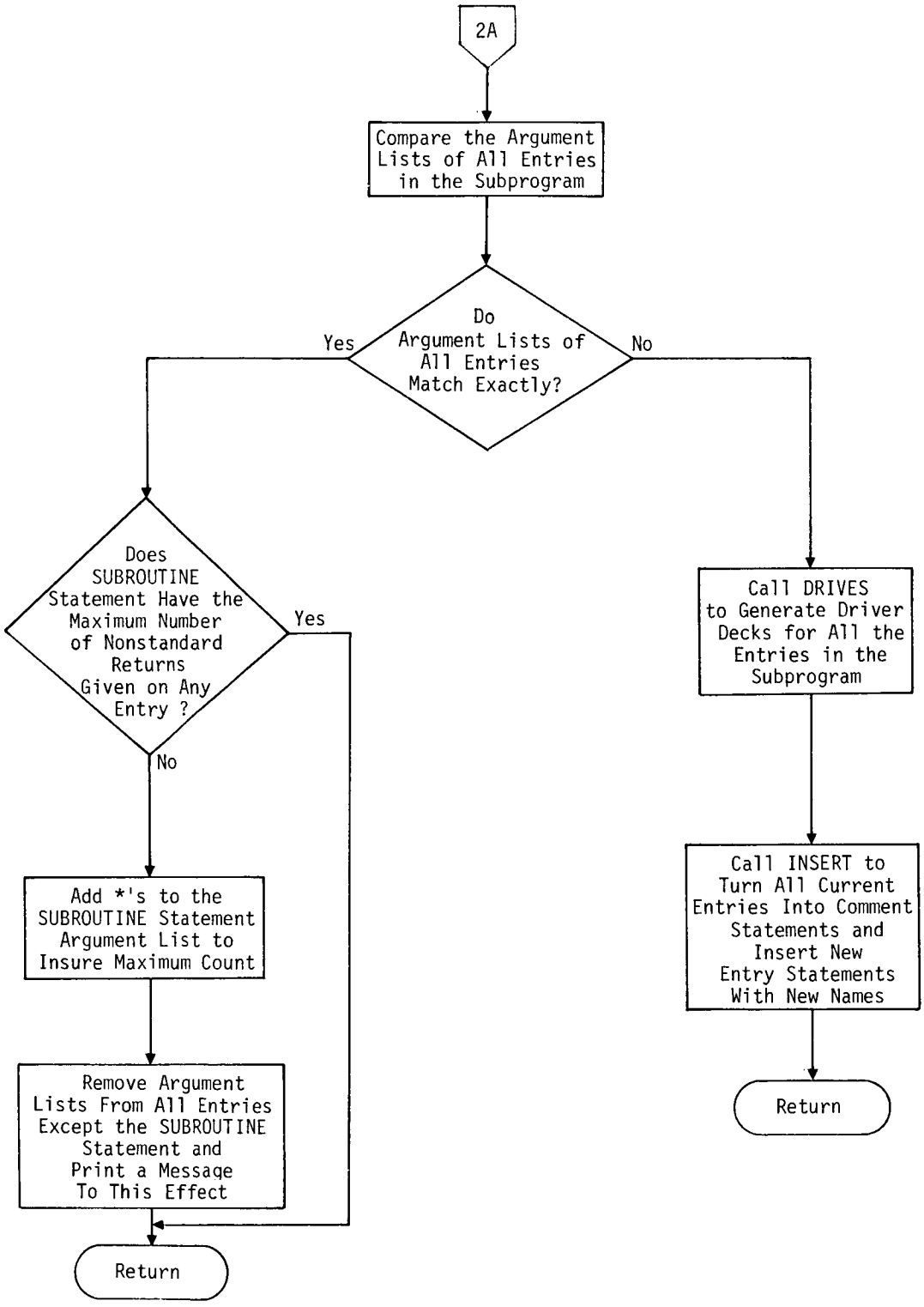


Figure 8(b). Flowchart for MULTEN.

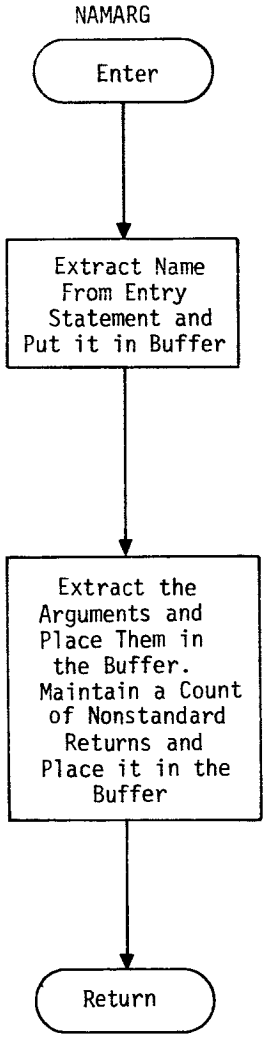


Figure 9. Flowchart for NAMARG.

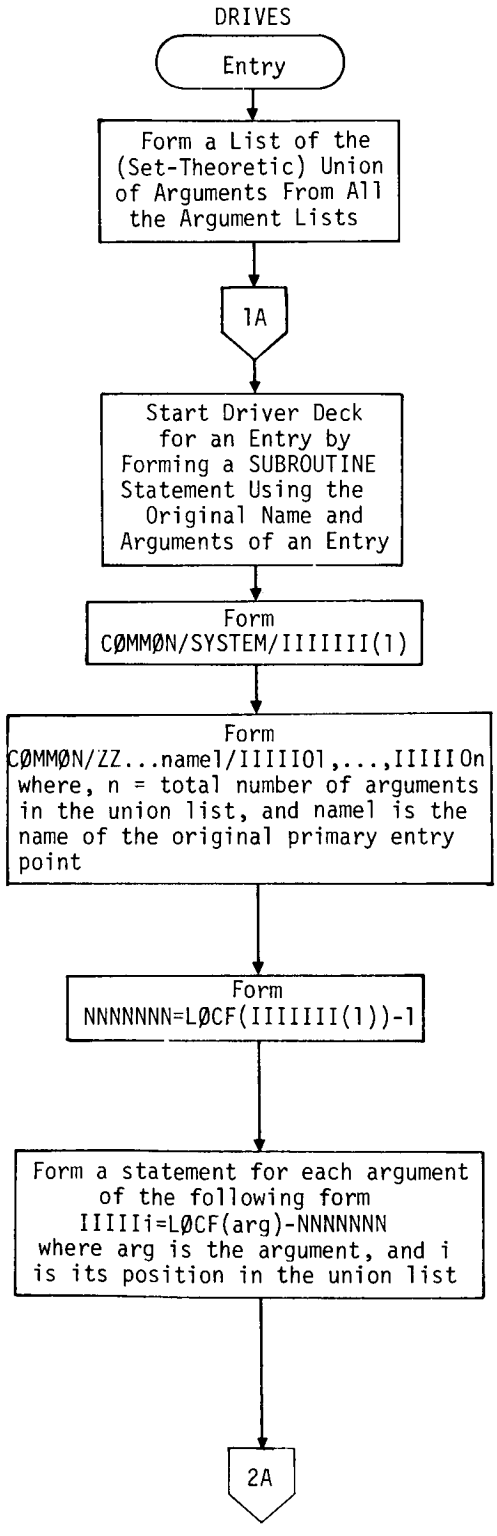


Figure 10(a). Flowchart for DRIVES.

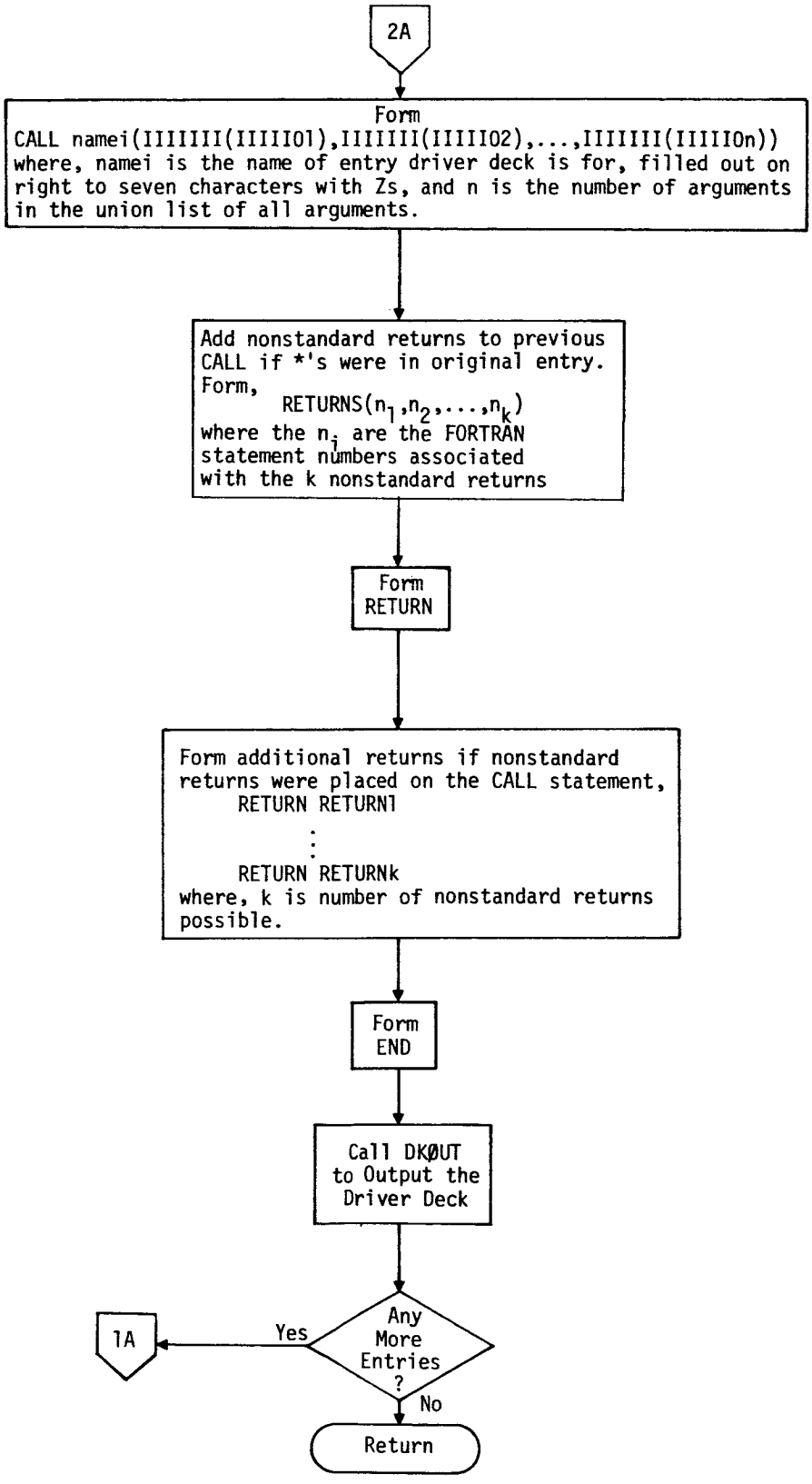


Figure 10(b). Flowchart for DRIVES.

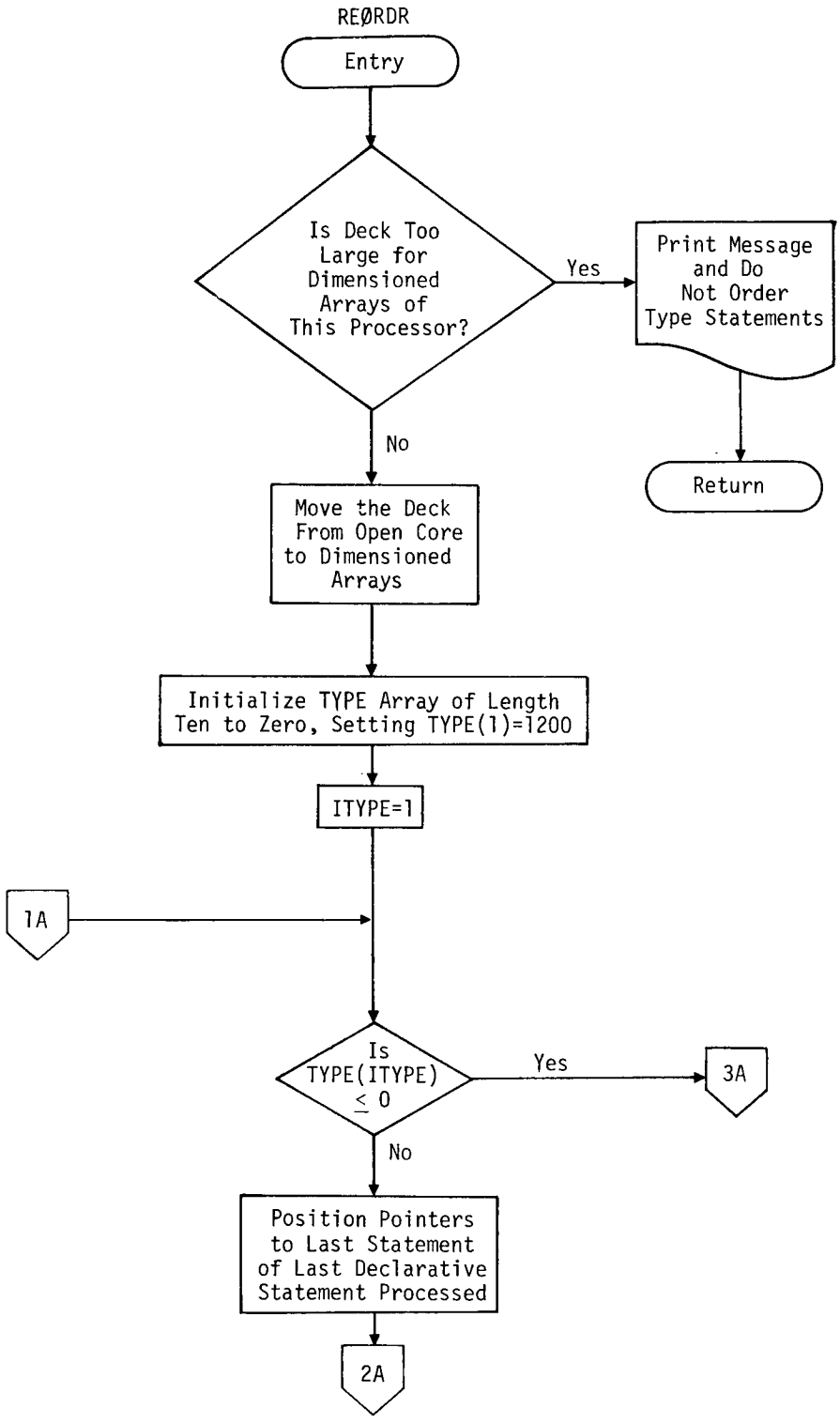


Figure 11(a). Flowchart for REØRDR.

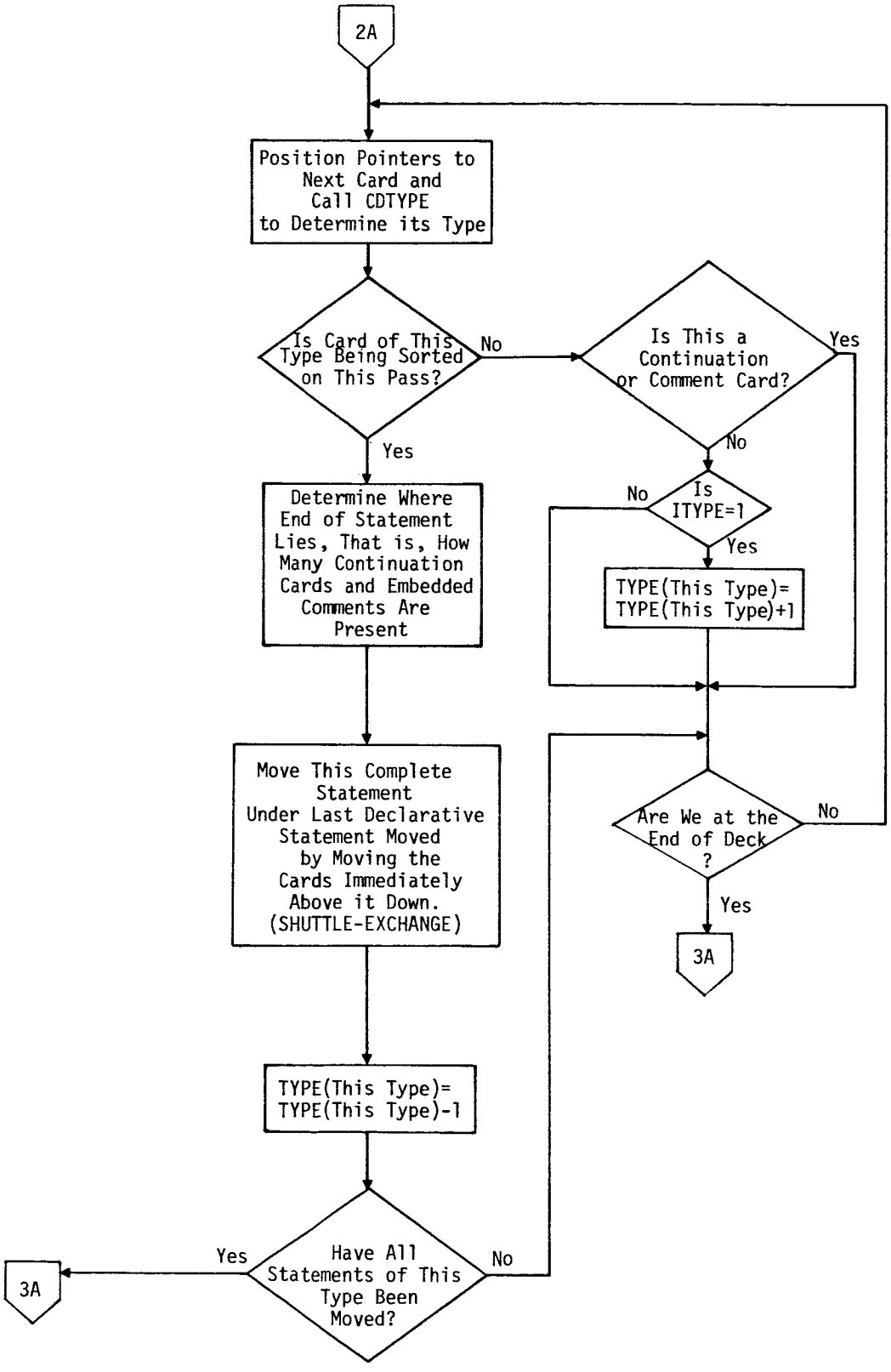


Figure 11(b). Flowchart for REØRDR.

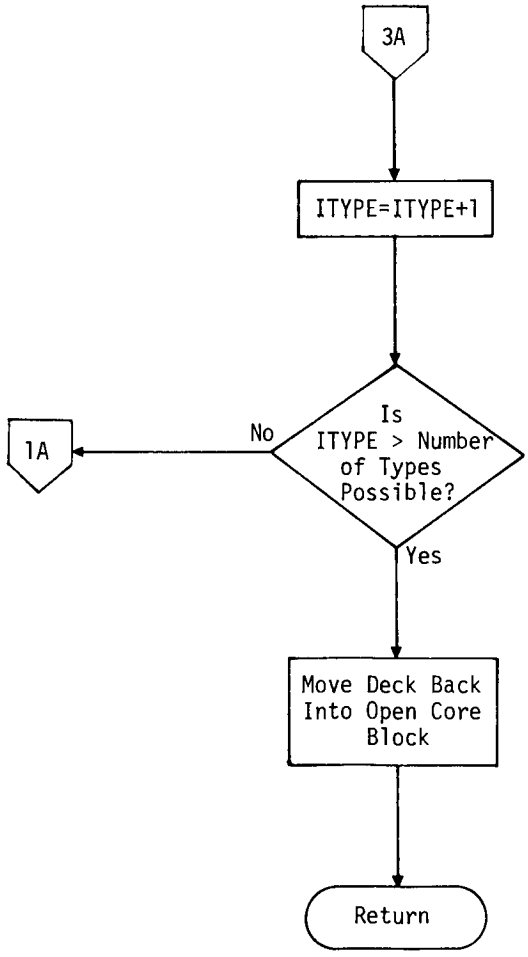


Figure 11(c). Flowchart for REØRDR.

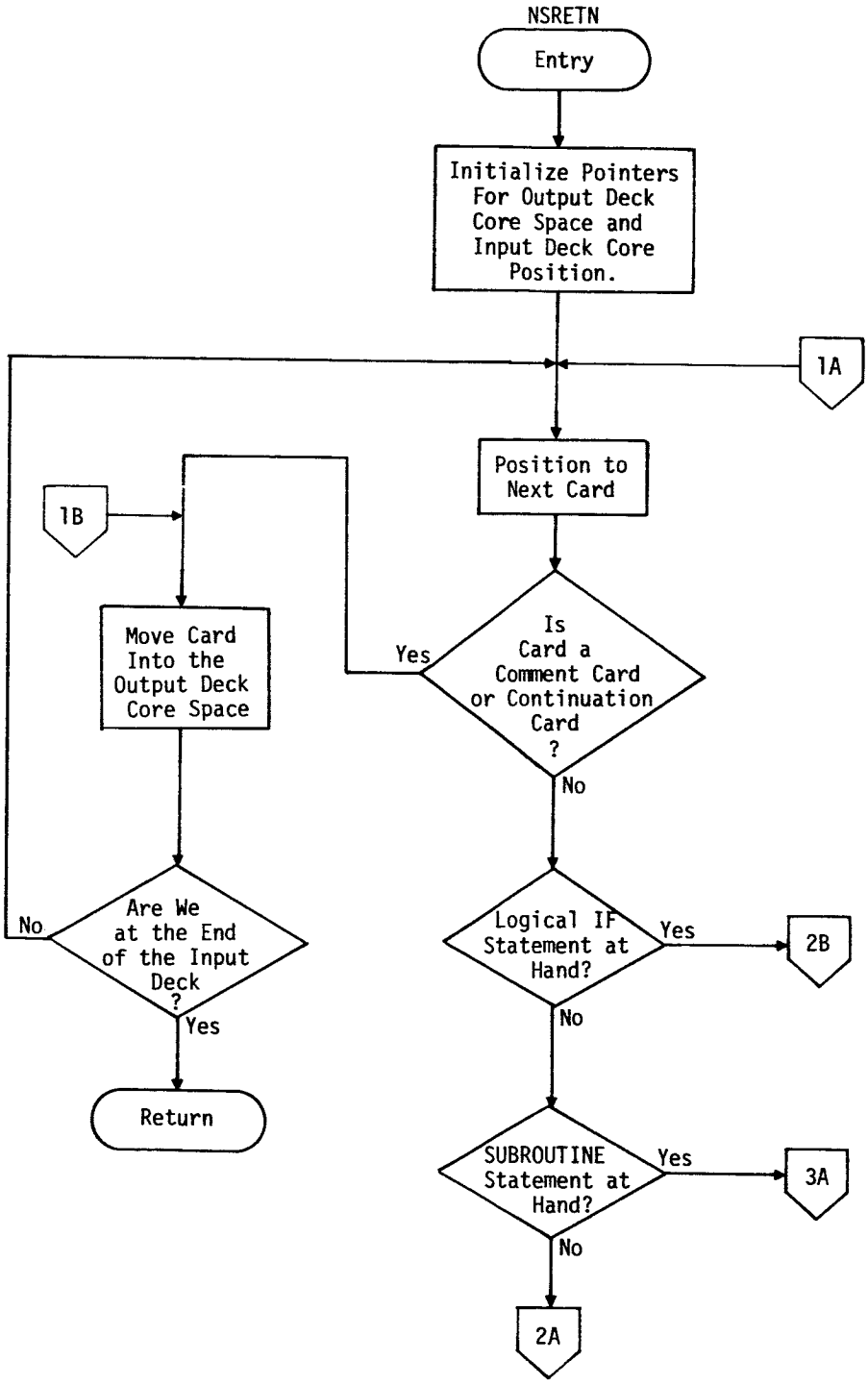


Figure 12(a). Flowchart for NSRETN.

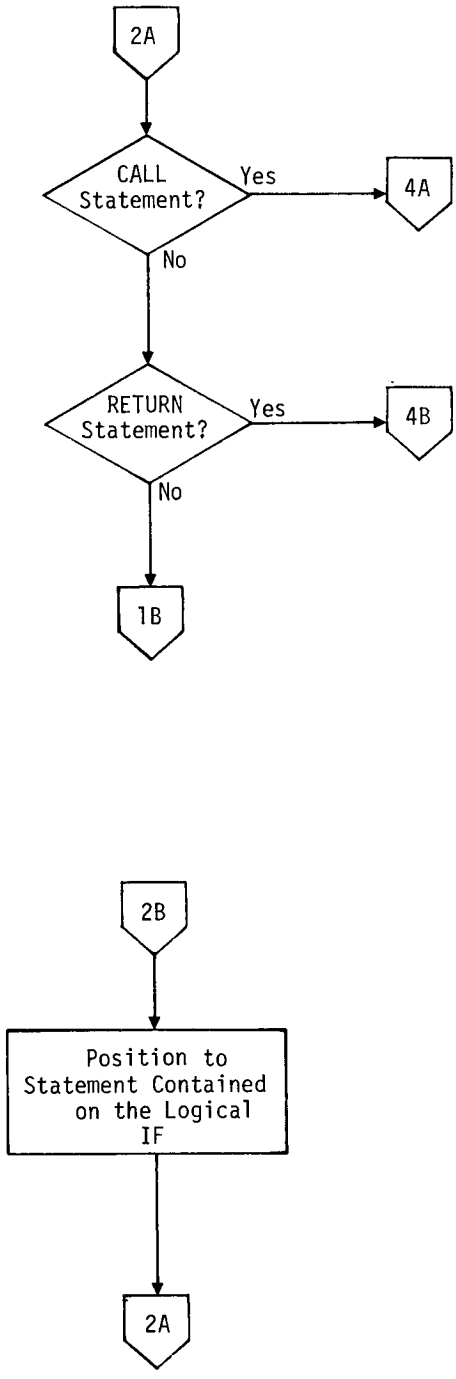


Figure 12(b). Flowchart for NSRETN.

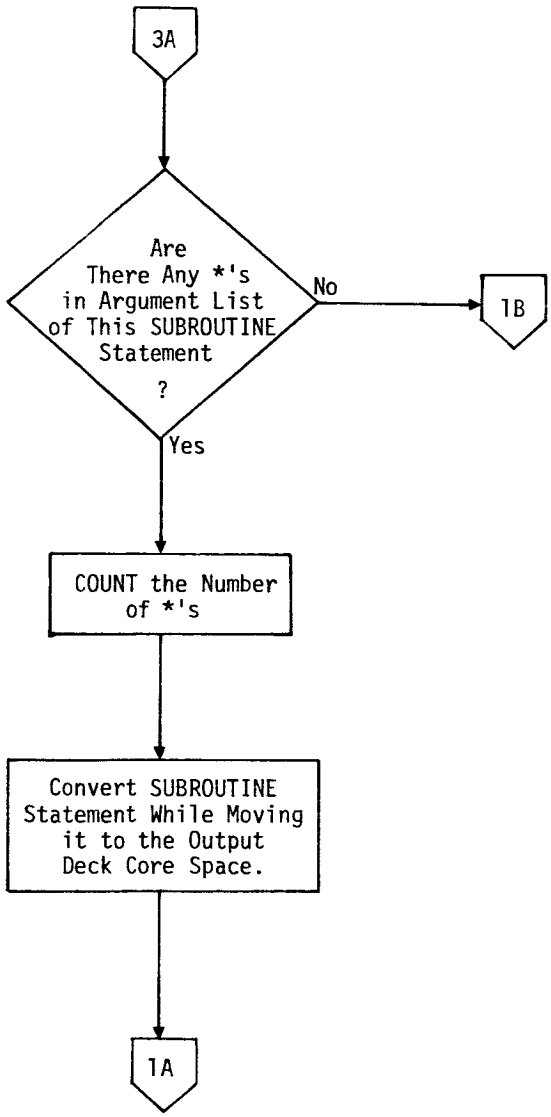


Figure 12(c). Flowchart for NSRETN.

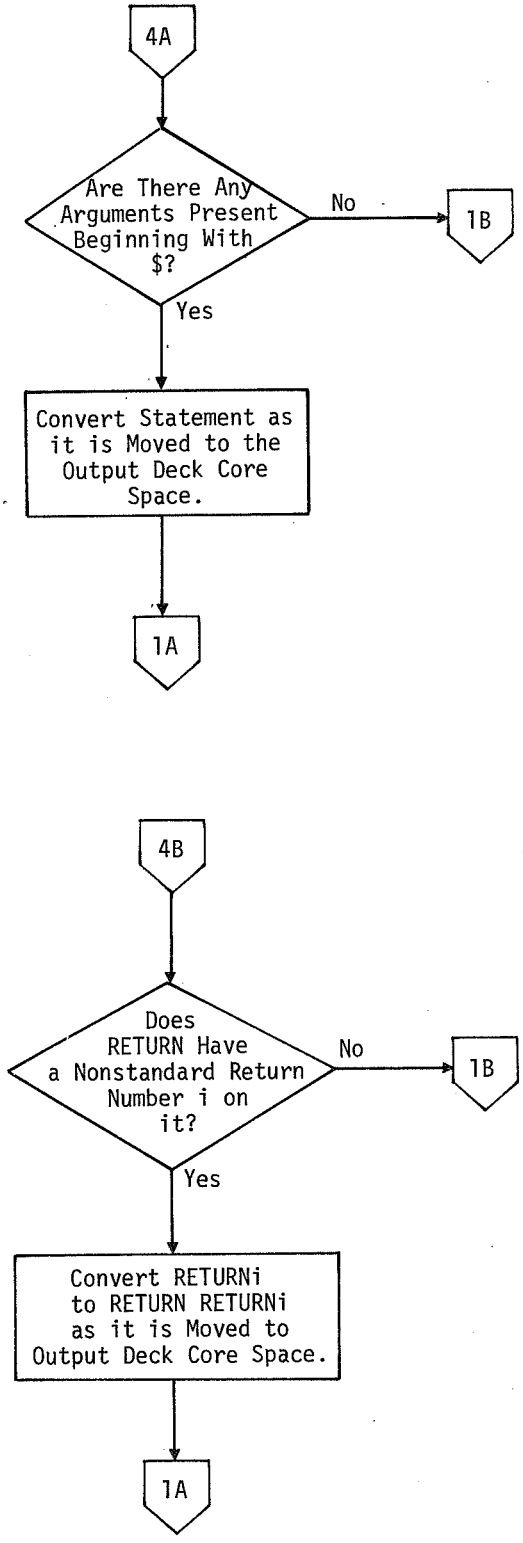


Figure 12(d). Flowchart for NSRETN.