NASA SP-222(08)
VOLUME II

NASTRAN® USER'S MANUAL

JUNE 1986

NASA

NASA SP-222(08)
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June 1986

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INTRODUCTION

The User's Manual is one of four manuals that constitute the documentation for NASTRAN, the other three being the Theoretical Manual, the Programmer's Manual and the Demonstration Problem Manual. Although the User's Manual contains all of the information that is directly associated with the solution of problems with NASTRAN, the user will find it desirable to refer to the other manuals for assistance in the solution of specific user problems.

The Theoretical Manual gives an excellent introduction to NASTRAN and presents developments of the analytical and numerical procedures that underlie the program. The User's Manual is instructive and encyclopedic in nature, but is restricted to those items related to the use of NASTRAN that are generally independent of the computing system being used. Computer-dependent topics and information that is required for the maintenance and modification of the program are treated in the Programmer's Manual. The Programmer's Manual also provides a complete description of the program, including the mathematical equations implemented in the code. The Demonstration Problem Manual presents a discussion of the sample problems delivered with NASTRAN, thereby illustrating the formulation of the different types of problems that can be solved with NASTRAN.

In addition to the four manuals described above, there is also a NASTRAN User's Guide that serves as a handbook for users. It describes all of the NASTRAN features and options and illustrates them by examples. Other excellent sources for NASTRAN-related topics are the proceedings of the NASTRAN Users' Colloquia (held normally every year) which provide a large body of information based on user experiences with NASTRAN.

The User's Manual has recently been completely revised and updated. With a view to facilitate easier updating of the manual in the future to keep up with newer releases of NASTRAN, it has now been divided into two volumes.

Volume I consists of seven sections and contains all of the material that was in the old single volume, except Section 3. This section has been re-arranged into four sections and forms Volume II. In order to avoid confusion, Section 3 of Volume I does not contain anything other than a reference to the new Volume II. Also, it should be noted here that, unless explicitly indicated otherwise, all references to sections in each volume refer only to sections in that volume.

NASTRAN uses the finite element approach to structural modeling, wherein the distributed physical properties of a structure are represented by a finite number of structural elements which are interconnected at a finite number of grid points, to which loads are applied and for which displacements are calculated. The procedures for defining and loading a structural model are

described in Volume I, Section 1. This section contains a functional reference for every card that is used for structural modeling.

The NASTRAN Data Deck, including the details for each of the data cards, is described in Volume I, Section 2. This section also discusses the NASTRAN control cards that are associated with the use of the program.

As mentioned earlier, Volume I, Section 3 does not contain anything other than a reference to Volume II.

The procedures for using the NASTRAN plotting capability are described in Volume I, Section 4. Both deformed and undeformed plots of the structural model are available. Response curves are also available for static, transient response, frequency response, modal flutter and modal aeroelastic response analyses.

NASTRAN contains problem solution sequences, called rigid formats. Each of these rigid formats is associated with the solution of problems for a particular type of static or dynamic analysis. In addition to the rigid format procedures, the user may choose to write his own Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The rules governing the creation of DMAP programs are described in Volume I, Section 5.

The NASTRAN diagnostic messages are documented and explained in Volume I, Section 6. The NASTRAN Dictionary, in Volume I, Section 7, contains descriptions of mnemonics, acronyms, phrases, and other commonly used NASTRAN terms.

Volume II, Section 1 contains a general description of rigid format procedures. Specific instructions and information for the use of each rigid format are given in Volume II, Sections 2, 3 and 4, which deal with the rigid formats associated with the DISPLACEMENT, HEAT and AERØ approaches, respectively.

There is a limited number of sample problems included in the User's Manual. However, a more comprehensive set of demonstration problems, at least one for each of the rigid formats, is described in the NASTRAN Demonstration Problem Manual. The data decks are available on tape for each of the computer systems on which NASTRAN has been implemented. Samples of the printer output and of structure plots and response plots can be obtained by executing these demonstration problems. The printer output for these problems is also available on microfiche.

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1.1 GENERAL DESCRIPTION OF RIGID FORMATS

The most general way of using NASTRAN is with a user-written Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The user may even choose to write a module of his own. The rules governing all of these operations are described in Volume I, Section 5.

In order to relieve the user of the necessity of constructing a DMAP sequence for each of his problems, a number of such sequences, called rigid formats, have been included with NASTRAN. All of these rigid formats are resident on a data base called the Rigid Format Data Base, which is described in detail in Section 1.1.7. Each rigid format in this data base consists of a DMAP sequence and the associated restart tables. These restart tables are automatically used by the program to modify the series of DMAP operations to account for any changes that are made in any part of the Data Deck when making a restart, after having previously run all, or a part, of the problem. Without such tables, the user would have to carefully modify his DMAP sequence to account for the conditions surrounding each restart. The chances for error in making these modifications for restart are very great. The restart tables not only relieve the user of the burden of modifying his DMAP sequence, but also assure him of a correct and efficient program execution.

In addition to the DMAP sequence provided with each rigid format, a number of options are available, which are subsets of each complete DMAP sequence. Subsets are selected by specifying the subset numbers (zero for the complete DMAP sequence) along with the rigid format number on the SØL card in the Executive Control Deck. See the description of the SØL card in Volume I, Section 2.2 for the list of available subsets.

If the user wishes to modify the DMAP sequence of a rigid format in some manner not provided for in the available subsets, he can use the ALTER feature described in Section 2.2. Typical uses are to schedule an EXIT prior to completion, in order to check intermediate output, schedule the printing of a table or a matrix for diagnostic purposes, and to delete or add a functional module to the DMAP sequence. (The manner in which DMAP ALTERs are handled in restarts is discussed in Section 1.1.5.) The user should be familiar with the rules for DMAP programming, as described in Volume I, Section 5, prior to making ALTERs to a rigid format.

The following rigid formats for structural analysis are currently included in NASTRAN:

1. Static Analysis

2. Static Analysis with Inertia Relief
3. Normal Modes Analysis
4. Static Analysis with Differential Stiffness
5. Buckling Analysis
6. Piecewise Linear Static Analysis
7. Direct Complex Eigenvalue Analysis
8. Direct Frequency and Random Response
9. Direct Transient Response
10. Modal Complex Eigenvalue Analysis
11. Modal Frequency and Random Response
12. Modal Transient Response
13. Normal Modes Analysis with Differential Stiffness
14. Static Analysis with Cyclic Symmetry
15. Normal Modes Analysis with Cyclic Symmetry
16. Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following rigid formats for heat transfer analysis are included in NASTRAN:

1. Linear Static Heat Transfer Analysis
3. Nonlinear Static Heat Transfer Analysis
9. Transient Heat Transfer Analysis

The following rigid formats for aeroelastic analysis are included in NASTRAN:

9. Blade Cyclic Modal Flutter Analysis
10. Modal Flutter Analysis
11. Modal Aeroelastic Response

1.1.1 Input File Processor

The Input File Processor operates in the Preface prior to the execution of the DMAP operations in the rigid format. A complete description of the operations in the Preface is given in the Programmer's Manual. The main interest here is to indicate the source of data blocks that are created in the Preface and hence appear only as inputs in the DMAP sequences of the rigid formats. None of the data blocks created by the Input File Processor are checkpointed, as they are always regenerated on restart. The Input File Processor is divided into five parts. The first part (IFP1) processes the Case Control Deck, the second part (IFP) processes the Bulk Data Deck,

the third part (IFP3) performs additional processing of the bulk data cards associated with the conical shell element, and the fourth part (IFP4) performs additional processing of the bulk data cards associated with the fluid element. The fifth section (IFP5) processes data related to acoustic cavity analysis.

IFP1 processes the Case Control Deck and creates the Case Control Data Block (CASECC), the Plot Control Data Block (PCDB), and the XY-Plot Control Data Block (XYCDB). IFP1 also examines all of the cards, except those associated with plotting, for errors in format or use. If errors are detected, they are classed as either fatal or warning, and suitable error messages are provided. Reference to Volume I, Section 2.3 will assist the user in correcting errors in the Case Control Deck. If the error is fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface.

The Bulk Data Deck is sorted in the Preface, if necessary, before the execution of the second part of the Input File Processor. IFP checks all of the bulk data cards for errors according to the rules given for each card in Volume I, Section 2.4. If errors are detected, suitable messages are provided to the user. If the error is classed as fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface. IFP creates the data blocks that are input to the various part of the Geometry Processor (GEØM1, GEØM2, GEØM3 and GEØM4), the Element Properties Table (EPT), the Material Properties Table (MPT), the Element Deformation Table (EDT), and the Direct Input Table (DIT).

The third part of the Input File Processor (IFP3) converts the information on the special conical shell cards (CCØNEAX, CTRAPAX, CTRIAAX, FØRCEAX, MØMAX, MPCAX, ØMITAX, PCØNEAX, PØINTAX, PRESAX, PTRAPAX, PTRIAAX, RINGAX, SECTAX, SPCAX, SUPAX, and TEMPAX) to reflect the number of harmonics specified by the user on the AXIC card. This converted information is added to any existing information on data blocks GEØM1, GEØM2, GEØM3 and GEØM4.

The fourth part of the input file processor (IFP4) converts the information on the fluid-related cards (AXIF, BDYLIST, CFLUID2, CFLUID3, CFLUID4, DMIAX, FLSYM, FREEPT, FSLIST, GRIDB, PRESPT, and RINGFL) to reflect the desired harmonics, boundaries, and matrix input. This converted information is added to GEØM1, GEØM2, GEØM4 and MATPØØL.

The fifth part of the input file processor (IFP5) converts the information on the acoustic cavity related cards (AXSLØT, CAXIF2, CAXIF3, CAXIF4, CSLØT3, CSLØT4, GRIDF, GRIDS, and SLBDY) to equivalent structural scalar points, elements, scalar springs and plotting elements. This converted information is added to the GEØM1 and GEØM2 data blocks.

1.1.2 Functional Modules and Supporting DMAP Operations

The DMAP listings of the rigid formats currently included with NASTRAN are presented in the following sections. Following each listing are subsections that deal with the following items for each rigid format:

1. Brief description of important DMAP operations for the rigid format
2. Output available from the rigid format
3. Case Control Deck setup for the rigid format
4. Parameters used in the rigid format
5. Automatic ALTERs for Automated Multi-Stage Substructuring (if applicable to the rigid format)
6. Rigid format error messages
7. Any other features peculiar to the rigid format

Descriptions of all major functional modules are given in the Programmer's Manual. Additional information is also given in the Theoretical Manual. Descriptions of all other NASTRAN modules are given in Volume I, Section 5.

The modules in the following list appear repeatedly in the rigid formats. Since the purpose of these operations in a rigid format is obvious, they are generally omitted from the descriptions of the DMAP operations in the following sections. More complete descriptions of these modules are given in Volume I, Section 5.

1. BEGIN indicates the beginning of the DMAP sequence constituting the rigid format.
2. END indicates the end of the DMAP sequence constituting the rigid format and causes a normal termination when executed.
3. FILE makes declarations relative to a particular file.

   ABC = TAPE states that file ABC will be assigned as a sequential file.

   DEF = APPEND states that file DEF may be extended as the result of an internal loop in the rigid format.

   GHI = SAVE states that file GHI should not be dropped after use as it may be needed for subsequent executions of an internal loop.
4. LABEL specifies a labeled point in the sequence of DMAP instructions. Labels are referenced by REPT, JUMP and CØND instructions.
5. PARAM performs specified operations on integer DMAP parameters.
6. PRECHK actuates the automatic generation of explicit CHKPNT instructions. (PRECHK ALL immediately and automatically CHKPNTs all output data blocks from each functional module, all data blocks mentioned in each PURGE instruction and all secondary data blocks in each EQUIV instruction.)* The CHKPNT instruction specifies a list of files to be written on

* The only exceptions to this are the CASESS, CASEI and CASECC data blocks appearing as output in substructure analyses.

the new problem tape (NPTP), including files that may have been purged, either because they were not generated in this particular execution or were explicitly purged with a PURGE instruction.

7. PURGE specifies the names of files that are conditionally dropped based on the parameter named.

1.1.3 Checkpoint/Restart Procedures

The checkpoint/restart feature available in NASTRAN is a very sophisticated and useful capability. The purpose of this feature is to enable a user to checkpoint a NASTRAN run and then restart it (with or without changes in data) by executing only those modules that need to be executed for the restart.

There are several situations in which the use of the checkpoint/restart feature may be desirable. Some of these are listed below:

1. The user may wish to perform his analysis task in two or more stages by specifying scheduled exits in one or more runs.
2. The user may want to ensure that unscheduled exits (resulting from such causes as data errors, insufficient time, insufficient core or hardware failures) will not require him to repeat his entire analysis.
3. The user may wish to rerun his problem by making limited changes in his data.

Scheduled exits can be requested at any point in a rigid format by means of the ALTER feature. (The manner in which ALTERs are handled in restarts is discussed in Section 1.1.5). An exit is scheduled by inserting the following cards in the Executive Control Deck:

```
ALTER        K1  $
EXIT         K2  $
ENDALTER         $
```

where K1 = DMAP statement number after which exit will take place

and K2 = Number of times EXIT instruction will be skipped before being executed - default is zero. For use with loops, where the user wishes to execute the loop K2 times before scheduling the exit.

If the user chooses to restart the problem without making any changes, the Executive System will execute an unmodified restart following the last completed checkpoint.

Unscheduled exits are usually caused by errors on input cards or errors in the structural model resulting from missing or inconsistent input data. When such errors are detected, an unscheduled exit is performed accompanied with the output of the applicable user error messages. Following the correction of the input data errors, a modified restart can be performed.

Unscheduled exits may also occur because of machine failure or insufficient time allowance. In these cases, an unmodified restart is usually made following the last completed checkpoint. In some cases, where a portion of the problem has been completed, including the output for the completed portion, a modified restart must be made following an unscheduled exit due to insufficient time allowance. These situations are discussed under Case Control Deck requirements in the sections dealing with the individual rigid formats.

The initial execution of any problem must be made with a complete NASTRAN Data Deck, including all of the bulk data. However, all or part of the bulk data may be assembled from alternate input sources, such as the User's Master File or a module written by the user to generate input. The User's Master File is described in Volume I, Section 2.5 and user generated input is discussed in Volume I, Section 2.6.

For restarts, the Bulk Data Deck consists only of delete cards (see Volume I, Section 2.4) and new cards which the user wishes to add. The previous Bulk Data Deck is read from the Old Problem Tape. All other parts of the NASTRAN Data Deck, including the Executive Control Deck, the Case Control Deck, the BEGIN BULK card and the ENDDATA card must be resubmitted even though no changes are made in the control decks and no new bulk data is added. In addition, the RESTART cards (or dictionary) punched during the previous execution must be included in the Executive Control Deck. When changing rigid formats, the solution number (SØL) must be changed to the number of the new rigid format.

A New Problem Tape (NPTP) is constructed only when checkpointing is requested (CHKPNT YES) in the Executive Control Deck. The NPTP should be assigned to a physical tape or other storage device that can be dismounted and saved at the conclusion of the execution. At the completion of an initial execution, the NPTP contains the input deck, with the bulk data in sorted form, and all of the files that were checkpointed during the execution.

For restarts, the Old Problem Tape (ØPTP) is defined as the Problem Tape that was written during the previous execution. The NPTP is defined as the Problem Tape written during the current execution, beginning with the restart. At the completion of an unmodified restart, the NPTP contains the input deck, with the bulk data in sorted form, all files from the ØPTP that are necessary to complete the solution, and all of the files checkpointed during the current execution. At the completion of a modified restart, the NPTP is similar, except that the input deck is modified according to the information submitted for the restart.

1.1.4 Types of Restarts

The type of a restart is determined automatically by the program by comparing the input data of the restart run with that of the checkpoint run. The user need not be concerned about the manner in which this is done, but may be interested in knowing the resulting type.

The types of restarts presently recognized in NASTRAN are summarized in the following table.

Types of Restarts in NASTRAN

Restart data compared to checkpoint data	Resulting type of restart	Applicable environment	
		Rigid format	DMAP
No effective changes	Unmodified restart	Yes	Yes
Effective changes only to the Case Control Deck and/or the Bulk Data Deck	Modified restart	Yes	Yes
Change in rigid format	Modified restart with rigid format switch	Yes	No

In earlier versions of NASTRAN, an additional type of restart, called the pseudo modified restart, was recognized for cases involving changes only in output requests. This is no longer done since it is now handled as a special case of the modified restart.

The manner in which a restart is handled by the program depends on its type and on its environment (rigid format or DMAP environment). This is discussed in the following sections.

An important term that is frequently encountered in the following discussion is the reentry point for a restart. This is defined as the last reentry point specified in the restart dictionary. It is an integer equal to the instruction number of the DMAP instruction in the checkpoint run at which an unmodified restart will resume execution. (See Volume I, Section 2.2.)

1.1.4.1 Unmodified Restart

An unmodified restart involves no effective changes to the data. The execution in this type of restart resumes at the reentry point. Unmodified restarts in both rigid format and DMAP environments are handled in an identical manner.

It is useful to distinguish between two types of unmodified restarts. These are described below.

- Unmodified restart in which the reentry point is not within a DMAP loop

This is the simplest type of restart possible. In this case, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. All input files or data blocks required for the restart already exist on the ØPTP and will be retrieved.

- Unmodified restart in which the reentry point is within a DMAP loop.

In this case, initially, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. This is so indicated in the DMAP source listing. However, subsequently, the DMAP instructions prior to the reentry point and within the DMAP loop are recognized and their execution flags are turned on. The user is informed about this in the output. Note, however, that the execution does resume at the reentry point, even though DMAP instructions prior to this point are turned on. DMAP instructions within the DMAP loop and prior to the reentry point are executed only if additional passes in the loop need to be executed. If the restart is within the last pass of the DMAP loop, obviously DMAP instructions within the loop and prior to the reentry point are not executed even though their execution flags are on.

All input files or data blocks required by the restart already exist on the ØPTP and will be retrieved.

1.1.4.2 Modified Restart

This type of restart involves one or more effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The heart of the restart logic for modified restarts in the rigid format environment is the Module Execution Decision Table (MEDT) associated with each rigid format. The MEDT for each rigid format actually comprises three distinct tables. These are the Card Name Restart Table, the Rigid Format Change Restart Table and the File Name Restart Table associated with that rigid format. (See discussion in Section 1.1.7. See also Sections 1.10 and 7 of the Programmer's Manual.)

In the case of modified restarts in the rigid format environment, all DMAP instructions from the reentry points onwards have their execution flags turned on. In addition, this type of restart generally requires that certain DMAP instructions prior to the reentry point also be turned on, depending on the specific data changes involved. The DMAP instructions that need to be so turned on are determined from the Card Name Restart Table. The DMAP source listing provided in the output indicates all the DMAP instructions whose execution flags are initially turned on by the above procedure.

Once the DMAP instructions are initially turned on as described above, the program checks to see if all of the required input data blocks are either being generated by prior modules or are available on the ØPTP for retrieval. If so, no additional DMAP instructions need to be turned on. If, however, there are any input data blocks that are neither being generated by prior modules nor are available on the ØPTP, the program needs to turn on additional DMAP instructions in order to generate the required data blocks. The DMAP instructions that need to be so turned on are determined from the File Name Restart Table.

After the additional DMAP instructions are turned on as described in the above paragraph, the process is repeated until it is ensured that all of the required input data blocks are either being generated by prior modules or can be retrieved from ØPTP.

All the DMAP instructions that are turned on as per the above logic (by the use of the File Name Restart Table) are identified and listed in the restart output just after the DMAP source listing.

It should be noted that the execution in a modified restart will start at the first module in the DMAP sequence whose execution flag is turned on. Generally, this is before the reentry point.

In the case of modified restarts in the DMAP environment, the effect of changes in the Case Control Deck and/or in the Bulk Data Deck on particular modules cannot be determined since the DMAP itself is, by definition, not predefined. (An MEDT is meaningless for a DMAP.) Hence, it is assumed that the changes will affect the entire DMAP which, therefore, needs to be re-executed. This is accomplished in the program by re-setting the reentry point to zero and treating this case as an unmodified restart. This causes the entire DMAP to be re-executed.

Those input files or data blocks that are needed for the restart and that are available on the ØPTP are retrieved, just as it is done in the case of modified restarts in the rigid format environment.

1.1.4.3 Modified Restart with Rigid Format Switch

This type of restart involves a switch from one rigid format to another. It may or may not involve effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The most important point to recognize in this type of restart is that the reentry point is quite meaningless since it was determined in relation to another rigid format. This is handled in the program by resetting the reentry point to an extremely high value which, for all practical purposes, can be considered to be infinite. As a result, all DMAP instructions in the restart are considered to be before the reentry point and no DMAP instructions are considered to exist after the reentry point.

Once this important change is made, this type of restart is handled in the program in the same manner as a modified restart, with one important modification: the DMAP instructions that are initially turned on are determined not only from the Card Name Restart Table, but also from the Rigid Format Change Restart Table.

1.1.5 Use of DMAP ALTERs in Restarts

Because different types of restarts are handled differently by the program, the user should be careful in the use of DMAP ALTERs in restarts.

In the case of an unmodified restart in which the reentry point is not within a DMAP loop, the only DMAP instructions that are flagged for execution are those that are beyond (and include) the reentry point. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point and will be ignored if it is before the reentry point.*

In the case of an unmodified restart in which the reentry point is within a DMAP loop, the only DMAP instructions flagged for execution are those that are beyond (and include) the reentry point and those that are before the reentry point but within the DMAP loop. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point or before it but within the DMAP loop. Otherwise, it will be ignored.*

* The user can ensure that a DMAP ALTER in an unmodified restart is flagged for execution by suitably deleting the latter part of the restart dictionary so that the reentry point is before the DMAP ALTER. This, of course, will cause more modules to be executed in the restart.

In the case of a modified restart and a modified restart with rigid format switch, a DMAP ALTER will be flagged for execution regardless of its position in the DMAP with respect to the reentry point.

1.1.6 Rigid Format Output

Although most of the rigid format output is optional, some of the printer output is automatic. The printer output is designed for 132 characters per line, with the lines per page controlled by the NLINES keyword on the NASTRAN card (see Volume I, Section 2.1) and the LINE card in the Case Control Deck (see Volume I, Section 2.3). The NLINES and LINE default is set to fit on 11-inch paper. Optional titles are printed at the top of each page from information in the Case Control Deck. These titles may be defined at the subcase level. The pages are automatically dated and numbered.

The output from the data recovery and plot modules is all optional, and its selection is controlled by cards in the Case Control Deck. The details of making selections in the Case Control Deck are described in Volume I, Section 2.3 for printer and punch output, and in Volume I, Section 4 for plotter output. Since the outputs from the data recovery and plot modules vary considerably with the rigid format, a list of available output is included in the section on the Case Control Deck for each rigid format. Information on the force and stress output available for each element type is given in Volume I, Section 1.3.

The first part of the output for a NASTRAN run is prepared during the execution of the Preface, prior to the beginning of the DMAP sequence of the rigid format. The following output is either automatically or optionally provided during the execution of the Preface:

1. NASTRAN title page - Two full pages automatic, unless changed with the TITLEØPT keyword on the NASTRAN card (see Volume I, Section 2.1) before the Executive Control Deck.
2. Executive Control Deck echo - Automatic.
3. Case Control Deck echo - Automatic.
4. Unsorted Bulk Data Deck echo - Optional, selected in Case Control Deck with the ECHØ Card. (Automatic in restart runs and in runs employing the User's Master File, unless suppressed in the Case Control Deck with the ECHØ card.)
5. Sorted Bulk Data Deck echo - Automatic, unless suppressed in the Case Control Deck with the ECHØ Card.
6. DMAP listing - Selected with DIAG 14 (or the LIST option on an XDMAP card) in the Executive Control Deck. Provides the list of DMAP instructions, including those resulting from ALTERs, for the subset of the rigid format being executed. (Automatic in restart runs and in runs using the DMAP approach (APP DMAP) or the substructure capability (APP DISP, SUBS), unless suppressed by the NØLIST option on an XDMAP card in the Executive Control Deck.)

7. Checkpoint Dictionary - Automatic, when operating in the checkpoint mode. A printed echo (unless suppressed with the DIAG 9 card in the Executive Control Deck) and punched output are prepared for additions to the checkpoint dictionary after the execution of each checkpoint.

When making restarts, the following additional output is automatically prepared during the execution of the Preface:

1. Asterisks (*) are placed beside the DMAP statement numbers of all instructions that are flagged for execution in the restart. (It should be emphasized that a DMAP instruction marked with the symbol * is only flagged for execution; whether it actually gets executed or not is decided by the logic in the DMAP.)

2. Pluses (+) are placed beside the DMAP statement numbers of all instructions that are processed only at DMAP compilation time. (DMAP instructions BEGIN, CØMPØFF, CØMPØN, FILE, LABEL, PRECHK and XDMAP are the only instructions that belong to this category.)

3. Message indicating the bit position activated by a rigid format change.

4. Message indicating the type of restart (unmodified, modified or modified with rigid format switch).

5. Table indicating, among other things, the effective data changes (if any) and the associated "packed bit positions" that control the restart. The table distinguishes between effective changes made to the Case Control Deck and those made to the Bulk Data Deck. The reader is referred to the Programmer's Manual for the full interpretation of this table.

6. List of files along with the DMAP instructions that were marked for execution (if any) by the File Name Restart Table.

7. List of files from the Old Problem Tape, including purged files, used to initiate the restart.

A number of fatal errors are detected by the DMAP statements in the various rigid formats. These messages indicate the presence of fatal user errors that either cannot be determined by the functional modules or can be more effectively detected by the DMAP statements in the rigid format. The detection of such an error causes a transfer to a LABEL instruction near the end of the rigid format. The text of the message is output and the execution is terminated. These messages will always appear at the end of the NASTRAN output. The messages applicable to each rigid format are described under the description of that rigid format.

NASTRAN diagnostic messages are usually identified by numbers. These messages may be either program diagnostics or user diagnostics, and they may contain information, warnings, or an indication of a fatal error. There are also a few unnumbered, self-explanatory messages, for example, the time that the execution of each functional module begins and ends.

The Grid Point Singularity Table (GPST) is automatically output following the execution of the Grid Point Singularity Processor (GPSP) if singularities remain in the stiffness matrix at the grid point level. This table contains all possible combinations of single-point constraints, in the global coordinate system, that can be used to remove the singularities. Entries in this table

should only be treated as warnings, because it cannot be determined at the grid point level whether or not the singularities are removed by other means, such as general elements or multipoint constraints. Further information on this matter is given in the Theoretical Manual.

Several items of output are discussed in other sections. Output that is not associated with all of the rigid formats is discussed in the sections treating the individual rigid formats. Some output is under the control of PARAM cards. These items are discussed in Volume I, Section 2.4 (PARAM card). The DIAG card is used to control the printing of some output. A list of the available output under DIAG control is given in the description of the Executive Control Deck in Volume I, Section 2.2.

Any of the matrices or tables that are prepared by the functional modules can be printed by using selected utility modules described in Volume I, Section 5.5. These utility modules can be scheduled at any point in a rigid format by using the ALTER feature. (See Section 1.1.5 for the manner in which ALTERs are handled in restarts.) In general, they should be scheduled immediately after the functional module that generates the table or matrix to be printed. Note that functional modules cannot be separated from a SAVE instruction. However, the user is cautioned to check the calling sequence for the utility module, in order to be certain that all required inputs have been generated prior to this point.

1.1.7 Rigid Format Data Base

As indicated earlier, the Rigid Format Data Base contains the DMAP sequences and other information for all of the rigid formats in NASTRAN. Its design allows for convenient maintenance of the existing rigid formats as well as the addition of new rigid formats. Editing of the data base may be done by using standard text editors provided on the host computer systems.

1.1.7.1 Design of the Data Base

The Rigid Format Data Base is a collection of all rigid formats available to the user in NASTRAN. Each Rigid Format is maintained as a separate card-image entry within the data base. The entry for each rigid format consists of three parts. The first part is the DMAP part. It contains the DMAP sequence for the rigid format, the DMAP sequence subset flags, the restart flags (card name, file name and rigid format switch restart flags) and the substructure DMAP ALTER control flags. The second part contains the card name table and the third part contains the file name table. The restart flags in the first part and the name tables comprising the second and third

parts are not processed by NASTRAN in non-restart runs. Similarly, the substructure control flags in the first part are not processed in non-substructure runs.

The format of the data base is free field. Each of the three parts in a rigid format entry is separated from the other parts by a "$*" card. The following fictitious example illustrates a rigid format entry in the data base.

```
APR.86
$$$$ THIS IS A CØMMENT
$$$$ ******************************************************
MØDULE1   IN1,IN2,/ØUT1,ØUT2//*PARM1* $
****SBST  1,3,9-12
****RFMT  188,200-201
****CARD  1-20,30,44
****FILE  100-104,110
****PHS1  I1
****PHS2  DB5
****PHS3  D7
$$$$ ******************************************************
MØDULE2   IN3,IN4/ØUT3/*PARM2* $
****CARD  1-40,45
****FILE  101,102
****PHS2  DE5
$$$$ ******************************************************
        .
        .
        .

$$$$
$*CARD NAME TABLE
$$$$
1       AXIC   AXIF   CELAS1   CELAS2
2       ADUM1  CDUM1  CRØD
        .
        .
        .
$$$$
$*FILE NAME TABLE
$$$$
94      SLT    GPTT
95      KGGX   GPST
        .
        .
        .
$*
```

The very first card of an entry identifies the release of NASTRAN with which the rigid format is associated. In this example, the rigid format is associated with the April 1986 release.

The "$*CARD" card separates the card name table from the DMAP part of the entry and the "$*FILE" card separates the file name table from the card name table. A "$*" card terminates the file name table and the rigid format entry.

Comment cards are identified in the data base by the "$$$$" identification in the first four columns of the field and control cards are identified by the "****" identification in the first four columns of the field.

Comment cards may be placed anywhere in the card name or file name tables (the second and third parts of a rigid format entry). However, comment cards have a required usage and serve a specific purpose in the DMAP part of a rigid format entry. In this part, a comment card is used to distinguish and separate a DMAP entry (that is, a DMAP statement and its associated control cards) from another DMAP entry. Hence, there must be at least one comment card separating a DMAP entry from the next DMAP entry. In the data base supplied with NASTRAN, a comment card with a trailing string of "*" is used for this purpose to serve as a cosmetic delineation between successive DMAP entries.

All DMAP statements must conform to the rules as specified in Volume I, Section 5.2. Any card in the DMAP part of a rigid format entry that does not begin with "$$$$" or "****" in the first four columns of the field is considered to be a DMAP statement or part of a DMAP statement.

Comment and control cards in a rigid format entry can extend up to 80 columns. However, DMAP cards can only extend up to 72 columns.

Control cards (that is, cards that begin with "****" in the first four columns of the field) are permitted only in the DMAP part of a rigid format entry. A control card must have any one of seven four-character names in columns five through eight. The permissible names are: SBST, RFMT, CARD, FILE, PHS1, PHS2 and PHS3. Control cards follow the corresponding DMAP statement in the entry and may be specified in any order.

The "SBST", "RFMT", "CARD" and "FILE" control cards contain sequences of numbers and/or ranges of numbers in ascending order represented by the use of a dash. A comma is required after each number in a sequence or after a range of numbers, if an additional number or range of numbers is to follow. There may be multiple cards for any one of these control cards for a specific DMAP statement.

The "SBST" control card provides DMAP sequence subset controls. If a user requests a given subset on the SØL card of a NASTRAN run and that number is in the sequence of numbers given on the "SBST" card, then the associated DMAP statement is deleted. The range of subset numbers is from 1 to 9 and each number is documented under the description of the SØL Executive Control card in Volume I, Section 2.2.

The "RFMT" control card is processed in restart runs and is applicable to cases where a rigid format switch has occurred. Each rigid format has a unique number assigned to it. For APPRØACH DISP, rigid formats 1 through 16 are assigned the numbers 187 through 202, respectively. For APPRØACH HEAT, rigid formats 1, 3 and 9 are assigned the numbers 207, 208 and 209, respectively.

For APPRØACH AERØ, rigid formats 9, 10 and 11 are assigned the numbers 216, 214 and 215, respectively. A DMAP statement is flagged for execution in a modified restart if the number associated with the rigid format that was used in the checkpointed run is listed in the sequence of numbers given on the "RFMT" card provided with the DMAP statement.

The "CARD" and "FILE" control cards provide restart information for changes that involve input data or files within the DMAP. For a given rigid format, every type of effective change in the Case Control and Bulk Data Decks and each output file (or data block) in the DMAP is assigned a number as defined in the card name and file name tables in the second and third parts of a rigid format entry. In a modified restart, if the number associated with an input data change or an affected file appears in the sequence of numbers given on the "CARD" or "FILE" cards, then the corresponding DMAP statement is flagged for execution in the restart run.

The information provided by all of the "CARD" control cards in a rigid format entry is collectively referred to as the Card Name Restart Table. Similarly, the information provided by all of the "FILE" and "RFMT" control cards in a rigid format entry is collectively referred to as the File Name Restart Table and the Rigid Format Change Restart Table, respectively. For a given rigid format, these three restart tables compose the Module Execution Decision Table (MEDT) of that rigid format.

The "PHS1", "PHS2" and "PHS3" control cards are used to indicate where substructure DMAP ALTERs are to be generated. The number following the "PHS" refers to the substructure phase number. These cards must have one of the following flags: "In", "Dn", "DBn" or "DEn". The "n" in these flags is an integer that refers to the subroutine governing the substructure run (subroutine ASCM01, ASCM05, ASCM07 or ASCM08) and must have the value "1" for Phase 1 cards, either the value "5" or "8" for Phase 2 cards, and either the value "1" or "7" for Phase 3 cards. The "I" in the "In" flag indicates that a DMAP ALTER is to be inserted after this DMAP statement. The "D" in the "Dn" flag indicates that this DMAP statement is to be deleted and possibly replaced by a DMAP ALTER. The "DB" in the "DBn" flag and the "DE" in the "DEn" flag indicate the beginning and the end of a group of contiguous DMAP statements that are to be deleted and possibly replaced by a DMAP ALTER. Users are cautioned to be very careful in making any changes to these substructure control cards because of their impact on the DMAP ALTERs automatically generated in substructure analyses. (The automated substructure capability is currently implemented only in rigid formats 1, 2, 3, 8 and 9, APPRØACH DISP.)

The card name and file name tables assign numbers to every type of effective change in the Case Control and Bulk Data Decks and to every output file (or data block) in the DMAP. Numbers 1 through 93 are allocated to card names and numbers 94 through 186 are allocated to file (or data block) names. This information is used subsequently to determine the DMAP statements to be flagged for execution in modified restarts. The format of these tables is free field. Each entry in these tables must have an integer number in the first field and a list of names in the remaining fields of the entry. All names are to be alphanumeric and may contain up to a maximum of eight characters. No name should appear twice in these tables. Comment cards may be freely used in these tables to facilitate readability.

1.1.7.2 Implementation of the Data Base

The Rigid Format Data Base is implemented differently on the CDC, DEC VAX, IBM and UNIVAC versions. On the CDC and DEC VAX versions, each rigid format entry is stored as a separate file. The local names of these files during a NASTRAN execution are: DISP1 through DISP16 for APPRØACH DISP; HEAT1, HEAT3 and HEAT9 for APPRØACH HEAT; AERØ9, AERØ10 and AERØ11 for APPRØACH AERØ. These same files are stored as members of a partitioned data set (PDS) on the IBM version and as elements of the *NASTRAN file on the UNIVAC version. The member and element names are exactly the same as the local file names on the CDC and DEC VAX versions. On the IBM version, the PDS containing the Rigid Format Data Base must be referred to by a Data Definition card, "DD", with the DDname of RFDATA. On the UNIVAC version, the *NASTRAN file is the file containing the NASTRAN program absolutes. (See References 1 and 2 for the formats of file names for the CDC and DEC VAX versions, respectively. See Reference 3 for the formats of DDnames and member names for the IBM version. See Reference 4 for the format of UNIVAC file names.)

1.1.7.3 Usage of the Data Base

The following examples illustrate the manner in which the Rigid Format Data Base is accessed and used on all of the four versions of NASTRAN.

CDC VERSION

```
/JØB.
.
.
GET,DISP1,DISP2,DISP3,DISP4,DISP5.
GET,DISP6,DISP7,DISP8,DISP9,DISP10.
GET,DISP11,DISP12,DISP13,DISP14,DISP15,DISP16.
```

```
GET,HEAT1,HEAT3,HEAT9,AERØ9,AERØ10,AERØ11.
RFL,220000.
REDUCE,-.
LINK1,INPUT,ØUTPUT,PUNCH,UT1.
/EØR
ID ....
.
.
ENDDATA
/EØF
```

DEC VAX VERSION

```
ASSIGN  DDB1:[NASDIR]DISP1.DT DISP1.
ASSIGN  DDB1:[NASDIR]DISP2.DT DISP2.
        .
        .
ASSIGN  DDB1:[NASDIR]HEAT1.DT HEAT1.
        .
        .
ASSIGN  DDB1:[NASDIR]AERØ11.DT AERØ11.
@DDB1:[NASDIR]NASTRAN   DEMØ.DT
```

IBM VERSION

```
//   EXEC   NASTRAN
//NS.RFDATA  DD  DSN=RIGID.FØRMAT.DATA,DISP=SHR
//NS.SYSIN   DD  *
ID ....
.
.
ENDDATA
//
```

UNIVAC VERSION

```
@ASG,A   *NASTRAN.
@XQT     *NASTRAN.LINK1
```

1.1.7.4 Development of User Rigid Formats

In addition to using COSMIC-supplied rigid formats, users may develop their own rigid formats, with restart capabilities included. Rigid formats developed by users must conform to the rules explained earlier and must be similar in content and structure to the COSMIC-supplied rigid formats. Each user-developed rigid format must reside as a separate file on the CDC and DEC VAX versions, as a member of a PDS on the IBM version and as a file or file.element on the UNIVAC version.

Before developing their own rigid formats, users are strongly advised to carefully study and examine the COSMIC-supplied rigid formats, particularly with regard to their use of control cards. The following important guidelines should help users in developing their own rigid formats.

1. The DMAP sequence of the user rigid format must be tested for its correctness and logic. This testing may be done either in a DMAP environment or in the environment of an existing rigid format by use of ALTERs.
2. The card name table (the second part of a rigid format entry) must be constructed by assigning numbers 1 through 93 for all types of Case Control and Bulk Data Deck changes that will affect the logic of the rigid format. Normally, those input data changes that have the same effect on the logic of the rigid format are assigned the same number.
3. The file name table (the third part of a rigid format entry) must be constructed by assigning numbers 94 through 186 for all files (or data blocks) that are output by the functional modules in the rigid format. Normally, all files (or data blocks) output from a given functional module are assigned the same number.
4. The DMAP part (the first part of a rigid format entry) must be constructed by following each statement in the DMAP sequence by the appropriate control cards and by ensuring that each DMAP entry (that is, a DMAP statement and its associated control cards) is separated from the next DMAP entry by at least one comment card.
5. A given DMAP statement must be followed by a "SBST" control card if that DMAP statement belongs to one or more of the DMAP subsets. These subset numbers must be specified on the "SBST" card. The acceptable subset numbers and their meanings are documented under the description of the SØL Executive Control card in Volume I, Section 2.2.
6. A "RFMT" control card must follow a DMAP statement if that DMAP instruction is to be flagged for execution on restart from a checkpoint of one of the COSMIC-supplied rigid formats. (It is not possible to have a restart in a COSMIC-supplied rigid format from a checkpoint of an user-developed rigid format.) This will be so if this DMAP instruction is not part of the DMAP sequence of the rigid format that was used in the checkpoint run. The "RFMT" control card must list the numbers of the appropriate COSMIC-supplied rigid formats (187 through 202 for rigid formats 1 through 16, respectively, for APPRØACH DISP; 207, 208 and 209 for rigid formats 1, 3 and 9, respectively, for APPRØACH HEAT; and 216, 214 and 215 for rigid formats 9, 10 and 11, respectively, for APPRØACH AERØ).
7. A DMAP statement must be followed by one or more "CARD" control cards indicating the effective input data changes that require that DMAP instruction to be flagged for execution on restart. Any effective input data change will affect one or more files (or data blocks) or parameters in the DMAP sequence. Therefore, for a given data change, all

DMAP instructions that use the affected files (or data blocks) or parameters as input are potential candidates to be flagged for execution on restart. However, the logic of these individual DMAP instructions must be checked further (see the Programmer's Manual) to see if they are really impacted by the given data change. This procedure must be applied in turn to those DMAP instructions that use the output of the affected DMAP instructions as input. This procedure must be repeated until the entire DMAP sequence has been considered.

8. A DMAP statement must be followed by one or more "FILE" control cards indicating the DMAP files (or data blocks) whose generation requires the execution flag for that DMAP statement to be turned on during restart. Normally, for a given DMAP file (or data block) that is required on restart but is not available from the checkpoint run, the DMAP instruction that generated it must be flagged for execution. However, in practice, additional DMAP instructions like PURGE and EQUIV that manipulate the given file (or data block) must also be flagged for execution.
9. The restart flags for a CØND DMAP instruction (and its companion LABEL DMAP instruction) must include the restart flags for those DMAP instructions whose execution it controls.
10. "PHS1", "PHS2" and "PHS3" control cards must not be used as the substructure capability is not applicable to user rigid formats.

1.1.7.5 Usage of User-Developed Rigid Formats

An user-developed rigid format is referenced through the use of the SØL card in the Executive Control Deck. However, instead of specifying the solution number or the name of the COSMIC-supplied rigid format on this card, the name of the user-developed rigid format is specified. This name is a file name on the CDC and DEC VAX versions, a member name of a PDS on the IBM version and a file or file.element name on the UNIVAC version. The member name given on the IBM version must be in the file referenced on the RFDATA DD statement. The manner in which an user-developed rigid format is accessed and used is similar to that of a COSMIC-supplied rigid format, as explained in the examples given Section 1.1.7.3. Thus, for instance, an user-developed rigid format can be accessed and used on the CDC version in the following manner.

```
/JØB.
.
.
GET,NEWRF.
RFL,220000.
```

```
REDUCE,-.
LINK1,INPUT,ØUTPUT,PUNCH,UT1.
/EØR
ID ....
SØL NEWRF
.
.
/EØF
```

REFERENCES

1. Control Data Corporation NOS 1.0 Reference Manual, Document No. 60435400.

2. VAX/VMS Command Language User's Guide, Digital Equipment Corporation, Order No. AA-D023C-TE.

3. IBM OS/VS2 MVS JCL, Document No. GC28-0692-4.

4. Sperry UNIVAC 1100 Series Executive System EXEC Programmer Reference, Volume 2, Document No. UP-4144.2.

2.1 STATIC ANALYSIS

2.1.1 DMAP Sequence for Static Analysis

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 01 - STATIC ANALYSIS - APR.86 $

    2  FILE     OPTP2=SAVE/EST1=SAVE $

    3  FILE     QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE $

    4  SETVAL   //V,Y,INTERACT/0/V,Y,SYS21/0 $

    5  PARAM    //*MPY*/CARDNO/0/0 $

    6  COMPOFF  1,INTERACT $

    7  PRECHK   ALL $

    8  COMPON   1,INTERACT $

   10  COMPOFF  LBLINT02,SYS21 $

   11  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/ALWAYS=-1 $

   12  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

   13  GP2      GEOM2,EQEXIN/ECT $

   14  PARAML   PCDB//*PRES*////JUMPPLOT $

   15  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   16  COND     P1,JUMPPLOT $

   17  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   18  PRTMSG   PLTSETX// $

   19  PARAM    //*MPY*/PLTFLG/1/1 $

   20  PARAM    //*MPY*/PFILE/0/0 $

   21  COND     P1,JUMPPLOT $

   22  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE  $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 23  PRTMSG   PLOTX1// $
 24  LABEL    P1 $
 25  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV/NEVER=1 $
 26  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $
 27  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
              LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
 28  PARAM    //*AND*/NOELMT/NOGENL/NOSIMP $
 29  COND     ERROR4,NOELMT $
 30  PURGE    KGGX,GPST/NOSIMP/OGPST/GENEL $
 31  OPTPR1   MPT,EPT,ECT,DIT,EST/OPTP1/S,N,PRINT/S,N,TSTART/S,N,COUNT $
 32  LABEL    LOOPTOP $
 33  COND     LBL1,NOSIMP $
 34  PARAM    //*ADD*/NOKGGX/1/0 $
 35  EQUIV    OPTP1,OPTP2/NEVER/EST,EST1/NEVER $
 36  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $
 37  COND     JMPKGG,NOKGGX $
 38  EMA      GPECT,KDICT,KELM/KGGX,GPST $
 39  LABEL    JMPKGG $
 40  PURGE    MGG/NOMGG $
 41  COND     JMPMGG,NOMGG $
 42  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 43  LABEL    JMPMGG $
 44  COND     LBL1,GRDPNT $
 45  COND     ERROR2,NOMGG $
 46  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 47  OFP       OGPWG,,,,,//S,N,CARDNO $

 48  LABEL     LBL1 $

 49  EQUIV     KGGX,KGG/NOGENL $

 50  COND      LBL11A,NOGENL $

 51  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 52  LABEL     LBL11A $

 53  PARAM     //*MPY*/NSKIP/0/0 $

 54  LABEL     LBL11 $

 55  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
               S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
               S,Y,AUTOSPC $

 56  COND      ERROR3,NOL $

 57  PARAM     //*AND*/NOSR/SINGLE/REACT $

 58  PURGE     KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
               KFS,KSS/SINGLE/QG/NOSR $

 59  COND      LBL4,GENEL $

 60  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $

 61  COND      LBL4,GPSPFLG $

 62  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $

 63  OFP       OGPST,,,,,//S,N,CARDNO $

 64  LABEL     LBL4 $

 65  EQUIV     KGG,KNN/MPCF1 $

 66  COND      LBL2,MPCF2 $

 67  MCE1      USET,RG/GM $

 68  MCE2      USET,GM,KGG,,,/KNN,,, $

 69  LABEL     LBL2 $

 70  EQUIV     KNN,KFF/SINGLE $

 71  COND      LBL3,SINGLE $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 72  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $

 73  LABEL    LBL3 $

 74  EQUIV    KFF,KAA/OMIT $

 75  COND     LBL5,OMIT $

 76  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

 77  LABEL    LBL5 $

 78  EQUIV    KAA,KLL/REACT $

 79  COND     LBL6,REACT $

 80  RBMG1    USET,KAA,/KLL,KLR,KRR,,, $

 81  LABEL    LBL6 $

 82  RBMG2    KLL/LLL $

 83  COND     LBL7,REACT $

 84  RBMG3    LLL,KLR,KRR/DM $

 85  LABEL    LBL7 $

 86  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/NSKIP $

 87  EQUIV    PG,PL/NOSET $

 88  COND     LBL10,NOSET $

 89  SSG2     USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $

 90  LABEL    LBL10 $

 91  SSG3     LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              NSKIP/S,N,EPSI $

 92  COND     LBL9,IRES $

 93  MATGPR   GPL,USET,SIL,RULV//*L* $

 94  MATGPR   GPL,USET,SIL,RUOV//*O* $

 95  LABEL    LBL9 $

 96  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/
              *STATICS* $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 97  COND     LBL8,REPEAT $

 98  REPT     LBL11,360 $

 99  JUMP     ERROR1 $

100  PARAM    //*NOT*/TEST/REPEAT $

101  COND     ERROR5,TEST $

102  LABEL    LBL8 $

103  GPFDR    CASECC,UGV,KELM,KDICT,ECT,EQEXIN,GPECT,PGG,QG/ONRGY1,OGPFB1/
              *STATICS* $

104  OFP      ONRGY1,OGPFB1,,,,//S,N,CARDNO $

105  COND     NOMPCF,GRDEQ $

106  EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/
              OQM1/V,Y,OPT=0/V,Y,GRDEQ/NSKIP $

107  OFP      OQM1,,,,,//S,N,CARDNO $

108  LABEL    NOMPCF $

109  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,
              XYCDB,PGG/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS*/S,N,
              NOSORT2/-1/S,N,STRNFLG $

110  COND     LBLSTRS,STRESS $

111  CURV     OES1,MPT,CSTM,EST,SIL,GPL/OES1M,OES1G/V,Y,STRESS/
              V,Y,NINTPTS $

112  LABEL    LBLSTRS $

113  PURGE    OES1M/STRESS $

114  COND     LBLSTRN,STRNFLG $

115  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST,,/
              ,,,OES1A,,/*STATICS*//1 $

116  COND     LBLSTRN,STRAIN $

117  CURV     OES1A,MPT,CSTM,EST,SIL,GPL/OES1AM,OES1AG/V,Y,STRAIN/
              V,Y,NINTPTS $

118  LABEL    LBLSTRN $

119  PURGE    OES1A/STRNFLG $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


120  COND      LBL17,NOSORT2 $

121  SDR3      OUGV1,OPG1,OQG1,OEF1,OES1,/OUGV2,OPG2,OQG2,OEF2,OES2, $

122  PARAM     //*SUB*/PRTSORT2/NOSORT2/1 $

123  COND      LBLSORT1,PRTSORT2 $

124  OFP       OUGV2,OPG2,OQG2,OEF2,OES2,//S,N,CARDNO $

125  SCAN      CASECC,OES2,OEF2/OESF2/*RF* $

126  OFP       OESF2,,,,,//S,N,CARDNO $

127  JUMP      LBLXYPLT $

128  LABEL     LBLSORT1 $

129  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $

130  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $

131  OFP       OESF1,,,,,//S,N,CARDNO $

132  LABEL     LBLXYPLT $

133  OFP       OES1M,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $

134  XYTRAN    XYCDB,OPG2,OQG2,OUGV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/S,N,
               PFILE/S,N,CARDNO $

135  XYPLOT    XYPLTT// $

136  JUMP      DPLOT $

137  LABEL     LBL17 $

138  PURGE     OUGV2/NOSORT2 $

139  COND      LBLOFP,COUNT $

140  OPTPR2    OPTP1,OES1,EST/OPTP2,EST1/S,N,PRINT/TSTART/S,N,COUNT/S,N,
               CARDNO $

141  EQUIV     EST1,EST/ALWAYS/OPTP2,OPTP1/ALWAYS $

142  COND      LOOPEND,PRINT $

143  LABEL     LBLOFP $

144  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


145  SCAN     CASECC,OES1,OEF1/OESF1X/*RF* $
146  OFP      OESF1X,,,,,//S,N,CARDNO $
147  OFP      OES1M,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $
148  LABEL    DPLOT $
149  COND     P2,JUMPPLOT $
150  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
151  PRTMSG   PLOTX2// $
152  LABEL    P2 $
153  LABEL    LOOPEND $
154  COND     FINIS,COUNT $
155  REPT     LOOPTOP,360 $
156  JUMP     FINIS $
157  LABEL    ERROR1 $
158  PRTPARM  //-1/*STATICS* $
159  LABEL    ERROR2 $
160  PRTPARM  //-2/*STATICS* $
161  LABEL    ERROR3 $
162  PRTPARM  //-3/*STATICS* $
163  LABEL    ERROR4 $
164  PRTPARM  //-4/*STATICS* $
165  LABEL    ERROR5 $
166  PRTPARM  //-5/*STATICS* $
167  LABEL    FINIS $
168  PURGE    DUMMY/ALWAYS $
169  LABEL    LBLINT02 $
170  COMPON   LBLINT01,SYS21 $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


224  LABEL    LBLINT1 $

225  END      $
```

2.1.2 Description of Important DMAP Operations for Static Analysis

Note: The DMAP sequence for static analysis involves the use of parameters INTERACT and SYS21 (see Section 2.1.5). These parameters are of relevance only when the primary purpose of the user is to make interactive restart runs. (The two parameters are then specified via the PARAM card in the Bulk Data Deck.) However, these two parameters are not required for normal non-interactive batch runs. Consequently, the rigid format DMAP listing shown in Section 2.1.1 was generated by not specifying these parameters (via the PARAM bulk data card). As a result, the CØMPØFF and CØMPØN instructions using these parameters assume a value of 0 for these parameters (see Volume I, Section 5.7).

6. CØMPØFF causes the DMAP compiler to compile the next instruction (DMAP No. 7) as the parameter INTERACT is 0 (see Note above).

8. CØMPØN causes the DMAP compiler to skip the compilation of the next instruction (DMAP No. 9, not shown) as the parameter INTERACT is 0 (see Note above).

10. CØMPØFF causes the DMAP compiler to compile all of the following instructions through LABEL LBLINT02 (DMAP Nos. 11 through 169) as the parameter SYS21 is 0 (see Note above).

11. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

12. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

13. GP2 generates Element Connection Table with internal indices.

16. Go to DMAP No. 24 if there are no structure plot requests.

17. PLTSET transforms user input into a form used to drive the structure plotter.

18. PRTMSG prints error messages associated with the structure plotter.

21. Go to DMAP No. 24 if no undeformed structure plots are requested.

22. PLØT generates all requested undeformed structure plots.

23. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

25. GP3 generates Static Loads Table and Grid Point Temperature Table.

27. TA1 generates element tables for use in matrix assembly and stress recovery.

29. Go to DMAP No. 163 and print Error Message No. 4 if no elements have been defined.

31. ØPTPR1 performs phase one property optimization and initialization check.

32. Beginning of loop for property optimization.

33. Go to DMAP No. 48 if there are no structural elements.

36. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

37. Go to DMAP No. 39 if no stiffness matrix is to be assembled.

38. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

41. Go to DMAP No. 43 if no mass matrix is to be assembled.

42. EMA assembles mass matrix $[M_{gg}]$.

44. Go to DMAP No. 48 if no weight and balance information is requested.

45. Go to DMAP No. 159 and print Error Message No. 2 if no mass matrix exists.

46. GPWG generates weight and balance information.

47. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

49. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

50. Go to DMAP No. 52 if no general elements exist.

51. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

54. Beginning of loop for multiple constraint sets.

55. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

56. Go to DMAP No. 161 and print Error Message No. 3 if no independent degrees of freedom are defined.

59. Go to DMAP No. 64 if general elements are present.

61. Go to DMAP No. 64 if no potential grid point singularities exist.

62. GPSP generates a table of potential grid point singularities.

63. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output ile for printing.

65. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

66. Go to DMAP No. 69 if the MPC set for the current pass is unchanged from that of the previous pass.

67. MCE1 partitions multipoint constraint equations $[R_g] = [R_m | R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

68. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nm}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

70. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

71. Go to DMAP No. 73 if no single-point constraints exist.

72. SCE1 partitions out single-point constraints

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

74. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

75. Go to DMAP No. 77 if no omitted coordinates exist.

76. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

78. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

79. Go to DMAP No. 81 if no free-body supports exist.

80. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right].$$

82. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

83. Go to DMAP No. 85 if no free-body supports exist.

84. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] \quad ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{||X||}{||K_{rr}||} \quad .$$

86. SSG1 generates static load vectors $\{P_g\}$.

87. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

88. Go to DMAP No. 90 if no constraints are applied.

89. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\} \quad , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} \quad ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} \quad , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} \ ,$$

$$\{P_f\} = \left\{\begin{array}{c}\bar{P}_a \\ \hline P_o\end{array}\right\} \quad , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} \ ,$$

$$\{P_a\} = \left\{\begin{array}{c}P_\ell \\ \hline P_r\end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

91. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} \ ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} \ ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} \ ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} \ ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

92. Go to DMAP No. 95 if residual vectors are not to be printed.

93. MATGPR prints the residual vector for independent coordinates (RULV).

94. MATGPR prints the residual vector for omitted coordinates (RUØV).

96. SDR1 recovers dependent displacements

$$\left\{\begin{array}{c}u_\ell \\ \hline u_r\end{array}\right\} = \{u_a\} \ , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \ ,$$

$$\left\{\begin{array}{c}u_a \\ \hline u_o\end{array}\right\} = \{u_f\} \ , \qquad \left\{\begin{array}{c}u_f \\ \hline Y_s\end{array}\right\} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} , \qquad \left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

97. Go to DMAP No. 102 if all constraint sets have been processed.

98. Go to DMAP No. 54 if additional sets of constraints need to be processed.

99. Go to DMAP No. 157 and print Error Message No. 1 as the number of constraint sets exceeds 360.

101. Go to DMAP No. 165 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

103. GPFDR calculates the grid point force balance (ØGPFB1) and element strain energy (ØNRGY1) for requested sets.

104. ØFP formats the tables prepared by GPFDR and places them on the system output file for printing.

105. Go to DMAP No. 108 if no multipoint constraint force balance is requested.

106. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

107. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

109. SDR2 calculates the element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vectors (PUGV1).

110. Go to DMAP No. 112 if element stresses in material coordinate system and stresses at the connected grid points are not to be calculated.

111. CURV calculates element stresses in material coordinate system (ØES1M) and stresses at the connected grid points (ØES1G).

114. Go to DMAP No. 118 if element strains/curvatures are not to be calculated.

115. SDR2 calculates element strains/curvatures (ØES1A).

116. Go to DMAP No. 118 if element strains/curvatures in material coordinate system and strains/curvatures at the connected grid points are not to be calculated.

117. CURV calculates element strains/curvatures in material coordinate system (ØES1AM) and strains/curvatures at the connected grid points (ØES1AG).

120. Go to DMAP No. 137 if there are no requests for output sorted by grid point number or element number.

121. SDR3 prepares requested output sorted by grid point number of element number.

123. Go to DMAP No. 128 if printed output sorted by grid point number or element number is not required.

124. ØFP formats the tables prepared by SDR3 for output sorted by grid point number or element number and places them on the system output file for printing.

125. SCAN examines the element stresses and forces calculated by SDR3 and generates scanned output that meets the specifications set by the user.

126. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

127. Go to DMAP No. 132.

129. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.

130. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

131. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

133. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.

134. XYTRAN prepares the input for requested X-Y plots.

135. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. subcase.

136. Go to DMAP No. 148.

139. Go to DMAP No. 143 if there is no phase two property optimization.

140. ØPTPR2 performs phase two property optimization.

141. Equivalence EST1 to EST and ØPTP2 to ØPTP1.

142. Go to DMAP No. 153 if no additional output is to be printed for this loop.

144. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.

145. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

146. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

147. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.

149. Go to DMAP No. 152 if no deformed structure plots are requested.

150. PLØT generates all requested deformed structure and contour plots.

151. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

154. Go to DMAP No. 167 and make normal exit if property optimization is complete.

155. Go to DMAP No. 32 if additional loops for property optimization are needed.

156. Go to DMAP No. 167 and make normal exit.

158. Print Error Message No. 1 and terminate execution.

160. Print Error Message No. 2 and terminate execution.

162. Print Error Message No. 3 and terminate execution.

164. Print Error Message No. 4 and terminate execution.

166. Print Error Message No. 5 and terminate execution.

170. CØMPØN causes the DMAP compiler to skip the compilation of all of the following instructions through LABEL LBLINT01 (DMAP Nos. 171 through 223, not shown) as the parameter SYS21 is 0 (see Note at the beginning of this section).

2.1.3 Output for Static Analysis

The following printed output, sorted by loads (SØRT1) or by grid point number or element number (SØRT2), may be requested for Static Analysis solutions:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and stresses in selected elements.
3. Strains/curvatures in selected elements (only for TRIA1, IRIA2, QUAD1 and QUAD2 elements).

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point versus subcase.
4. X-Y plot of any stress or force component for an element versus subcase.

2.1.4 Case Control Deck for Static Analysis

The following items relate to subcase definition and data selection for Static Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection unless all loading is specified with grid point displacements on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless the model is a properly supported free body, or all constraints are specified on GRID cards, Scalar Connection cards, or with General Elements.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

2.1.5 Parameters for Static Analysis

The following parameters are used in Static Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
6. INTERACT - optional. This parameter, like the SYS21 parameter, is of relevance only when the primary purpose of the user is to make interactive restart runs. In such a case, the integer value of this parameter must be set to -1 (via a PARAM bulk data card) in both the batch checkpoint run (that precedes the interactive restart run) as well as in the interactive restart run. If not so specified via a PARAM bulk data card, the CØMPØFF and CØMPØN instructions in the DMAP sequence that use this parameter assume a value of 0 for this parameter (see Volume I, Section 5.7).
7. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following each execution of the SSG3 module.
8. NINTPTS - optional. A positive integer value of this parameter specifies the number of closest independent points to be used in the interpolation for computing stresses or strains/curvatures at grid points (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). A negative integer value or 0 specifies that all independent points are to be used in the interpolation. The default value is 0.
9. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

10. STRAIN - optional. This parameter controls the transformation of element strains/curvatures to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the strains/curvatures for these elements are transformed to the material coordinate system. If it is zero, strains/curvatures at the connected grid points are also computed in addition to the element strains/curvatures in the material coordinate system. A negative integer value results in no transformation of the strains/curvatures. The default value is -1.
11. STRESS - optional. This parameter controls the transformation of element stresses to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the stresses for these elements are transformed to the material coordinate system. If it is zero, stresses at the connected grid points are also computed in addition to the element stresses in the material coordinate system. A negative integer value results in no transformation of the stresses. The default value is -1.
12. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
13. SYS21 - optional. This parameter, like the INTERACT parameter, is of relevance only when the primary purpose of the user is to make interactive restart runs. In such a case, the integer value of this parameter must be set to -1 (via a PARAM bulk data card) in the interactive restart run (that follows a batch checkpoint run). If not so specified via a PARAM bulk data card, the CØMPØFF and CØMPØN instructions in the DMAP sequence that use this parameter assume a value of 0 for this parameter (see Volume I, Section 5.7).
14. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.1.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis, Rigid Format 1, are ALTERed for automated substructure analyses.

Phase 1: 5, 56, 78-85, 87-153

Phase 2: 5, 11-11, 14-24, 28-29, 35-35, 49-52, 59-64, 103-153

Phase 3: 78-85, 88-95, 96

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

2.1.7 Rigid Format Error Messages from Static Analysis

The following fatal errors are detected by the DMAP statements in the Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions or more than 360 passes in the optimization loop have been attempted. This number may be increased by ALTERing the REPT instruction following SDR1 in the former case and the REPT instruction following the last PRTMSG instruction in the latter case.

STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATIC ANALYSIS ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

2.2 STATIC ANALYSIS WITH INERTIA RELIEF

2.2.1 DMAP Sequence for Static Analysis With Inertia Relief

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 02 - STATIC ANALYSIS WITH INERTIA RELIEF - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE/MNN=SAVE  $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/ALWAYS=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE  $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR6,NOSIMP $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    OGPST/GENEL $

 23  PARAM    //*ADD*/NOKGGX/1/0 $

 24  PARAM    //*ADD*/NOMGG/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX $

 27  COND     JMPKGG,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGG $

 30  COND     ERROR1,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  COND     LGPWG,GRDPNT $

 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 34  OFP      OGPWG,,,,,//S,N,CARDNO $

 35  LABEL    LGPWG $

 36  EQUIV    KGGX,KGG/NOGENL $

 37  COND     LBL11A,NOGENL $

 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 39  LABEL    LBL11A $

 40  PARAM    //*MPY*/NSKIP/0/0 $

 41  LABEL    LBL11 $

 42  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 43  COND     ERROR3,NOL $

 44  COND     ERROR4,REACT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  PURGE    GM/MPCF1/GO,KOO,LOO,MOO,MOA,PO,UOOV,RUOV/OMIT/KSS,KFS,PS/
              SINGLE $
 46  COND     LBL4,GENEL $
 47  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 48  COND     LBL4,GPSPFLG $
 49  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 50  OFP      OGPST,,,,,//S,N,CARDNO $
 51  LABEL    LBL4 $
 52  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 53  COND     LBL2,MPCF2 $
 54  MCE1     USET,RG/GM $
 55  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 56  LABEL    LBL2 $
 57  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 58  COND     LBL3,SINGLE $
 59  SCE1     USET,KNN,MNN,,/KFF,KFS,KSS,MFF,, $
 60  LABEL    LBL3 $
 61  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
 62  COND     LBL5,OMIT $
 63  SMP1     USET,KFF,MFF,,/GO,KAA,KOO,LOO,MAA,MOO,MOA,, $
 64  LABEL    LBL5 $
 65  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 66  RBMG2    KLL/LLL $
 67  RBMG3    LLL,KLR,KRR/DM $
 68  RBMG4    DM,MLL,MLR,MRR/MR $
 69  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/NSKIP $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $

 71  SSG4      PL,QR,PO,MR,MLR,DM,MLL,MOO,MOA,GO,USET/PLI,POI/OMIT $

 72  SSG3      LLL,KLL,PLI,LOO,KOO,POI/ULV,UOOV,RULV,RUOV/OMIT/V,Y,
               IRES=-1/NSKIP/S,N,EPSI $

 73  COND      LBL9,IRES $

 74  MATGPR    GPL,USET,SIL,RULV//*L* $

 75  MATGPR    GPL,USET,SIL,RUOV//*O* $

 76  LABEL     LBL9 $

 77  SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/
               *STATICS* $

 78  COND      LBL8,REPEAT $

 79  REPT      LBL11,360 $

 80  JUMP      ERROR2 $

 81  PARAM     //*NOT*/TEST/REPEAT $

 82  COND      ERROR5,TEST $

 83  LABEL     LBL8 $

 84  COND      NOMPCF,GRDEQ $

 85  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/
               OQM1/V,Y,OPT=0/V,Y,GRDEQ/NSKIP $

 86  OFP       OQM1,,,,,//S,N,CARDNO $

 87  LABEL     NOMPCF $

 88  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
               OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $

 89  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $

 90  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $

 91  OFP       OESF1,,,,,//S,N,CARDNO $

 92  COND      P2,JUMPPLOT $

 93  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 94  PRTMSG   PLOTX2// $
 95  LABEL    P2 $
 96  JUMP     FINIS $
 97  LABEL    ERROR1 $
 98  PRTPARM  //-1/*INERTIA* $
 99  LABEL    ERROR2 $
100  PRTPARM  //-2/*INERTIA* $
101  LABEL    ERROR3 $
102  PRTPARM  //-3/*INERTIA* $
103  LABEL    ERROR4 $
104  PRTPARM  //-4/*INERTIA* $
105  LABEL    ERROR5 $
106  PRTPARM  //-5/*INERTIA* $
107  LABEL    ERROR6 $
108  PRTPARM  //-6/*INERTIA* $
109  LABEL    FINIS $
110  PURGE    DUMMY/ALWAYS $
111  END      $
```

2.2.2 Description of Important DMAP Operations for Static Analysis with Inertia Relief

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 107 and print Error Message No. 6 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 97 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. Beginning of loop for multiple constraint sets.

42. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

43. Go to DMAP No. 101 and print Error Message No. 3 if no independent degrees of freedom are defined.

44. Go to DMAP No. 103 and print Error Message No. 4 if no free-body supports exist.

46. Go to DMAP No. 51 if general elements are present.

48. Go to DMAP No. 51 if no potential grid point singularities exist.

49. GPSP generates a table of potential grid point singularities.

50. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

52. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

53. Go to DMAP No. 56 if the MPC set for the current pass is unchanged from that of the previous pass.

54. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

55. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m].$$

57. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

58. Go to DMAP No. 60 if no single-point constraints exist.

59. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right].$$

61. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

62. Go to DMAP No. 64 if no omitted coordinates exist.

63. SMP1 partitions constrained stiffness and mass matrices

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] \quad \text{and} \quad [M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reductions $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$

and $$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

66. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

67. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||}$$

68. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

69. SSG1 generates static load vectors $\{P_g\}$.

70. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\} , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c} \bar{P}_f \\ \hline P_s \end{array}\right\} , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c} \bar{P}_a \\ \hline P_o \end{array}\right\} , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\begin{array}{c} P_\ell \\ \hline P_r \end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

71. SSG4 calculates inertia loads and combines them with static loads

$$\{P_\ell^i\} = \{P_\ell\} + \left([M_{\ell\ell}][D] + [M_{\ell r}]\right)[m_r]^{-1}\{q_r\} \quad \text{and}$$

$$\{P_o^i\} = \{P_o\} + \left([M_{oo}][G_o] + [M_{ao}^T]\right)\begin{bmatrix} D \\ \hline I \end{bmatrix}[m_r]^{-1}\{q_r\} \ .$$

72. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell^i\} \ ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o^i\} \ ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell^i\} = \{P_\ell^i\} - [K_{\ell\ell}]\{u_\ell\}$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell^i\}}{\{P_\ell^i\}^T\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o^i\} = \{P_o^i\} - [K_{oo}]\{u_o^o\} \ ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o^i\}}{\{P_o^i\}^T\{u_o^o\}} \ .$$

73. Go to DMAP No. 76 if residual vectors are not to be printed.

74. MATGPR prints the residual vector for independent coordinates (RULV).

75. MATGPR prints the residual vector for omitted coordinates (RUØV).

77. SDR1 recovers dependent displacements

$$\begin{Bmatrix} u_\ell \\ \hline u_r \end{Bmatrix} = \{u_a\} \ , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \ ,$$

$$\begin{Bmatrix} u_a \\ \hline u_o \end{Bmatrix} = \{u_f\} \ , \qquad \begin{Bmatrix} u_f \\ \hline Y_s \end{Bmatrix} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \quad \begin{Bmatrix} u_n \\ \hline u_m \end{Bmatrix} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} .$$

78. Go to DMAP No. 83 if all constraint sets have been processed.

79. Go to DMAP No. 41 if additional sets of constraints need to be processed.

80. Go to DMAP No. 99 and print Error Message No. 2 as the number of constraint sets exceeds 360.

82. Go to DMAP No. 105 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

84. Go to DMAP No. 87 if no multipoint constraint force balance is requested.

85. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

86. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

88. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1), and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

89. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

90. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

91. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

92. Go to DMAP No. 95 if no deformed structure plots are requested.

93. PLØT generates all requested deformed structure and contour plots.

94. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

96. Go to DMAP No. 109 and make normal exit.

98. Print Error Message No. 1 and terminate execution.

100. Print Error Message No. 2 and terminate execution.

102. Print Error Message No. 3 and terminate execution.

104. Print Error Message No. 4 and terminate execution.

106. Print Error Message No. 5 and terminate execution.

108. Print Error Message No. 6 and terminate execution.

2.2.3 Output for Static Analysis with Inertia Relief

The following output may be requested for Static Analysis with Inertia Relief:

1. Displacements at selected grid points due to the sum of the applied loads and the inertia loads.
2. Nonzero components of the applied static loads at selected grid points.
3. Reactions on free-body supports due to applied loads (single-point forces of constraint).
4. Forces and stresses in selected elements due to the sum of the applied loads and inertia loads.
5. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.

2.2.4 Case Control Deck for Static Analysis with Inertia Relief

The following items relate to subcase definition and data selection for Static Analysis with Inertia Relief:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD selection.
3. An SPC set may be selected only if used to remove grid point singularities or some, but not all, of the free body motions. At least one free body support must be provided with a SUPØRT card in the Bulk Data Deck.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets for the same output item.

2.2.5 Parameters for Static Analysis with Inertia Relief

The following parameters are used in Static Analysis with Inertia Relief:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
6. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
7. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
8. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.2.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis with Inertia Relief, Rigid Format 2, are ALTERed in automated substructure analyses.

Phase 1: 4, 44-44, 65-68, 70-96

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 46-51, 84-98

Phase 3: 65-68, 70-76, 77

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

2.2.7 Rigid Format Error Messages from Static Analysis with Inertia Relief

The following fatal errors are detected by the DMAP statements in the Static Analysis with Inertia Relief rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR CALCULATIØN ØF INERTIA LØADS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 4 - FREE-BØDY SUPPØRTS ARE REQUIRED.

A statically determinate set of supports must be specified on a SUPØRT card in order to determine the rigid body characteristics of the structural model.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.3 NORMAL MODES ANALYSIS

2.3.1 DMAP Sequence for Normal Modes Analysis

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 03 - NORMAL MODES ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     LAMA=APPEND/PHIA=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/ALWAYS=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE  $

   17  PRTMSG   PLOTX1//$

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR4,NOSIMP $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    OGPST/GENEL $

 23  PARAM    //*ADD*/NOKGGX/1/0 $

 24  PARAM    //*ADD*/NOMGG/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX $

 27  COND     JMPKGG,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGG $

 30  COND     ERROR1,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  COND     LGPWG,GRDPNT $

 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 34  OFP      OGPWG,,,,,//S,N,CARDNO $

 35  LABEL    LGPWG $

 36  EQUIV    KGGX,KGG/NOGENL $

 37  COND     LBL11,NOGENL $

 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 39  LABEL    LBL11 $

 40  PARAM    //*MPY*/NSKIP/0/0 $

 41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 42  COND     ERROR3,NOL $

 43  PURGE    KRR,KLR,DM,MLR,MR/REACT/GM/MPCF1/GO/OMIT/KFS/SINGLE/QG/NOSET $

 44  COND     LBL4,GENEL $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 46  COND     LBL4,GPSPFLG $
 47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 48  OFP      OGPST,,,,,//S,N,CARDNO $
 49  LABEL    LBL4 $
 50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 51  COND     LBL2,MPCF1 $
 52  MCE1     USET,RG/GM $
 53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 54  LABEL    LBL2 $
 55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 56  COND     LBL3,SINGLE $
 57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 58  LABEL    LBL3  $
 59  EQUIV    KFF,KAA/OMIT $
 60  EQUIV    MFF,MAA/OMIT $
 61  COND     LBL5,OMIT $
 62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 63  SMP2     USET,GO,MFF/MAA $
 64  LABEL    LBL5 $
 65  COND     LBL6,REACT $
 66  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 67  RBMG2    KLL/LLL $
 68  RBMG3    LLL,KLR,KRR/DM $
 69  RBMG4    DM,MLL,MLR,MRR/MR $
 70  LABEL    LBL6 $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 71  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/
               LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
               NONLFT/NOTRL/S,N,NOEED//NOUE $

 72  COND      ERROR2,NOEED $

 73  PARAM     //*MPY*/NEIGV/1/-1 $

 74  READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/
               S,N,NEIGV $

 75  OFP       OEIGS,,,,,//S,N,CARDNO $

 76  COND      FINIS,NEIGV $

 77  OFP       LAMA,,,,,//S,N,CARDNO $

 78  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $

 79  COND      NOMPCF,GRDEQ $

 80  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/
               OQM1/V,Y,OPT=0/V,Y,GRDEQ/-1 $

 81  OFP       OQM1,,,,,//S,N,CARDNO $

 82  LABEL     NOMPCF $

 83  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/
               ,OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $

 84  OFP       OPHIG,OQG1,OEF1,OES1,,//S,N,CARDNO $

 85  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $

 86  OFP       OESF1,,,,,//S,N,CARDNO $

 87  COND      P2,JUMPPLOT $

 88  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

 89  PRTMSG    PLOTX2// $

 90  LABEL     P2 $

 91  JUMP      FINIS $

 92  LABEL     ERROR1 $

 93  PRTPARM   //-1/*MODES* $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 94  LABEL    ERROR2 $
 95  PRTPARM  //-2/*MODES* $
 96  LABEL    ERROR3 $
 97  PRTPARM  //-3/*MODES* $
 98  LABEL    ERROR4 $
 99  PRTPARM  //-4/*MODES* $
100  LABEL    FINIS $
101  PURGE    DUMMY/ALWAYS $
102  END      $
```

2.3.2 Description of Important DMAP Operations for Normal Modes Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 98 and print Error Message No. 4 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 92 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g] \{u_g\} = 0$.

42. Go to DMAP No. 96 and print Error Message No. 3 if no independent degrees of freedom are defined.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \text{ and } \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \quad .$$

65. Go to DMAP No. 70 if no free-body supports exist.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right]$$

67. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{||X||}{||K_{rr}||} \quad .$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

72. Go to DMAP No. 94 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

74. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 \quad ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] \quad ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

75. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

76. Go to DMAP No. 100 and make normal exit if no eigenvalues were found.

77. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\}, \qquad \left\{\begin{matrix}\phi_a \\ \hline \phi_o\end{matrix}\right\} = \{\phi_f\},$$

$$\left\{\begin{matrix}\phi_f \\ \hline \phi_s\end{matrix}\right\} = \{\phi_n\}, \qquad \{\phi_m\} = [G_m]\{\phi_n\},$$

$$\left\{\begin{matrix}\phi_n \\ \hline \phi_m\end{matrix}\right\} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.

80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

83. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØQG1) for output and translation components of the eigenvectors (PPHIG).

84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

85. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

86. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

87. Go to DMAP No. 90 if no deformed structure plots are requested.

88. PLØT generates all requested deformed structure and contour plots.

89. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

91. Go to DMAP No. 100 and make normal exit.

93. Print Error Message No. 1 and terminate execution.

95. Print Error Message No. 2 and terminate execution.

97. Print Error Message No. 3 and terminate execution.

99. Print Error Message No. 4 and terminate execution.

2.3.3 Output for Normal Modes Analysis

Each eigenvalue is identified with a mode number determined by sorting the eigenvalues by their algebraic magnitude. The following summary of the eigenvalues extracted is automatically printed:

1. Mode Number
2. Extraction Order
3. Eigenvalue
4. Radian Frequency
5. Cyclic Frequency
6. Generalized Mass
7. Generalized Stiffness

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.
5. Number of vector iterations.
6. Reason for termination.
   (1) Two consecutive singularities encountered while performing triangular decomposition.
   (2) Four shift points while tracking a single root.
   (3) All eigenvalues found in the frequency range specified.
   (4) Three times the number of roots estimated in the frequency range have been extracted.
   (5) All eigenvalues that exist in the problem have been found.
   (6) The number of roots desired have been found.
   (7) One or more eigenvalues have been found outside the frequency range specified.
   (8) Insufficient time to find another root.
   (9) Unable to converge
7. Largest off-diagonal modal mass term and the number failing the criterion.

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Reason for termination.
   (1) The number of roots desired have been found.
   (2) All predictions for eigenvalues are outside the frequency range specified.
   (3) Insufficient time to find another root.
   (4) Matrix is singular at first three starting points.
8. Largest off-diagonal modal mass term and the number failing the criterion.
9. Swept determinant function for each starting point.

The following summary of the eigenvalue analysis performed, using the Givens method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of eigenvectors computed.
3. Number of eigenvalue convergence failures.
4. Number of eigenvector convergence failures.
5. Reason for termination.
   (1) Normal termination.
   (2) Insufficient time to calculate eigenvalues and number of eigenvectors requested.
   (3) Insufficient time to find additional eigenvectors.
6. Largest off-diagonal modal mass term and the number failing the criterion.

The following summary of the eigenvalue analysis performed, using the Tridiagonal Reduction (FEER - Fast Eigenvalue Extraction Routine) method, is automatically printed.

1. Number of eigenvalues extracted.
2. Number of starting points used.
   This corresponds to the total number of random starting and restart vectors used by the FEER process.

3. Number of starting point moves.

   Not used in FEER (set equal to zero).

4. Number of triangular decompositions.

   Always equal to one, except for unshifted vibration problems (roots starting from the lowest requested). In this case, a maximum of three shifts and three decompositions are employed to remove possible stiffness matrix singularities.

5. Total number of vector iterations.

   The total number of reorthogonalizations of all the trial vectors employed.

6. Reason for termination.

   (0) Normal termination.

   (1) Fewer than the requested number of eigenvalues and eigenvectors have been extracted.

   (3) The problem size has been reduced. However, the desired number of accurate eigensolutions specified on the EIGB or EIGR card may have been obtained. A detailed list of the computed error bounds can be obtained by requesting DIAG 16 in the Executive Control Deck.

7. Largest off-diagonal modal mass term and the number failing the mass orthogonality criterion.

The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected modes.
2. Contour plots of stresses and displacements for selected modes.

2.3.4 Case Control Deck for Normal Modes Analysis

The following items relate to subcase definition and data selection for Normal Modes Analysis:

1. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.

2. On restart, the current EIGR card controls the eigenvalue extraction, regardless of what calculations were made in the previous execution. Consequently, when making restarts with either the Determinant method, the Inverse Power method or the Tridiagonal Reduction (FEER) method, METHØD should be changed to select an EIGR card that avoids the extraction of previously found eigenvalues. This is particularly important following unscheduled exits due to insufficient time to find all eigenvalues in the range of interest.
3. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.

2.3.5 Parameters for Normal Modes Analysis

The following parameters are used in Normal Modes Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

6. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.3.6 Optional Diagnostic Output for FEER

Special detailed information related to the generation of the reduced problem size, the elements of the reduced tridiagonal matrix, computed error bounds and other numerical tests can be obtained by requesting DIAG 16 in the NASTRAN Executive Control Deck.

The meaning of this information is explained below in the order in which it appears in the DIAG 16 output.

ØRDER - The order of the unreduced problem (size of the $[K_{aa}]$ matrix)

MAX RANK - The maximum number of existing finite eigensolutions as initially detected by FEER

RED ØRDER - The order of the reduced eigenproblem which will be solved to obtain the number of accurate solutions requested by the user

ØRTH VCT - The number of previously computed accurate eigenvectors on the eigenvector file which were generated prior to a restart or by the NASTRAN rigid body mode generator

USER SHIFT - The user specified shift after conversion from cycles to radians - squared (used only in frequency problems).

INTERNAL SHIFT - A small positive value automatically computed to remove singularities if the user has specified a zero shift. Otherwise, the negative of the user shift (used only in frequency problems).

SINGULARITY CHECK - PASS: the shifted stiffness matrix is non-singular
- ****: the number of internal shifts needed to remove stiffness matrix singularities

TRIDIAGONAL ELEMENTS ROW j, **, ***, **** - The computed tridiagonal elements of the reduced eigenmatrix:

j - Matrix row
** - Diagonal element
*** - Off-diagonal element
**** - First estimate of off-diagonal element in the next row

ØRTH ITER - The number of times a reorthogonalization of a trial vector has been performed.

MAX PRØJ - The maximum projection of the above trial vector on the previously computed accurate trial vectors (prior to the current reorthogonalization)

NØRMAL FACT - The normalization factor for the reorthogonalized trial vector

ØPEN CØRE NØT USED *** FEER3 - Open core not used by Subroutine FEER3, in single-precision words

FEER QRW ELEMENT *, ITER **, ***, RATIØ ****, PRØJ *****:

* - The internal eigenvalue number in the order of its extraction by FEER

** - The number of inverse power iterations performed to extract the associated eigenvector of the reduced system (this is not a physical eigenvector)

*** - If a multiple root has been detected, the number of times that the previous multiple-root, reduced-system eigenvectors have been projected out of the current multiple-root eigenvector before repeating the inverse power iterations

**** - The absolute ratio of maximum, reduced-system eigenvector elements for successive inverse power iterations

***** - The maximum projection of a current multiple-root eigenvector on previously computed eigenvectors for the same root

PHYSICAL EIGENVALUE *, **, THEØR ERRØR *** PERCENT, PASS ØR FAIL:

* - The internal eigenvalue number in the order of its extraction by FEER

** - The associated physical eigenvalue (λ for buckling problems, ω^2 for frequency problems)

*** - Theoretical upper bound on the relative eigenvalue error

PASS - The computed error is less than or equal to the allowable specified on the EIGB or EIGR bulk data card (default is .001/n where n is the order of the stiffness matrix)

FAIL - The computed error is greater than the allowable and this mode is not accepted for further processing

ØPEN CØRE NØT USED *** FEER4 - Open core not used by Subroutine FEER4, in single-precision words

FEER CØMPLETE *, **, ***, ****

* - The remaining CPU time available following decomposition of the shifted stiffness matrix, in seconds (the total time is specified on the TIME card in the Executive Control Deck)

** - The remaining CPU time, in seconds after completing Subroutine FEER3

*** - The remaining CPU time, in seconds after completing Subroutine FEER4

**** - The total operation count for FEER after decomposition of the shifted stiffness matrix. One operation is considered to be a multiplication or division followed by an addition

2.3.7 The APPEND Feature

In real eigenvalue analysis, it is frequently necessary to add new eigenvalues and eigenvectors to those already computed in a previous run. The APPEND feature (see Section 9.2.2 of the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem. It is available when using the Inverse Power, Determinant and Iridiagonal Reduction (FEER) methods of eigenvalue extraction.

In order to use the APPEND feature, the user should employ the following steps:

1. Request a checkpoint of an eigenvalue problem by employing either the Inverse Power, Determinant or Tridiagonal Reduction (FEER) method.
2. Check to ensure that at least one eigenvalue and one eigenvector are computed in this run and that the LAMA (eigenvalue) and PHIA (eigenvector) files are successfully checkpointed.
3. Restart the problem by changing either the METHØD card in the Case Control Deck and/or the EIGR card in the Bulk Data Deck and ensuring that the following conditions are satisfied:
   a. The structural model and the constraint data for the restart must be the same as that used in the checkpoint run.
   b. The method of eigenvalue extraction employed in the restart need not be the same as that used in the checkpoint run, but the range of eigenvalues specified on the EIGR Bulk Data card should not include the eigenvalues already checkpointed in Step 1.
   c. If the user wishes to retrieve only a subset of the checkpointed eigenvalues and eigenvectors, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NEIGV to the desired value by means of a PARAM statement just before the READ module in the DMAP sequence. (See Section 9.2.2 of the Theoretical Manual for details.)

4. Note that the eigenvalues and eigenvectors output by the restart include those retrieved from the checkpointed run of Step 1. Also, the resulting eigenvectors are normalized according to the method of normalization specified in the restart.

2.3.8 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Normal Modes Analysis, Rigid Format 3, are ALTERed in automated substructure analyses.

Phase 1: 4, 42, 65-70, 71-91

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 44-49, 79-93

Phase 3: 65-70, 71-77, 78

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

2.3.9 Rigid Format Error Messages from Normal Modes Analysis

The following fatal errors are detected by the DMAP statements in the Normal Modes Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 4 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.4 STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

2.4.1 DMAP Sequence for Static Analysis With Differential Stiffness

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 04 - DIFFERENTIAL STIFFNESS ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  PARAM    //*MPY*/CARDNO/0/0 $

    4  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/MINUS1=-1 $

    5  COND     ERROR3,NOGPDT $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $

   20  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $

   21  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  COND      ERROR1,NOSIMP $

 23  PURGE     OGPST/GENEL $

 24  PARAM     //*ADD*/NOKGGX/1/0 $

 25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
               S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
               C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
               C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
               V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $

 27  COND      JMPKGG,NOKGGX $

 28  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL     JMPKGG $

 30  COND      JMPMGG,NOMGG $

 31  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  LABEL     JMPMGG $

 33  COND      LBL1,GRDPNT $

 34  COND      ERROR4,NOMGG $

 35  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $

 36  OFP       OGPWG,,,,,//S,N,CARDNO $

 37  LABEL     LBL1 $

 38  EQUIV     KGGX,KGG/NOGENL $

 39  COND      LBL11,NOGENL $

 40  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 41  LABEL     LBL11 $

 42  PARAM     //*MPY*/NSKIP/0/0 $

 43  CASE      CASECC,/CASEXX/*TRANRESP*/0/NOLOOP $

 44  GP4       CASEXX,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
               NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
               S,Y,AUTOSPC $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  COND      ERROR5,NOL $
 46  PURGE     GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG,
               YBS,PBS,KBFS,KBSS,KDFS,KDSS/SINGLE $
 47  COND      LBL4D,REACT $
 48  JUMP      ERROR2 $
 49  LABEL     LBL4D $
 50  COND      LBL4,GENEL$
 51  PARAM     //*EQ*/GPSPFLG/AUTOSPC/O $
 52  COND      LBL4,GPSPFLG $
 53  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 54  OFP       OGPST,,,,,//S,N,CARDNO $
 55  LABEL     LBL4 $
 56  EQUIV     KGG,KNN/MPCF1 $
 57  COND      LBL2,MPCF1 $
 58  MCE1      USET,RG/GM $
 59  MCE2      USET,GM,KGG,,,/KNN,,, $
 60  LABEL     LBL2 $
 61  EQUIV     KNN,KFF/SINGLE $
 62  COND      LBL3,SINGLE $
 63  SCE1      USET,KNN,,,/KFF,KFS,KSS,,, $
 64  LABEL     LBL3 $
 65  EQUIV     KFF,KAA/OMIT $
 66  COND      LBL5,OMIT $
 67  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 68  LABEL     LBL5 $
 69  RBMG2     KAA/LLL $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASEXX,DIT,/
              PG,,,,/LUSET/1 $

 71  EQUIV    PG,PL/NOSET $

 72  COND     LBL10,NOSET $

 73  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $

 74  LABEL    LBL10 $

 75  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              1/S,N,EPSI $

 76  COND     LBL9,IRES $

 77  MATGPR   GPL,USET,SIL,RULV//*L* $

 78  MATGPR   GPL,USET,SIL,RUOV//*O* $

 79  LABEL    LBL9 $

 80  SDR1     USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/1/*DSO* $

 81  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*DSO* $

 82  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $

 83  SCAN     CASECC,OES1,OEF1/OESF1/*RF* $

 84  OFP      OESF1,,,,,//S,N,CARDNO $

 85  COND     P2,JUMPPLOT $

 86  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

 87  PRTMSG   PLOTX2// $

 88  LABEL    P2 $

 89  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/
              NOSIMP/0/NOGENL/GENEL $

 90  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/
              DSCOSET $

 91  PARAM    //*ADD*/SHIFT/-1/0 $

 92  PARAM    //*ADD*/COUNT/ALWAYS=-1/NEVER= 1 $
```

RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 93  PARAMR   //*ADD*/DSEPSI/0.0/0.0 $
 94  PARAML   YS//*NULL*////NOYS $
 95  LABEL    OUTLPTOP $
 96  EQUIV    PG,PG1/NOYS $
 97  PARAM    //*KLOCK*/TO $
 98  EQUIV    KDGG,KDNN/MPCF1 $
 99  COND     LBL2D,MPCF1 $
100  MCE2     USET,GM,KDGG,,,/KDNN,,, $
101  LABEL    LBL2D $
102  EQUIV    KDNN,KDFF/SINGLE $
103  COND     LBL3D,SINGLE $
104  SCE1     USET,KDNN,,,/KDFF,KDFS,KDSS,,, $
105  LABEL    LBL3D $
106  EQUIV    KDFF,KDAA/OMIT $
107  COND     LBL5D,OMIT $
108  SMP2     USET,GO,KDFF/KDAA $
109  LABEL    LBL5D $
110  ADD      KAA,KDAA/KBLL $
111  ADD      KFS,KDFS/KBFS $
112  ADD      KSS,KDSS/KBSS $
113  COND     PGOK,NOYS $
114  MPYAD    KBSS,YS,/PSS/0/1/1/1 $
115  MPYAD    KBFS,YS,/PFS/0/1/1/1 $
116  UMERGE   USET,PFS,PSS/PN/*N*/*F*/*S* $
117  EQUIV    PN,PGX/MPCF1 $
118  COND     LBL6D,MPCF1 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


119  UMERGE   USET,PN,/PGX/*G*/*N*/*M* $
120  LABEL    LBL6D $
121  ADD      PGX,PG/PGG/(-1.0,0.0) $
122  EQUIV    PGG,PG1/ALWAYS $
123  LABEL    PGOK $
124  ADD      PG1,/PGO/ $
125  RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $
126  PRTPARM  //0/*DET* $
127  PRTPARM  //0/*POWER* $
128  LABEL    INLPTOP $
129  PARAM    //*KLOCK*/TI $
130  SSG2     USET,GM,YS,KDFS,GO,,PG1/,PBO,PBS,PBL $
131  SSG3     LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/S,N,
              EPSI $
132  COND     LBL9D,IRES $
133  MATGPR   GPL,USET,SIL,RUBLV//*L* $
134  LABEL    LBL9D $
135  SDR1     USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/1/*DS1* $
136  ADD      UBGV,UGV/DUGV/(-1.0,0.0) $
137  DSMG1    CASECC,GPTT,SIL,EDT,DUGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/
              DSCOSET $
138  MPYAD    DKDGG,UBGV,PGO/PG11/0/1/1/0 $
139  DSCHK    PG1,PG11,UBGV//C,Y,EPSI0=1.E-5/S,N,DSEPSI/C,Y,NT=10/TO/
              TI/S,N,DONE/S,N,SHIFT/S,N,COUNT/C,Y,BETAD=4 $
140  COND     DONE,DONE $
141  COND     SHIFT,SHIFT $
142  EQUIV    PG,PG1/NEVER/PG11,PG1/ALWAYS/PG1,PG11/NEVER $
143  REPT     INLPTOP,1000 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


144  TABPT    PG11,PG1,PG,,// $
145  LABEL    SHIFT $
146  ADD      DKDGG,KDGG/KDGG1/(-1.0,0.0) $
147  EQUIV    UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $
148  EQUIV    KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $
149  REPT     OUTLPTOP,1000 $
150  TABPT    KDGG1,KDGG,UGV,,// $
151  LABEL    DONE $
152  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/
              ,OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $
153  OFP      OUBGV1,OQBG1,OEFB1,OESB1,,//S,N,CARDNO $
154  COND     P3,JUMPPLOT $
155  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUBGV1,,GPECT,
              OESB1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,
              PFILE $
156  PRTMSG   PLOTX3// $
157  LABEL    P3 $
158  JUMP     FINIS $
159  LABEL    ERROR1 $
160  PRTPARM  //-1/*DIFFSTIF* $
161  LABEL    ERROR2 $
162  PRTPARM  //-2/*DIFFSTIF* $
163  LABEL    ERROR3 $
164  PRTPARM  //-3/*DIFFSTIF* $
165  LABEL    ERROR4 $
166  PRTPARM  //-4/*DIFFSTIF* $
167  LABEL    ERROR5 $
168  PRTPARM  //-5/*DIFFSTIF* $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


169  LABEL    FINIS $

170  PURGE    DUMMY/MINUS1 $

171  END      $
```

2.4.2 Description of Important DMAP Operations for Static Analysis with Differential Stiffness

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

5. Go to DMAP No. 163 and print Error Message No. 3 if there is no Grid Point Definition Table.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

22. Go to DMAP No. 159 and print Error Message No. 1 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 32 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

33. Go to DMAP No. 37 if no weight and balance information is requested.

34. Go to DMAP No. 165 and print Error Message No. 4 if no mass matrix exists.

35. GPWG generates weight and balance information.

36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

38. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

39. Go to DMAP No. 41 if no general elements exist.

40. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

43. CASE copies the first record of CASECC to CASEXX.

44. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

45. Go to DMAP No. 167 and print Error Message No. 5 if no independent degrees of freedom are defined.

47. Go to DMAP No. 49 if no free-body supports are supplied.

48. Go to DMAP No. 161 and print Error Message No. 2.

50. Go to DMAP No. 55 if general elements are present.

52. Go to DMAP No. 55 if no potential grid point singularities exist.

53. GPSP generates a table of potential grid point singularities.

54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

56. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

57. Go to DMAP No. 60 if no multipoint constraints exist.

58. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

62. Go to DMAP No. 64 if no single-point constraints exist.

63. SCE1 partitions out single-point constraints

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

65. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

66. Go to DMAP No. 68 if no omitted coordinates exist.

67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

69. RMBG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

70. SSG1 generates static load vectors $\{P_g\}$.

71. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

72. Go to DMAP No. 74 if no constraints are applied.

73. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c}\bar{P}_n \\ \hline P_m\end{array}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c}P_a \\ \hline P_o\end{array}\right\} \quad \text{and} \quad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{aa}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{aa}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.

77. MATGPR prints the residual vector for independent coordinates (RULV).

78. MATGPR prints the residual vector for omitted coordinates (RUØV).

80. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \ ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} \ , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

82. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

83. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

84. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

85. Go to DMAP No. 88 if no deformed static solution structure plots are requested.

86. PLØT generates all requested static solution deformed structure and contour plots.

87. PRTMSG prints plotter data, engineering data, and contour data for each deformed static solution plot generated.

89. TA1 generates element tables for use in differential stiffness matrix assembly.

90. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

95. Beginning of outer (stiffness adjustment) loop for differential stiffness iteration.

96. Equivalence $\{P_g\}$ to $\{P_{g1}\}$ if no enforced displacements are specified.

98. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ if no multipoint constraints exist.

99. Go to DMAP No. 101 if no multipoint constraints exist.

100. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{array}{c|c} K_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array}\right]$$

and performs matrix reduction

$$[K^d_{nn}] = [\bar{K}^d_{nn}] + [G^T_m][K^d_{mn}] + [K^d_{mn}][G_m] + [G^T_m][K^d_{mm}][G_m].$$

102. Equivalence $[K^d_{nn}]$ to $[K^d_{ff}]$ if no single-point constraints exist.

103. Go to DMAP No. 105 if no single-point constraints exist.

104. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right].$$

106. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ if no omitted coordinates exist.

107. Go to DMAP No. 109 if no omitted coordinates exist.

108. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right].$$

and performs matrix reduction

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{oa}]^T[G_o] + [G_o]^T[K^d_{oa}] + [G_o]^T[K^d_{oo}][G_o].$$

110. ADD $[K_{aa}]$ and $[K^d_{aa}]$ to form $[K^b_{\ell\ell}]$.

111. ADD $[K_{fs}]$ and $[K^d_{fs}]$ to form $[K^b_{fs}]$.

112. ADD $[K_{ss}]$ and $[K^d_{ss}]$ to form $[K^b_{ss}]$.

113. Go to DMAP No. 123 if no enforced displacements are specified.

114. MPYAD multiplies $[K^b_{ss}]$ and $\{Y_s\}$ to form $\{P_{ss}\}$.

115. MYPAD multiplies $[K^b_{fs}]$ and $\{Y_s\}$ to form $\{P_{fs}\}$.

116. UMERGE combines $\{P_{fs}\}$ and $\{P_{ss}\}$ to form $\{P_n\}$.

117. Equivalence $\{P_n\}$ to $\{P^x_g\}$ if no multipoint constraints exist.

118. Go to DMAP No. 120 if no multipoint constraints exist.

119. UMERGE expands $\{P_n\}$ to form $\{P^x_g\}$.

121. ADD $-\{P^x_g\}$ and $\{P_g\}$ to form $\{P_{gg}\}$.

122. Equivalence $\{P_{gg}\}$ to $\{P_{g1}\}$.

124. ADD $\{P_{g1}\}$ and nothing to create $\{P_{go}\}$.

125. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K^b_{\ell\ell}] = [L^b_{\ell\ell}][U^b_{\ell\ell}].$$

126. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

127. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

128. Beginning of inner (load correction) loop for differential stiffness iteration.

130. SSG2 applies constraints to static load vectors

$$\{P_{g1}\} = \left\{\begin{array}{c}\bar{P}^b_n \\ \hline P^b_m\end{array}\right\} , \qquad \{P^b_n\} = \{\bar{P}^b_n\} + [G^T_m]\{P^b_m\} ,$$

$$\{P^b_n\} = \left\{\begin{array}{c}\bar{P}^b_f \\ \hline P^b_s\end{array}\right\} , \qquad \{P_f\} = \{\bar{P}^b_f\} - [K^d_{fs}]\{Y_s\} ,$$

$$\{P^b_f\} = \left\{\begin{array}{c}\bar{P}^b_a \\ \hline P^b_o\end{array}\right\} \quad \text{and} \quad \{P^b_\ell\} = \{P^b_a\} + [G^T_o]\{P^b_o\} .$$

131. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u^b_\ell\} = [K^b_{\ell\ell}]^{-1}\{P^b_\ell\} ,$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P^b_\ell\} = \{P^b_\ell\} - [K^b_{\ell\ell}]\{u^b_\ell\} ,$$

$$\varepsilon^b_\ell = \frac{\{u^b_\ell\}^T\{\delta P^b_\ell\}}{\{P^b_\ell\}^T\{u^b_\ell\}}$$

132. Go to DMAP No. 134 if the residual vector for current differential stiffness solution is not to be printed.

133. MATGPR prints the residual vector for current differential stiffness solution.

135. SDR1 recovers dependent displacements for the current differential stiffness solution

$$\{u^b_o\} = [G_o]\{u^b_\ell\} + \{u^{ob}_o\} , \qquad \left\{\begin{array}{c}u^b_\ell \\ \hline u^b_o\end{array}\right\} = \{u_f\} ,$$

$$\left\{\begin{array}{c} u_f^b \\ \hline Y_s^b \end{array}\right\} = \{u_n^b\} \quad , \qquad \{u_m^b\} = [G_m]\,\{u_n^b\} \quad ,$$

$$\left\{\begin{array}{c} u_n^b \\ \hline u_m^b \end{array}\right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b]\{u_f^b\} + [K_{ff}^b]\{Y_s^b\} \ .$$

136. ADD $-\{U_g^b\}$ and $\{U_g\}$ to form $\{U_g^d\}$.

137. DSMG1 generates differential stiffness matrix $[\delta K_{gg}^d]$.

138. MYPAD forms the load vector for inner loop iteration

$$\{P_{g_{I1}}\} = [\delta K_{gg}^d]\,\{U_g^b\} + \{P_{go}\}.$$

139. DSCHK performs differential stiffness convergence checks.

140. Go to DMAP No. 151 if differential stiffness iteration is complete.

141. Go to DMAP No. 145 if additional differential stiffness matrix changes are necessary for further iteration.

142. Break the previous equivalence of $\{P_g\}$ to $\{P_{g1}\}$ and $\{P_{g1}\}$ to $\{P_{g_{I1}}\}$ and establish equivalence of $\{P_{g_{I1}}\}$ to $\{P_{g1}\}$.

143. Go to DMAP No. 128 for an additional inner loop differential stiffness iteration.

144. TABPT table prints vectors $\{P_{g_{I1}}\}$, $\{P_{g1}\}$, and $\{P_g\}$.

146. ADD $-[\delta K_{gg}^d]$ and $[K_{gg}^d]$ to form $[K_{gg1}^d]$.

147. Equivalence $\{U_g^b\}$ to $\{U_g\}$ and $[K_{gg1}^d]$ to $[K_{gg}^d]$.

148. Break the previous equivalence of $[K_{gg}^d]$ to $[K_{gg1}^d]$ and $\{U_g\}$ to $\{U_g^b\}$.

149. Go to DMAP No. 95 for an additional outer loop differential stiffness iteration.

150. TABPT table prints $[K_{gg1}^d]$, $[K_{gg}^d]$, and $\{U_g\}$.

152. SDR2 calculates element forces (ØEFB1) and stresses (ØESB1) and prepares displacement vectors (ØUBGV1) and single-point forces of constraint (ØQBG1) for output and translation components of the displacement vector (PUBGV1) for the differential stiffness solution.

153. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

154. Go to DMAP No. 157 if no differential stiffness solution deformed plots are requested.

155. PLØT generates all requested differential stiffness solution deformed structure and contour plots.

156. PRTMSG prints plotter data, engineering data, and contour data for each differential stiffness solution deformed plot generated.

158. Go to DMAP No. 169 and make normal exit.

160. Print Error Message No. 1 and terminate execution.

162. Print Error Message No. 2 and terminate execution.

164. Print Error Message No. 3 and terminate execution.

166. Print Error Message No. 4 and terminate execution.

168. Print Error Message No. 5 and terminate execution.

2.4.3 Output for Static Analysis with Differential Stiffness

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is automatically printed for each differential stiffness loading condition.

Iterative differential stiffness computations are terminated for one of five reasons. Iteration termination reasons are automatically printed in an information message. These reasons have the following meanings:

1. REASON 0 means the iteration procedure was incomplete at the time of exit. This is caused by either an unexpected interruption of the iteration procedure (i.e., system abort) or termination is not scheduled (for the other four reasons) at the completion of the current iteration.
2. REASON 1 means the iteration procedure converged to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
3. REASON 2 means the iteration procedure is diverging from the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
4. REASON 3 means insufficient time remaining to achieve convergence to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
5. REASON 4 means the number of iterations supplied by the user on a PARAM bulk data card has been met. (The default number of iterations is 10.)

Parameter values at the time of exit are automatically output as follows:

1. Parameter DØNE: -1 is normal; + N is the estimate of the number of iterations required to achieve convergence.
2. Parameter SHIFT: +1 indicates a return to the top of the inner loop was scheduled; -1 indicates a return to top of the outer loop was scheduled following the current iteration.
3. Parameter DSEPSI: the value of the ratio of energy error to total energy at the time of exit.

The following output may be requested:

1. Nonzero Components of the applied static load for the linear solution at selected grid points.
2. Displacements and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.

4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.

2.4.4 Case Control Deck for Static Analysis with Differential Stiffness

The following items relate to subcase definition and data selection for Static Analysis with Differential Stiffness:

1. The Case Control Deck must contain two subcases.
2. A static loading condition must be defined above the subcase level with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.
4. Output requests that apply only to the linear solution must appear in the first subcase.
5. Output requests that apply only to the solution with differential stiffness must be placed in the second subcase.
6. Output requests that apply to both solutions, with and without differential stiffness, may be placed above the subcase level.

2.4.5 Parameters for Static Analysis with Differential Stiffness

The following parameters are used in Static Analysis with Differential Stiffness:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. BETAD - optional. The integer value of this parameter is the number of iterations allowed for computing the load correction in the inner (load) loop before shifting to the outer (stiffness) loop, which adjusts the differential stiffness. The default value is 4 iterations.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT,

CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. EPSIØ - optional. The real value of this parameter is used to test the convergence of the iterated differential stiffness. The default value is 10^{-5}.
6. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
7. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
8. NT - optional. The integer value of this parameter limits the cumulative number of iterations in both loops. The default value is 10 iterations.
9. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
11. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.4.6 Rigid Format Error Messages from Static Analysis with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Static Analysis with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED.

No points have been defined with GRID or SPØINT cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

2.5 BUCKLING ANALYSIS

2.5.1 DMAP Sequence for Buckling Analysis

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 05 - BUCKLING ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     LAMA=APPEND/PHIA=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $

   20  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $

   21  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  COND     ERROR1,NOSIMP $

 23  PURGE    OGPST/GENEL $

 24  PARAM    //*ADD*/NOKGGX/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $

 27  COND     JMPKGG,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGG $

 30  COND     JMPMGG,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  LABEL    JMPMGG $

 33  COND     LBL1,GRDPNT $

 34  COND     ERROR5,NOMGG $

 35  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $

 36  OFP      OGPWG,,,,,//S,N,CARDNO $

 37  LABEL    LBL1 $

 38  EQUIV    KGGX,KGG/NOGENL $

 39  COND     LBL11,NOGENL $

 40  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 41  LABEL    LBL11 $

 42  PARAM    //*MPY*/NSKIP/0/0 $

 43  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 44  COND     ERROR6,NOL $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  PARAM    //*AND*/NOSR/SINGLE/REACT $
 46  PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,KDFS/SINGLE/
              QG/NOSR $
 47  COND     LBL4D,REACT $
 48  JUMP     ERROR2 $
 49  LABEL    LBL4D $
 50  COND     LBL4,GENEL $
 51  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 52  COND     LBL4,GPSPFLG $
 53  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 54  OFP      OGPST,,,,,//S,N,CARDNO $
 55  LABEL    LBL4 $
 56  EQUIV    KGG,KNN/MPCF1 $
 57  COND     LBL2,MPCF1 $
 58  MCE1     USET,RG/GM $
 59  MCE2     USET,GM,KGG,,,/KNN,, $
 60  LABEL    LBL2 $
 61  EQUIV    KNN,KFF/SINGLE $
 62  COND     LBL3,SINGLE $
 63  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
 64  LABEL    LBL3 $
 65  EQUIV    KFF,KAA/OMIT $
 66  COND     LBL5,OMIT $
 67  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 68  LABEL    LBL5 $
 69  RBMG2    KAA/LLL $
 70  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/
              PG,,,,/LUSET/1 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 71  EQUIV    PG,PL/NOSET $
 72  COND     LBL10,NOSET $
 73  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
 74  LABEL    LBL10 $
 75  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              1/S,N,EPSI $
 76  COND     LBL9,IRES $
 77  MATGPR   GPL,USET,SIL,RULV//*L* $
 78  MATGPR   GPL,USET,SIL,RUOV//*O* $
 79  LABEL    LBL9 $
 80  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/
              *BKLO* $
 81  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKLO* $
 82  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
 83  SCAN     CASECC,OES1,OEF1/OESF1/*RF* $
 84  OFP      OESF1,,,,,//S,N,CARDNO $
 85  COND     P2,JUMPPLOT $
 86  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
 87  PRTMSG   PLOTX2// $
 88  LABEL    P2 $
 89  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/
              NOSIMP/0/NOGENL/GENEL $
 90  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/
              DSCOSET $
 91  EQUIV    KDGG,KDNN/MPCF1 $
 92  COND     LBL2D,MPCF1 $
 93  MCE2     USET,GM,KDGG,,,/KDNN,,, $
 94  LABEL    LBL2D $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 95  EQUIV    KDNN,KDFF/SINGLE $
 96  COND     LBL3D,SINGLE $
 97  SCE1     USET,KDNN,,,/KDFF,KDFS,,,, $
 98  LABEL    LBL3D $
 99  EQUIV    KDFF,KDAA/OMIT $
101  SMP2     USET,GO,KDFF/KDAA $
102  LABEL    LBL5D $
103  ADD      KDAA,/KDAAM/(-1.0,0.0)/(0.0,0.0) $
104  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/
              LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
              NONLFT/NOTRL/S,N,NOEED//NOUE $
105  COND     ERROR3,NOEED $
106  PARAM    //*MPY*/NEIGV/1/-1 $
107  READ     KAA,KDAAM,,,EED,USET,CASECC/LAMA,PHIA,,OEIGS/*BUCKLING*/
              S,N,NEIGV/2 $
108  OFP      OEIGS,LAMA,,,,//S,N,CARDNO $
109  COND     ERROR4,NEIGV $
110  SDR1     USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,BQG/1/*BKL1* $
111  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,BQG,PHIG,EST,,/
              ,OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*BKL1* $
112  OFP      OPHIG,OBQG1,OBEF1,OBES1,,//S,N,CARDNO $
113  COND     P3,JUMPPLOT $
114  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,
              OBES1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/
              S,N,PFILE $
115  PRTMSG   PLOTX3// $
116  LABEL    P3 $
117  JUMP     FINIS $
118  LABEL    ERROR1 $
119  PRTPARM  //-1/*BUCKLING* $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


120  LABEL    ERROR2 $
121  PRTPARM  //-2/*BUCKLING* $
122  LABEL    ERROR3 $
123  PRTPARM  //-3/*BUCKLING* $
124  LABEL    ERROR4 $
125  PRTPARM  //-4/*BUCKLING* $
126  LABEL    ERROR5 $
127  PRTPARM  //-5/*BUCKLING* $
128  LABEL    ERROR6 $
129  PRTPARM  //-6/*BUCKLING* $
130  LABEL    FINIS $
131  PURGE    DUMMY/MINUS1 $
132  END      $
```

2.5.2 Description of Important DMAP Operations for Buckling Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

22. Go to DMAP No. 118 and print Error Message No. 1 if no structural elements have been defined.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 32 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

33. Go to DMAP No. 37 if no weight and balance information is requested.

34. Go to DMAP No. 126 and print Error Message No. 5 if no mass matrix exists.

35. GPWG generates weight and balance information.

36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

38. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

39. Go to DMAP No. 41 if there are no general elements.

40. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

43. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

44. Go to DMAP No. 128 and print Error Message No. 6 if no independent degrees of freedom are defined.

47. Go to DMAP No. 49 if there are no free-body supports.

48. Go to DMAP No. 120 and print Error Message No. 2.

50. Go to DMAP No. 55 if general elements are present.

52. Go to DMAP No. 55 if no potential grid point singularities exist.

53. GPSP generates a table of potential grid point singularities.

54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

56. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if there are no multipoint constraints.

57. Go to DMAP No. 60 if there are no multipoint constraints.

58. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

62. Go to DMAP No. 64 if no single-point constraints exist.

63. SCE1 partitions out single-point constraints

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

65. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

66. Go to DMAP No. 68 if no omitted coordinates exist.

67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

69. RMBG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

70. SSG1 generates static load vectors $\{P_g\}$.

71. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

72. Go to DMAP No. 74 if no constraints are applied.

73. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{matrix}\bar{P}_n \\ \hline P_m\end{matrix}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{matrix}\bar{P}_f \\ \hline P_s\end{matrix}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\}$$

and $\{P_f\} = \left\{\begin{matrix}P_a \\ \hline P_o\end{matrix}\right\}$ and $\{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\}$.

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.

77. MATGPR prints the residual vector for independent coordinates (RULV).

78. MATGPR prints the residual vector for omitted coordinates (RUØV).

80. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \quad ,$$

$$\left\{\begin{matrix} u_a \\ \hline u_o \end{matrix}\right\} = \{u_f\} \quad , \qquad \left\{\begin{matrix} u_f \\ \hline Y_s \end{matrix}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces(ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

82. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

83. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

84. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

85. Go to DMAP No. 88 if no static solution deformed structure plots are requested.

86. PLØT generates all requested static solution deformed structure and contour plots.

87. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.

89. TA1 generates element tables for use in differential stiffness matrix assembly.

90. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

91. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ if no multipoint constraints exist.

92. Go to DMAP No. 94 if no multipoint constraints exist.

93. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{matrix} \bar{K}_{nn}^d & | & K_{nm}^d \\ \hline K_{mn}^d & | & K_{mm}^d \end{matrix}\right]$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

95. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ if no single-point constraints exist.

96. Go to DMAP No. 98 if no single-point constraints exist.

97. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right].$$

99. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ if no omitted coordinates exist.

100. Go to DMAP No. 102 if no omitted coordinates exist.

101. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right].$$

and performs matrix reduction

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{oa}]^T[G_o] + [G_o]^T[K^d_{oa}] + [G_o]^T[K^d_{oo}][G_o].$$

103. ADD $-[K^d_{aa}]$ and nothing to create $[K^{dm}_{aa}]$.

104. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

105. Go to DMAP No. 122 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.

107. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} + \lambda K^{dm}_{aa}]\{u_a\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component.

108. ØFP formats the eigenvalues (LAMA) and summary of eigenvalue extraction information (ØEIGS) prepared by READ and places them on the system output file for printing.

109. Go to DMAP No. 124 and print Error Message No. 4 if no eigenvalues were found.

110. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\}, \qquad \left\{\begin{array}{c} \phi_a \\ \hline \phi_o \end{array}\right\} = \{\phi_f\},$$

$$\left\{\begin{array}{c} \phi_f \\ \hline \phi_s \end{array}\right\} = \{\phi_n\}, \qquad \{\phi_m\} = [G_m]\{\phi_n\},$$

$$\left\{\begin{array}{c} \phi_n \\ \hline \phi_m \end{array}\right\} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K^T_{fs}]\ \{\phi_f\}$.

111. SDR2 calculates element forces (ØBEF1) and stresses (ØBES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØBQG1) for output and translation components of the eigenvectors (PPHIG) for the buckling solution.

112. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

113. Go to DMAP No. 116 if no buckling solution deformed structure plots are requested.

114. PLØT generates all requested buckling solution deformed structure and contour plots.

115. PRTMSG prints plotter data, engineering data, and contour data for each buckling solution deformed plot generated.

117. Go to DMAP No. 130 and make normal exit.

119. Print Error Message No. 1 and terminate execution.

121. Print Error Message No. 2 and terminate execution.

123. Print Error Message No. 3 and terminate execution.

125. Print Error Message No. 4 and terminate execution.

127. Print Error Message No. 5 and terminate execution.

129. Print Error Message No. 6 and terminate execution.

2.5.3 Output for Buckling Analysis

The summary of the eigenvalues associated with the buckling modes and the summary of the eigenvalue analysis performed, as described in the Normal Mode Analysis rigid format (see Section 2.3.3), are automatically printed.

The following output may be requested:

1. Displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for the static analysis.
2. Forces and stresses in selected elements for the static loading condition.
3. Mode shapes and nonzero components of the single-point forces of constraint at selected grid points for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected buckling modes.
2. Contour plots of stresses and displacements for selected buckling modes.

2.5.4 Case Control Deck for Buckling Analysis

The following items relate to subcase definition and data selection for Buckling Analysis:

1. The Case Control Deck must contain at least two subcases. Subcases beyond the second are used only for output selection.
2. METHØD must appear in the second subcase to select an EIGB card from the Bulk Data Deck.
3. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
4. An SPC set must be selected above the subcase level, unless all constraints are specified on GRID cards.
5. Output requests that apply only to the solution under static load must be placed in the first subcase.
6. Output requests that apply to the buckling solution only must be placed in the second and succeeding subcases. If only two subcases exist, the output requests in the second subcase will be honored for all buckling modes.
7. Output requests that apply to both the static solution and the buckling modes may be placed above the subcase level.

2.5.5 Parameters for Buckling Analysis

The following parameters are used in Buckling Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
5. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.5.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.5.7 Rigid Format Error Messages from Buckling Analysis

The following fatal errors are detected by the DMAP statements in the Buckling Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Buckling Analysis. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGB card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGB set.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUES FØUND.

No buckling modes exist in the range specified by the user.

BUCKLING ANALYSIS ERRØR MESSAGE NØ 5 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

2.6 PIECEWISE LINEAR STATIC ANALYSIS

2.6.1 DMAP Sequence for Piecewise Linear Static Analysis

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 06 - PIECEWISE LINEAR STATIC ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     QG1=APPEND/UGV1=APPEND/KGGSUM=SAVE/PGV1=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $

   20  PARAM    //*AND*/SKPMGG/NOGRAV/V,Y,GRDPNT $

   21  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,ECPT,GPCT/
                LUSET/S,N,NOSIMP/2/S,N,NOGENL/S,N,GENEL $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PARAM    //*AND*/NOELMT/NOGENL/NOSIMP $

 23  COND     ERROR4,NOELMT $

 24  PURGE    KGGX,GPST/NOSIMP/OGPST/GENEL $

 25  COND     LBL1,NOSIMP $

 26  PARAM    //*ADD*/NOKGGX/1/0 $

 27  PARAM    //*ADD*/NOMGG/1/0 $

 28  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/
              C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/
              C,Y,CPQDPLT/C,Y,CTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 29  PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $

 30  COND     JMPKGG,NOKGGX $

 31  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 32  LABEL    JMPKGG $

 33  COND     JMPMGG,NOMGG $

 34  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 35  LABEL    JMPMGG $

 36  COND     LBL1,GRDPNT $

 37  COND     ERROR3,NOMGG $

 38  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/V,Y,WTMASS $

 39  OFP      OGPWG,,,,,//S,N,CARDNO $

 40  LABEL    LBL1 $

 41  PLA1     CSTM,MPT,ECPT,GPCT,DIT,CASECC,EST/KGGXL,ECPTNL,ESTL,ESTNL/S,N,
              KGGLPG/S,N,NPLALIM/S,N,ECPTNLPG/S,N,PLSETNO/S,N,NONLSTR/S,N,
              PLFACT $

 42  COND     ERROR1,ECPTNLPG $

 43  PURGE    ONLES,ESTNL1/NONLSTR $

 44  PARAM    //*ADD*/ALWAYS/-1/0 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  PARAM    //*ADD*/NEVER/1/0 $
 46  EQUIV    KGGX,KGG/NOGENL/KGGXL,KGGL/NOGENL $
 47  COND     LBL11,NOGENL $
 48  SMA3     GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 49  SMA3     GE1,KGGXL/KGGL/LUSET/NOGENL/KGGLPG $
 50  LABEL    LBL11 $
 51  PARAM    //*MPY*/NSKIP/0/0 $
 52  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $
 53  PARAM    //*AND*/NOSR/SINGLE/REACT $
 54  PURGE    KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
              KFS,KSS/SINGLE/QG/NOSR $
 55  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,,,MGG,CASECC,DIT,/PG1,,,,/
              LUSET/1 $
 56  EQUIV    PG1,PL/NOSET $
 57  COND     LBL4,GENEL  $
 58  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 59  COND     LBL4,GPSPFLG $
 60  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 61  OFP      OGPST,,,,,//S,N,CARDNO $
 62  LABEL    LBL4 $
 63  PARAM    //*ADD*/PLACOUNT/1/0 $
 64  EQUIV    KGG,KNN/MPCF1 $
 65  COND     LBL2,MPCF1 $
 66  MCE1     USET,RG/GM $
 67  LABEL    LOOPBGN $
 68  EQUIV    KGG,KNN/MPCF1 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 69  COND      LBL2,MPCF1 $
 70  MCE2      USET,GM,KGG,,,/KNN,,, $
 71  LABEL     LBL2 $
 72  EQUIV     KNN,KFF/SINGLE $
 73  COND      LBL3,SINGLE $
 74  SCE1      USET,KNN,,,/KFF,KFS,KSS,,, $
 75  LABEL     LBL3 $
 76  EQUIV     KFF,KAA/OMIT $
 77  COND      LBL5,OMIT $
 78  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 79  LABEL     LBL5 $
 80  EQUIV     KAA,KLL/REACT $
 81  COND      LBL6,REACT $
 82  RBMG1     USET,KAA,/KLL,KLR,KRR,,, $
 83  LABEL     LBL6 $
 84  DECOMP    KLL/LLL,/1/0/MINDIAGK/DETKLLXX/IDETKLLX/
               S,N,SINGKLLX $
 85  COND      PLALBL4,SINGKLLX $
 86  COND      LBL7,REACT $
 87  RBMG3     LLL,KLR,KRR/DM $
 88  LABEL     LBL7 $
 89  ADD       PG1,/PG/PLFACT $
 90  COND      LBL10,NOSET  $
 91  SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $
 92  LABEL     LBL10  $
 93  SSG3      LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
               PLACOUNT/S,N,EPSI $
```

RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 94  COND      LBL9,IRES   $
 95  MATGPR    GPL,USET,SIL,RULV//*L* $
 96  MATGPR    GPL,USET,SIL,RUOV//*O* $
 97  LABEL     LBL9  $
 98  SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/DELTAUGV,DELTAPG,
               DELTAQG/1/*STATICS* $
 99  PLA2      DELTAUGV,DELTAPG,DELTAQG/UGV1,PGV1,QG1/S,N,PLACOUNT $
100  EQUIV     ESTNL,ESTNL1/NEVER/ECPTNL,ECPTNL1/NEVER $
101  COND      PLALBL2A,NONLSTR $
102  PLA3      CSTM,MPT,DIT,DELTAUGV,ESTNL,CASECC/ONLES,ESTNL1/PLACOUNT/
               PLSETNO $
103  OFP       ONLES,,,,,//S,N,CARDNO $
104  LABEL     PLALBL2A $
105  PARAM     //*SUB*/DIFF/NPLALIM/PLACOUNT $
106  COND      PLALBL5,DIFF $
107  PLA4      CSTM,MPT,ECPTNL,GPCT,DIT,DELTAUGV/KGGNL,ECPTNL1/S,N,PLACOUNT/S,
               N,PLSETNO/S,N,PLFACT $
108  EQUIV     KGGNL,KGGSUM/KGGLPG $
109  COND      PLALBL3,KGGLPG $
110  ADD       KGGNL,KGGL/KGGSUM $
111  LABEL     PLALBL3 $
112  EQUIV     ESTNL1,ESTNL/ALWAYS/ECPTNL1,ECPTNL/ALWAYS/KGGSUM,KGG/ALWAYS $
113  REPT      LOOPBGN,360 $
114  JUMP      ERROR2 $
115  LABEL     PLALBL4 $
116  PRTPARM   //-5/*PLA* $
117  LABEL      PLALBL5 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 6

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118  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG1,UGV1,ESTL,,
               PGV1/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*PLA* $

119  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $

120  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $

121  OFP       OESF1,,,,,//S,N,CARDNO $

122  COND      P2,JUMPPLOT $

123  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,ECPT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

124  PRTMSG    PLOTX2// $

125  LABEL     P2 $

126  JUMP      FINIS $

127  LABEL     ERROR1 $

128  PRTPARM   //-1/*PLA* $

129  LABEL     ERROR2 $

130  PRTPARM   //-2/*PLA* $

131  LABEL     ERROR3 $

132  PRTPARM   //-3/*PLA* $

133  LABEL     ERROR4 $

134  PRTPARM   //-4/*PLA* $

135  LABEL     FINIS $

136  PURGE     DUMMY/MINUS1 $

137  END       $
```

2.6.2 Description of Important DMAP Operations for Piecewise Linear Static Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user intput into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

23. Go to DMAP No. 133 and print Error Message No. 4 if no elements have been defined.

25. Go to DMAP No. 40 if there are no structural elements.

28. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

30. Go to DMAP No. 32 if no stiffness matrix is to be assembled.

31. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

33. Go to DMAP No. 35 if no mass matrix is to be assembled.

34. EMA assembles mass matrix $[M_{gg}]$.

36. Go to DMAP No. 40 if no weight and balance information is requested.

37. Go to DMAP No. 131 and print Error Message No. 3 if no mass matrix exists.

38. GPWG generates weight and balance information.

39. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

41. PLA1 extracts the linear terms from $[K^{x}_{gg}]$ to give $[K^{x\ell}_{gg}]$, extracts the nonlinear entries from the Element Connection and Properties Table to give ECPTNL, and separates the linear and nonlinear entries in the Element Summary Table to give ESTL and ESTNL.

42. Go to DMAP No. 127 and print Error Message No. 1 if no elements have a stress-dependent modulus of elasticity.

46. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ and $[K^{x\ell}_{gg}]$ to $[K^{\ell}_{gg}]$ if there are no general elements.

47. Go to DMAP No. 50 if there are no general elements.

48. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

49. SMA3 adds general elements to $[K_{gg}^{x\ell}]$ to obtain stiffness matrix of linear elements $[K_{gg}^{\ell}]$.

52. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

55. SSG1 generates total static load vector $\{P_g^1\}$.

56. Equivalence $\{P_g^1\}$ to $\{P_\ell\}$ if no constraints are applied.

57. Go to DMAP No. 62 ig general elements are present.

59. Go to DMAP No. 62 if no potential grid point singularities exist.

60. GPSP generates a table of potential grid point singularities.

61. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 71 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. Beginning of loop for additional load increments.

68. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

69. Go to DMAP No. 71 if no multipoint constraints exist.

70. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

72. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

73. Go to DMAP No. 75 if no single-point constraints exist.

74. SCE1 partitions out single-point constraints

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

76. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

77. Go to DMAP No. 79 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

80. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

81. Go to DMAP No. 83 if no free-body supports exist.

82. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right]$$

84. DECØMP decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

85. Go to DMAP No. 115 and print Error Message No. 5 if stiffness matrix $[K_{\ell\ell}]$ is singular (i.e., local plasticity).

86. Go to DMAP No. 88 if no free-body supports exist.

87. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}]^T + [K_{\ell r}][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

89. ADD multiplies total load vector $\{P_g^1\}$ by factor, PLFACT, and adds it to nothing to obtain applied load vector $\{P_g\}$ for current loop.

90. Go to DMAP No. 92 if no constraints are applied.

91. SSG2 applies constraints to static load vectors for current loop

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\}, \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c} \bar{P}_f \\ \hline P_s \end{array}\right\}, \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\frac{\bar{P}_a}{P_o}\right\} , \qquad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\frac{P_\ell}{P_r}\right\}$$

and calculates incremental determinate forces of reaction for current loop

$$\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}.$$

93. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

and $$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

94. Go to DMAP No. 97 if residual vectors are not to be printed.

95. MATGPR prints the residual vector for independent coordinates (RULV).

96. MATGPR prints the residual vector for omitted coordinates (RUØV).

98. SDR1 recovers dependent displacements for current loop

$$\left\{\begin{matrix} u_\ell \\ \hline u_r \end{matrix}\right\} = \{u_a\} \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \ ,$$

$$\left\{\begin{matrix} u_a \\ \hline u_o \end{matrix}\right\} = \{u_f\} \ , \qquad \left\{\begin{matrix} u_f \\ \hline Y_s \end{matrix}\right\} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} = \{u_g\}$$

and recovers single-point forces of constraint for current loop

$$\{\delta q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}.$$

99. PLA2 adds the incremental displacement vector (DELTAUGV) and the incremental single-point forces of constraint vector (DELTAQG) for the current loop to the accumulated sum of these vectors (DELTAPG).

$$\{u_{g_{i+1}}\} = \{\delta u_{g_i}\} + \{u_{g_i}\} \text{ and}$$

$$\{q_{g_{i+1}}\} = \{\delta q_{g_i}\} + \{q_{g_i}\} \ .$$

100. Allocate separate files for ESTNL and ESTNL1 and for ECPTNL and ECPTNL1.

101. Go to DMAP No. 104 if no stress output is requested for nonlinear elements.

102. PLA3 calculates incremental stresses in nonlinear elements (ØNLES) for which an output request has been made and updates the accumulated stresses (ESTNL1) in these elements.

103. ØFP formats the accumulated stresses in nonlinear elements prepared by PLA3 and places them on the system output file for printing.

106. Go to DMAP No. 117 if all loading increments have been completed.

107. PLA4 generates stiffness matrix for nonlinear elements $[K_{gg}^{n\ell}]$ and updates stress information.

108. Equivalence $[K_{gg}^{n\ell}]$ to $[K_{gg}]$ if all elements are nonlinear.

109. Go to DMAP No. 111 if all elements are nonlinear.

110. Add stiffness matrix for nonlinear elements (KGGNL) to stiffness matrix for linear elements (KGGL)

$$[K_{gg}^{n\ell}] + [K_{gg}^{\ell}] + [K_{gg}^{sum}]$$

112. Equivalence existing element tables to updated tables and equivalence $[K_{gg}^{sum}]$ to $[K_{gg}]$ for next pass through loop.

113. Go to DMAP No. 67 if additional load increments need to be processed.

114. Go to DMAP No. 129 and print Error Message No. 2 as the number of load increments exceeds 360.

116. Print Error Message No. 5 and terminate execution.

118. SDR2 calculates element forces (ØEF1) and stresses for linear elements (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

119. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

120. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

121. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

122. Go to DMAP No. 125 if no deformed structure plots are requested.

123. PLØT generates all requested deformed structure and contour plots.

124. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

126. Go to DMAP No. 135 and make normal exit.

128. Print Error Message No. 1 and terminate execution.

130. Print Error Message No. 2 and terminate execution.

132. Print Error Message No. 3 and terminate execution.

134. Print Error Message No. 4 and terminate execution.

2.6.3 Output for Piecewise Linear Static Analysis

The following output may be requested for Piecewise Linear Static Analysis:

1. Accumulated sums of displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for each load increment.
2. Stresses in selected elements. If an element is composed of a nonlinear material, the accumulated stress will be output for each load increment. Stresses in linear elements are only calculated for the total load.
3. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and deformed plots for each load increment.
2. Contour plots of stresses and displacements for each load increment.

2.6.4 Case Control Deck for Piecewise Linear Static Analysis

The following items relate to subcase definition and data selection for Piecewise Linear Static Analysis:

1. The Case Control Deck must contain one and only one subcase.
2. A static loading condition must be defined with a LØAD selection.
3. An SPC set must be selected unless all constraints are specified on GRID cards.
4. PLCØEFFICIENT must appear either to select a PLFACT set from the Bulk Data Deck or to explicitly select the default value of unity.

2.6.5 Parameters for Piecewise Linear Static Analysis

The following parameters are used in Piecewise Linear Static Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
5. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.6.6 Rigid Format Error Messages from Piecewise Linear Static Analysis

The following fatal errors are detected by the DMAP statements in the Piecewise Linear Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 1 - NØ NØNLINEAR ELEMENTS HAVE BEEN DEFINED.

A piecewise linear problem has not been formulated because none of the elements has a stress dependent modulus of elasticity defined on a Material card.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 load increments. This number may be increased by ALTERing the REPT instruction preceding SDR2.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 5 - STIFFNESS MATRIX SINGULAR DUE TØ MATERIAL PLASTICITY.

The stiffness matrix is singular due either to one or more grid point singularities or element material plasticity.

2.7 DIRECT COMPLEX EIGENVALUE ANALYSIS

2.7.1 DMAP Sequence for Direct Complex Eigenvalue Analysis

```
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OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 07 - DIRECT COMPLEX EIGENVALUE ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     GOD=SAVE/GMD=SAVE $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,EST,ECT,PLTSETX,PLTPAR,GPSETS,
                ELSETS/NOGPDT $

    8  COND     LBL5,NOGPDT $

    9  GP2      GEOM2,EQEXIN/ECT $

   10  PARAML   PCDB//*PRES*////JUMPPLOT $

   11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   12  COND     P1,JUMPPLOT $

   13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   14  PRTMSG   PLTSETX// $

   15  PARAM    //*MPY*/PLTFLG/1/1 $

   16  PARAM    //*MPY*/PFILE/0/0 $

   17  COND     P1,JUMPPLOT $

   18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $

   19  PRTMSG   PLOTX1// $

   20  LABEL    P1 $

   21  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
```

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```
 22  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
               LUSET/S,N,NOSIMP=-1/1/S,N,NOGENL=-1/S,N,GENEL $

 23  PURGE     K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
               KGGX/NOSIMP / OGPST/GENEL $

 24  COND      LBL1,NOSIMP $

 25  PARAM     //*ADD*/NOKGGX/1/0 $

 26  PARAM     //*ADD*/NOMGG/1/0 $

 27  PARAM     //*ADD*/NOBGG=-1/1/0 $

 28  PARAM     //*ADD*/NOK4GG/1/0 $

 29  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT,/S,N,
               NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/
               C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/
               C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
               V,Y,VOLUME/V,Y,SURFACE $

 30  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $

 31  COND      LBLKGGX,NOKGGX $

 32  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 33  LABEL     LBLKGGX $

 34  COND      LBLMGG,NOMGG $

 35  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 36  LABEL     LBLMGG $

 37  COND      LBLBGG,NOBGG $

 38  EMA       GPECT,BDICT,BELM/BGG, $

 39  LABEL     LBLBGG $

 40  COND      LBLK4GG,NOK4GG $

 41  EMA       GPECT,KDICT,KELM/K4GG,/NOK4GG $

 42  LABEL     LBLK4GG $

 43  PURGE     MNN,MFF,MAA/NOMGG $

 44  PURGE     BNN,BFF,BAA/NOBGG $
```

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```
 45  COND      LBL1,GRDPNT $
 46  COND      ERROR3,NOMGG $
 47  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
 48  OFP       OGPWG,,,,,//S,N,CARDNO $
 49  LABEL     LBL1 $
 50  EQUIV     KGGX,KGG/NOGENL $
 51  COND      LBL11,NOGENL $
 52  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 53  LABEL     LBL11 $
 54  PARAM     //*MPY*/NSKIP/0/0 $
 55  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
               S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/
               C,Y,ASETOUT/S,Y,AUTOSPC $
 56  PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,QPC/SINGLE $
 57  COND      LBL4,GENEL $
 58  COND      LBL4,NOSIMP $
 59  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $
 60  COND      LBL4,GPSPFLG $
 61  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 62  OFP       OGPST,,,,,//S,N,CARDNO $
 63  LABEL     LBL4 $
 64  EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
 65  COND      LBL2,MPCF1 $
 66  MCE1      USET,RG/GM $
 67  MCE2      USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
 68  LABEL     LBL2 $
 69  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

```
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 70  COND     LBL3,SINGLE $
 71  SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
 72  LABEL    LBL3 $
 73  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT/BFF,BAA/OMIT/K4FF,K4AA/OMIT $
 74  COND     LBL5,OMIT $
 75  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 76  COND     LBLM,NOMGG $
 77  SMP2     USET,GO,MFF/MAA $
 78  LABEL    LBLM $
 79  COND     LBLB,NOBGG $
 80  SMP2     USET,GO,BFF/BAA $
 81  LABEL    LBLB $
 82  COND     LBL5,NOK4GG $
 83  SMP2     USET,GO,K4FF/K4AA $
 84  LABEL    LBL5 $
 85  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/
              LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
              NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $
 86  COND     ERROR1,NOEED $
 87  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 88  PARAM    //*ADD*/NEVER/1/0 $
 89  PARAM    //*MPY*/REPEATE/1/-1 $
 90  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/
              S,N,MFACT $
 91  PARAM    //*AND*/NOFL/NOABFL/NOKBFL $
 92  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
 93  COND     LBL13,NOFL $
 94  MTRXIN,  ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/
              0 $
```

```
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 95  LABEL    LBL13 $
 96  PURGE    PHID,CLAMA,OPHID,OQPC1,OCPHIP,OESC1,OEFC1,CPHIP,QPC,
              K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $
 97  CASE     CASECC,/CASEXX/*CEIGN*/S,N,REPEATE/S,N,NOLOOP $
 98  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
              NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
 99  PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $
100  PARAM    //*AND*/NOK2PP/NOFL  /NOK2DPP $
101  EQUIV    K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
102  COND     LBLFL2,NOFL $
103  ADD5     ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
104  COND     LBLFL2,NOABFL $
105  TRNSP    ABFL/ABFLT $
106  ADD      ABFLT,M2DPP/M2PP/MFACT $
107  LABEL    LBLFL2 $
108  PARAM    //*AND*/BDEBA/NOUE/NOB2PP $
109  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
110  PARAM    //*AND*/KDEK2/NOGENL/NOSIMP $
111  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
112  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/
               MAA,MDD/MDEMA/BAA,BDD/BDEBA $
113  COND     LBL18,NOGPDT $
114  GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/*CMPLEV*/*DISP*/*DIRECT*/C,Y,G=0.0/
              0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
              MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/
              KDEK2/-1 $
115  LABEL    LBL18 $
116  EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $
117  CEAD     KDD,BDD,MDD,EED,CASEXX/PHID,CLAMA,OCEIGS,/S,N,EIGVS $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 7

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


118  OFP       OCEIGS,CLAMA,,,,//S,N,CARDNO $

119  COND      LBL16,EIGVS $

120  VDR       CASEXX,EQDYN,USETD,PHID,CLAMA,,/OPHID,/*CEIGN*/*DIRECT*/
               O/S,N,NOD/S,N,NOP/O $

121  COND      LBL15,NOD $

122  OFP       OPHID,,,,,//S,N,CARDNO $

123  LABEL     LBL15 $

124  COND      LBL16,NOP $

125  EQUIV     PHID,CPHIP/NOA $

126  COND      LBL17,NOA $

127  SDR1      USETD,, PHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $

128  LABEL     LBL17 $

129  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,CLAMA,QPC,CPHIP,EST,,/,OQPC1,
               OCPHIP,OESC1,OEFC1,/*CEIG* $

130  OFP       OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $

131  LABEL     LBL16 $

132  COND      FINIS,REPEATE $

133  REPT      LBL13,100 $

134  PRTPARM   //-2/*DIRCEAD* $

135  JUMP      FINIS $

136  LABEL     ERROR1 $

137  PRTPARM   //-1/*DIRCEAD* $

138  LABEL     ERROR3 $

139  PRTPARM   //-3/*DIRCEAD* $

140  LABEL     FINIS $

141  PURGE     DUMMY/MINUS1 $

142  END       $
```

2.7.2 Description of Important DMAP Operations for Direct Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 84 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K^{4}_{gg}]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 138 and print Error Message No. 3 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right], \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K^4_{nn}]$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right], \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right],$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right].$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$, $[M_{ff}]$ to $[M_{aa}]$, $[B_{ff}]$ to $[B_{aa}]$ and $[K_{ff}]^4$ to $[K^4_{aa}]$ if no omitted coordinates exist.

74. Go to DMAP No. 84 if no omitted coordinates exist.

75. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}][G_o]$.

76. Go to DMAP No. 78 if no mass matrix exists.

77. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

79. Go to DMAP No. 84 if no viscous damping matrix exists.

80. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} \bar{B}_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right],$$

and performs matrix reduction

$$[B_{aa}] = [\bar{B}_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o] \quad .$$

82. Go to DMAP No. 84 if no structural damping matrix exists.

83. SMP2 partitions constrained structural damping matrix

$$[K^4_{ff}] = \left[\begin{array}{c|c} \bar{K}^4_{aa} + K^4_{ao} \\ \hline K^4_{oa} \;|\; K^4_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[K^4_{aa}] = [K^4_{aa}] + [K^4_{ao}][G_o] + [K^4_{ao}G_o]^T + [G_o^T][K^4_{oo}][G_o]$$

85. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

86. Go to DMAP No. 136 and print Error Message No. 1 if there is no Eigenvalue Extraction Data.

87. Equivalence $[G_o]$ to $[G^d_o]$ and $[G_m]$ to $[G^d_m]$ if there are no extra points introduced for dynamic analysis.

90. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

93. Go to DMAP No. 95 if no fluid-structure interface is defined.

94. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the fluid.

95. Beginning of loop for additional sets of direct input matrices.

97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

98. MTRXIN selects the direct input matrices $[K^{2d}_{pp}]$, $[M^{2d}_{pp}]$ and $[B^2_{pp}]$ for the current loop.

101. Equivalence $[K^2_{pp}]$ to $[K^{2d}_{pp}]$ if no fluid-structure interface is defined and equivalence $[M^2_{pp}]$ to $[M^{2d}_{pp}]$ if there is no $[A_{b,f\ell}]$.

102. Go to DMAP No. 107 if no fluid-structure interface is defined.

103. ADD5 adds $[K_{b,f\ell}]$ and $[K^{2d}_{pp}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K^2_{pp}]$.

104. Go to DMAP No. 107 if there is no $[A_{b,f\ell}]$.

105. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

106. ADD assembles input matrix $[M^2_{pp}]$ = MFACT $[A_{b,f\ell}]^T$ + $[M^{2d}_{pp}]$.

112. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[B_{aa}]$ to $[B_{dd}]$ if there are no direct input damping matrices and no extra points.

113. Go to DMAP No. 115 if only extra points are defined.

114. GKAD assembles stiffness, mass and damping matrices for use in Direct Complex Eigenvalue Analysis

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}] ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad \text{and}$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

Direct input matrices may be complex.

116. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B^2_{dd}]$ to $[B_{dd}]$ is all damping is Direct Matrix Input.

117. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}] \{u_d\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit magnitude of a selected component
2) Unit magnitude of the largest component.

118. ØFP formats the summary of complex eigenvalues (CLAMA) and summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places them on the system output file for printing.

119. Go to DMAP No. 131 if no eigenvalues were found.

120. VDR prepares eigenvectors for output, using only the independent degrees of freedom.

121. Go to DMAP No. 123 if there is no output request for independent degrees of freedom.

122. ØFP formats the eigenvectors for independent degrees of freedom prepared by VDR and places them on the system output file for printing.

124. Go to DMAP No. 131 if there is no output request involving dependent degrees of freedom or forces and stresses.

125. Equivalence $\{\phi_d\}$ to $\{\phi_p\}$ if no constraints are applied.

126. Go to DMAP No. 128 if no constraints are applied.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_d\} \quad , \qquad \left\{\begin{matrix}\phi_d \\ \hline \phi_o\end{matrix}\right\} = \{\phi_f + \phi_e\} \quad ,$$

$$\left\{\begin{matrix}\phi_f + \phi_e \\ \hline \phi_s\end{matrix}\right\} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + \phi_e\} \quad ,$$

$$\left\{\begin{matrix}\phi_n + \phi_e \\ \hline \phi_m\end{matrix}\right\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$.

129. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output.

130. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

132. Go to DMAP No. 140 if no additional sets of direct input matrices need to be processed.

133. Go to DMAP No. 95 if additional sets of direct input matrices need to be processed.

134. Print Error Message No. 2 and terminate execution.

135. Go to DMAP No. 140 and make normal exit.

137. Print Error Message No. 1 and terminate execution.

139. Print Error Message No. 3 and terminate execution.

2.7.3 Output for Direct Complex Eigenvalue Analysis

Each complex eigenvalue is identified with a root number determined by sorting the complex eigenvalues according to the magnitude of the imaginary part, with positive values considered as a group ahead of all negative values. The following summary of the complex eigenvalues extracted is automatically printed for each set of direct input matrices:

1. Root Number
2. Extraction Order
3. Real and Imaginary Parts of the Eigenvalue
4. The coefficients f_j (frequency) and g_j (damping coefficient) in the following representation of the eigenvalue

$$P_j = 2\pi f_j(i - \frac{1}{2} g_j)$$

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed for each set of direct input matrices:

1. Number of eigenvalues extracted
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Number of predictions outside region.
8. Reason for termination:
   (1) The number of roots desired have been found.
   (2) All predictions for eigenvalues are outside the regions specified.
   (3) Insufficient time to find another root.
   (4) Matrix is singular at first three starting points.
9. Swept determinant functions for each starting point.

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed for each region specified:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.

5. Number of vector iterations.
6. Reason for termination.
   (1) Two consecutive singularities encountered while performing triangular decomposition.
   (2) Four starting point moves while tracking a single root.
   (3) All eigenvalues found in the region specified.
   (4) Three times the number of roots estimated in the region have been extracted.
   (5) All eigenvalues that exist in the problem have been found.
   (6) The number of roots desired have been found.
   (7) One or more eigenvalues have been found outside the region specified.
   (8) Insufficient time to find another root.
   (9) Unable to converge.

The following summary of the eigenvalue analysis performed, using the complex Tridiagonal Reduction (FEER) method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.
   This corresponds to the total number of random starting and restart vectors used by the complex FEER process for all neighborhoods.
3. Number of starting point moves.
   Not used in FEER (set equal to zero).
4. Number of triangular decompositions.
   Always equal to the number of points of interest (neighborhoods) in the complex plane processed by FEER, since ordinarily only one triangular decomposition is required by FEER for each point of interest, unless the dynamic matrix is singular at a given point of interest, in which case an additional decomposition is required (obtained by moving the point of interest slightly).
5. Total number of vector iterations.
   The total number of reorthogonalizations of all the trial vectors employed.
6. Reason for termination.
   (0) All, or more solutions than the number requested by the user, have been determined (normal termination).

(1) All neighborhoods have been processed, but FEER has not obtained the desired number of roots in each neighborhood, possibly because they have already been found in other neighborhoods.

(2) Abnormal termination - either no roots found or none passes the FEER error test.

The following printed output, sorted by complex eigenvalue root number (SØRT1), may be requested for any complex eigenvalue extracted, as either real and imaginary parts or magnitude and phase angle (0° - 360° lead):

1. The eigenvector for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements.

In addition, an undeformed plot of the structural model may be requested.

2.7.4 Case Control Deck for Direct Complex Eigenvalue Analysis

The following items relate to subcase definition and data selection for Direct Complex Eigenvalue Analysis:

1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP).
2. Multiple subcases for each set of direct input matrices are used only to control output requests. A single subcase for each set of direct input matrices is sufficient if the same output is desired for all modes. If consecutive multiple subcases are present for a single set of direct input matrices, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.
3. CMETHØD must be used to select an EIGC card from the Bulk Data Deck for each set of direct input matrices.
4. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and either CMETHØD must be changed to select an EIGC card that reflects any complex eigenvalues found in the previous execution or EIGP cards must be used to insert poles

for previously found eigenvalues. Otherwise, the previously found eigenvalues will be extracted again.

5. Constraints must be defined above the subcase level.

2.7.5 Parameters for Direct Complex Eigenvalue Analysis

The following parameters are used in Direct Complex Eigenvalue Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.7.6 Rigid Format Error Messages from Direct Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Direct Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR CØMPLEX EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGC card in the Bulk Data Deck and CMETHØD in the Case Control Deck must select an EIGC set.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERing the REPT instruction following SDR2.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

2.8 DIRECT FREQUENCY AND RANDOM RESPONSE

2.8.1 DMAP Sequence for Direct Frequency and Random Response

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OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 08 - DIRECT FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     KGGX=TAPE/KGG=TAPE/GOD=SAVE/GMD=SAVE/MDD=SAVE/BDD=SAVE $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/ALWAYS=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,PSF,QPC,EST,ECT,PLTSETX,PLTPAR,
                GPSETS,ELSETS/NOGPDT $

    8  COND     LBL5,NOGPDT $

    9  GP2      GEOM2,EQEXIN/ECT $

   10  PARAML   PCDB//*PRES*////JUMPPLOT $

   11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   12  COND     P1,JUMPPLOT $

   13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   14  PRTMSG   PLTSETX// $

   15  PARAM    //*MPY*/PLTFLG/1/1 $

   16  PARAM    //*MPY*/PFILE/0/0 $

   17  COND     P1,JUMPPLOT $

   18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   19  PRTMSG   PLOTX1//$

   20  LABEL    P1 $

   21  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
               LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

 23  PURGE     K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
               KGGX/NOSIMP/OGPST/GENEL $

 24  COND      LBL1,NOSIMP $

 25  PARAM     //*ADD*/NOKGGX/1/0 $

 26  PARAM     //*ADD*/NOMGG/1/0 $

 27  PARAM     //*ADD*/NOBGG=-1/1/0 $

 28  PARAM     //*ADD*/NOK4GG/1/0 $

 29  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT,/
               S,N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/
               C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/
               C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
               V,Y,VOLUME/V,Y,SURFACE $

 30  PURGE     GPST/NOKGGX/MGG/NOMGG $

 31  COND      LBLKGGX,NOKGGX $

 32  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 33  LABEL     LBLKGGX $

 34  COND      LBLMGG,NOMGG $

 35  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 36  LABEL     LBLMGG $

 37  COND      LBLBGG,NOBGG $

 38  EMA       GPECT,BDICT,BELM/BGG, $

 39  LABEL     LBLBGG $

 40  COND      LBLK4GG,NOK4GG $

 41  EMA       GPECT,KDICT,KELM/K4GG,/NOK4GG $

 42  LABEL     LBLK4GG $

 43  PURGE     MNN,MFF,MAA/NOMGG $

 44  PURGE     BNN,BFF,BAA/NOBGG $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  COND      LBL1,GRDPNT $
 46  COND      ERROR4,NOMGG $
 47  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 48  OFP       OGPWG,,,,,//S,N,CARDNO $
 49  LABEL     LBL1 $
 50  EQUIV     KGGX,KGG/NOGENL $
 51  COND      LBL11,NOGENL $
 52  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 53  LABEL     LBL11 $
 54  PARAM     //*MPY*/NSKIP/0/0 $
 55  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
               S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
               S,Y,AUTOSPC $
 56  PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
 57  COND      LBL4,GENEL $
 58  COND      LBL4,NOSIMP $
 59  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $
 60  COND      LBL4,GPSPFLG $
 61  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 62  OFP       OGPST,,,,,//S,N,CARDNO $
 63  LABEL     LBL4 $
 64  EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
 65  COND      LBL2,MPCF1 $
 66  MCE1      USET,RG/GM $
 67  MCE2      USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
 68  LABEL     LBL2 $
 69  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 70  COND     LBL3,SINGLE $
 71  SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
 72  LABEL    LBL3 $
 73  EQUIV    KFF,KAA/OMIT $
 74  EQUIV    MFF,MAA/OMIT $
 75  EQUIV    BFF,BAA/OMIT $
 76  EQUIV    K4FF,K4AA/OMIT $
 77  COND     LBL5,OMIT $
 78  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 79  COND     LBLM,NOMGG $
 80  SMP2     USET,GO,MFF/MAA $
 81  LABEL    LBLM $
 82  COND     LBLB,NOBGG $
 83  SMP2     USET,GO,BFF/BAA $
 84  LABEL    LBLB $
 85  COND     LBL5,NOK4GG $
 86  SMP2     USET,GO,K4FF/K4AA $
 87  LABEL    LBL5 $
 88  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,,
              EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/S,N,
              NOFRL/NONLFT/NOTRL/NOEED//S,N,NOUE $
 89  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 90  PARAM    //*ADD*/NEVER/1/0 $
 91  PARAM    //*MPY*/REPEATF/-1/1 $
 92  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/
              S,N,MFACT $
 93  PARAM    //*AND*/NOFL/NOABFL/NOKBFL $
 94  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 95  COND      LBL13,NOFL $

 96  MTRXIN,   ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/
               0 $

 97  LABEL     LBL13 $

 98  PURGE     OUDVC1,OUDVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,
               OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,
               K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $

 99  CASE      CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $

100  MTRXIN    CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
               NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $

101  PARAM     //*AND*/NOM2PP/NOABFL/NOM2DPP $

102  PARAM     //*AND*/NOK2PP/NOFL  /NOK2DPP $

103  EQUIV     K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $

104  COND      LBLFL2,NOFL $

105  ADD5      ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $

106  COND      LBLFL2,NOABFL $

107  TRNSP     ABFL/ABFLT $

108  ADD       ABFLT,M2DPP/M2PP/MFACT $

109  LABEL     LBLFL2 $

110  PARAM     //*AND*/BDEBA/NOUE/NOB2PP $

111  PARAM     //*AND*/KDEK2/NOGENL/NOSIMP $

112  PARAM     //*AND*/MDEMA/NOUE/NOM2PP $

113  PURGE     K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $

114  EQUIV     M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/
               MAA,MDD/MDEMA/BAA,BDD/BDEBA $

115  COND      LBL18,NOGPDT $

116  GKAD      USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
               GOD,K2DD,M2DD,B2DD/*FREQRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/
               0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
               MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/
               KDEK2/-1 $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


117  LABEL    LBL18 $

118  EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $

119  COND     ERROR1,NOFRL $

120  COND     ERROR2,NODLT $

121  FRRD     CASEXX,USETD,DLT,FRL,GMD,GOD,KDD,BDD,MDD,,DIT/UDVF,PSF,PDF,PPF/
              *DISP*/*DIRECT*/LUSETD/MPCF1/SINGLE/OMIT/
              NONCUP/FRQSET $

122  EQUIV    PPF,PDF/NOSET $

123  VDR      CASEXX,EQDYN,USETD,UDVF,PPF,XYCDB,/OUDVC1,/*FREQRESP*/
              *DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/0 $

124  COND     LBL15,NOD $

125  COND     LBL15A,NOSORT2 $

126  SDR3     OUDVC1,,,,,/OUDVC2,,,,, $

127  OFP      OUDVC2,,,,,//S,N,CARDNO $

128  XYTRAN   XYCDB,OUDVC2,,,,/XYPLTFA/*FREQ*/*DSET*/S,N,PFILE/
              S,N,CARDNO $

129  XYPLOT   XYPLTFA// $

130  JUMP     LBL15 $

131  LABEL    LBL15A $

132  OFP      OUDVC1,,,,,//S,N,CARDNO $

133  LABEL    LBL15 $

134  COND     LBL20,NOP $

135  EQUIV    UDVF,UPVC/NOA $

136  COND     LBL19,NOA $

137  SDR1     USETD,,UDVF,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $

138  LABEL    LBL19 $

139  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,XYCDB,
              PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/
              S,N,NOSORT2 $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


140  COND      LBL17,NOSORT2 $

141  SDR3      OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,
               OEFC2, $

142  OFP       OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $

143  XYTRAN    XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/
               S,N,PFILE/S,N,CARDNO $

144  XYPLOT    XYPLTF// $

145  COND      LBL16,NOPSDL $

146  RANDOM    XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
               S,N,NORD $

147  COND      LBL16,NORD $

148  XYTRAN    XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/
               S,N,CARDNO $

149  XYPLOT    XYPLTR// $

150  JUMP      LBL16 $

151  LABEL     LBL17 $

152  PURGE     PSDF/NOSORT2 $

153  OFP       OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $

154  LABEL     LBL16 $

155  PURGE     PSDF/NOPSDL $

156  COND      LBL20,JUMPPLOT $

157  PLOT      PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVC1,
               GPECT,OESC1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/
               S,N,PFILE $

158  PRTMSG    PLOTX2// $

159  LABEL     LBL20 $

160  COND      FINIS,REPEATF $

161  REPT      LBL13,100 $

162  PRTPARM   //-3/*DIRFRRD* $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


163  JUMP     FINIS $
164  LABEL    ERROR2 $
165  PRTPARM  //-2/*DIRFRRD* $
166  LABEL    ERROR1 $
167  PRTPARM  //-1/*DIRFRRD* $
168  LABEL    ERROR4 $
169  PRTPARM  //-4/*DIRFRRD* $
170  LABEL    FINIS $
171  PURGE    DUMMY/ALWAYS $
172  END      $
```

2.8.2 Description of Important DMAP Operations for Direct Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 87 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K^{4}_{gg}]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 168 and print Error Message No. 4 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right], \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right],$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K_{nn}]^4$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right], \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right],$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right].$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

74. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

75. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.

76. Equivalence $[K^4_{ff}]$ to $[K^4_{aa}]$ if no omitted coordinates exist.

77. Go to DMAP No. 87 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}][G_o]$.

79. Go to DMAP No. 81 if no mass matrix exists.

80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

82. Go to DMAP No. 84 if no viscous damping matrix exists.

83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} \bar{B}_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right],$$

and performs matrix reduction

$$[B_{aa}] = [\bar{B}_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

85. Go to DMAP No. 87 if no structural damping matrix exists.

86. SMP2 partitions constrained structural damping matrix

$$[K^4_{ff}] = \left[\begin{array}{c|c} \bar{K}^4_{aa} + K^4_{ao} \\ \hline K^4_{oa} \quad K^4_{oo} \end{array}\right]$$

and performs matrix reduction

$$[K^4_{aa}] = [\bar{K}^4_{aa}] + [K^4_{ao}][G_o] + [K^4_{ao}G_o]^T + [G_o^T][K^4_{oo}][G_o] \quad .$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers, including extra points introduced for dynamic analysis, and prepares Transfer Function Pool, Dynamics Load Table, Power Spectral Density List and Frequency Response List.

89. Equivalence $[G_o]$ to $[G^d_o]$ and $[G_m]$ to $[G^d_m]$ if there are no extra points introduced for dynamic analysis.

92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

95. Go to DMAP No. 97 if no fluid-structure interface is defined.

96. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the fluid.

97. Beginning of loop for additional sets of direct input matrices.

99. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

100. MTRXIN selects the direct input matrices $[K^{2d}_{pp}]$, $[M^{2d}_{pp}]$ and $[B^2_{pp}]$ for the current loop.

103. Equivalence $[K^2_{pp}]$ to $[K^{2d}_{pp}]$ if no fluid-structure interface is defined and equivalence $[M^2_{pp}]$ to $[M^{2d}_{pp}]$ if there is no $[A_{b,f\ell}]$.

104. Go to DMAP No. 109 if no fluid-structure interface is defined.

105. ADD5 adds $[K_{b,f\ell}]$ and $[K^{2d}_{pp}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K^2_{pp}]$.

106. Go to DMAP No. 109 if there is no $[A_{b,f\ell}]$.

107. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

108. ADD assembles input matrix $[M^2_{pp}]$ = MFACT $[A_{b,f\ell}]^T + [M^{2d}_{pp}]$.

114. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[B_{aa}]$ to $[B_{dd}]$ if there are no direct input damping matrices and no extra points.

115. Go to DMAP No. 117 if only extra points are defined.

116. GKAD assembles stiffness, mass and damping matrices for use in Direct Frequency Response:

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}] ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad \text{and}$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

Direct input matrices may be complex.

118. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B^2_{dd}]$ to $[B_{dd}]$ is all damping is Direct Matrix Input.

119. Go to DMAP No. 166 and print Error Message No. 1 if there is no Frequency Response List.

120. Go to DMAP No. 164 and print Error Message No. 2 if there is no Dynamics Load Table.

121. FRRD forms the dynamic load vectors $\{P_d\}$ and solves for the displacements using the following equation

$$[-M_{dd}\omega^2 + iB_{dd}\omega + K_{dd}] \{u_d\} = \{P_d\} .$$

122. Equivalence $\{P_p\}$ to $\{P_d\}$ if no constraints are applied.

123. VDR prepares solution set displacements, sorted by frequency, for output.

124. Go to DMAP No. 133 if there is no output request for the solution set.

125. Go to DMAP No. 131 if there is no output request for solution set displacements sorted by point number.

126. SDR3 sorts the solution set displacements by point number.

127. ØFP formats the requested solution set displacements, sorted by point number, prepared by SDR3 and places them on the system output file for printing.

128. XYTRAN prepares the input for requested X-Y plots of the solution set displacements vs. frequency.

129. XYPLØT prepares the requested X-Y plots of the solution set displacements vs. frequency.

130. Go to DMAP No. 133.

132. ØFP formats the requested solution set displacements, sorted by frequency, prepared by VDR and places them on the system output file for printing.

134. Go to DMAP No. 159 if there is no output request involving dependent degrees of freedom or forces and stresses.

135. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

136. Go to DMAP No. 138 if no constraints are applied.

137. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \left\{\begin{matrix} u_d \\ \hline u_o \end{matrix}\right\} = \{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_f + u_e \\ \hline u_s \end{matrix}\right\} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_n + u_e \\ \hline u_m \end{matrix}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

139. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1) and single-point forces of constraint (ØQPC1) for output and translation components of the displacement vector (PUGVC1), sorted by frequency.

140. Go to DMAP No. 151 if there are no output requests sorted by point number or element number.

141. SDR3 prepares requested output sorted by point number or element number.

142. ØFP formats the tables prepared by SDR3 sorted by point number or element number, and places them on the system output file for printing.

143. XYTRAN prepares the input for requested X-Y plots.

144. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.

145. Go to DMAP No. 154 if there is no Power Spectral Density List.

146. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

147. Go to DMAP No. 154 if no RANDØM calculations are requested.

148. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

149. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

150. Go to DMAP No. 154.

153. ØFP formats the frequency response output requests prepared by SDR2, sorted by frequency, and places them on the system output file for printing.

156. Go to DMAP No. 159 if no deformed structure plots are requested.

157. PLØT prepares all requested deformed structure and contour plots.

158. PRTMSG prints plotter data, engineering data and contour data for each deformed plot generated.

160. Go to DMAP No. 170 if no additional sets of direct input matrices need to be processed.

161. Go to DMAP No. 97 if additional sets of direct input matrices need to be processed.

162. Print Error Message No. 3 and terminate execution.

163. Go to DMAP No. 170 and make normal exit.

165. Print Error Message No. 2 and terminate execution.

167. Print Error Message No. 1 and terminate execution.

169. Print Error Message No. 4 and terminate execution.

2.8.3 Output for Direct Frequency and Random Response

The following printed output, sorted by frequency (SØRT1) or by point number or element number (SØRT2), is available, either as real and imaginary parts or magnitude and phase angle (0° - 360° lead), for the list of frequencies specified by ØFREQUENCY:

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements (ALL available only for SØRT1).

The following plotter output is available for Frequency Response calculations:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected frequencies.
3. Contour plots of stresses and displacements for selected frequencies.
4. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or SØLUTIØN point.
5. X-Y plot of any component of the applied load vector or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Section 4.3). This is the only form of printed output that is available for Random Response. Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

2.8.4 Case Control Deck for Direct Frequency and Random Response

The following items relate to subcase definition and data selection for Direct Frequency and Random Response:

1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
2. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading conditions - one subcase for each dynamic loading condition.
3. Constraints must be defined above the subcase level.
4. DLØAD must be used to define a frequency-dependent loading condition for each subcase.
5. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card from the Bulk Data Deck for each unique set of direct input matrices.
6. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and FREQUENCY must be changed to select a FREQ, FREQ1, or FREQ2 card that reflects any frequencies for which the response has already been determined. Otherwise, the previous calculations will be repeated.
7. ØFREQUENCY may be used above the subcase level or within each subcase to select a subset of the solution frequencies for output requests. The default is to use all solution frequencies.
8. If Random Response calculations are desired, RANDØM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one ØFREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

2.8.5 Parameters for Direct Frequency and Random Response

The following parameters are used in Direct Frequency and Random Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.

5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.8.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Frequency and Random Response, Rigid Format 8, are ALTERed in automated substructure analyses.

Phase 1: 4, 56, 88-120, 121-162

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 111-112, 118-118, 135-158

Phase 3: 87, 90-136, 138, 160-162

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

2.8.7 Rigid Format Error Messages from Direct Frequency and Random Response

The following fatal errors are detected by the DMAP statements in the Direct Frequency and Random Reponse rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 1 - FREQUENCY RESPØNSE LIST REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ,

FREQ1, or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 2 - DYNAMIC LØADS TABLE REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLØAD1 or RLØAD2 card in the Bulk Data Deck and DLØAD in the Case Control Deck must select a dynamic load set.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERing the REPT instruction following the last ØFP instruction.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

2.9 DIRECT TRANSIENT RESPONSE

2.9.1 DMAP Sequence for Direct Transient Response

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 09 - DIRECT TRANSIENT RESPONSE ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     UDVT=APPEND/TOL=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/ALWAYS=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,PST,KFS,QP,EST,ECT,PLTSETX,PLTPAR,
                GPSETS,ELSETS/NOGPDT $

    8  COND     LBL5,NOGPDT $

    9  GP2      GEOM2,EQEXIN/ECT $

   10  PARAML   PCDB//*PRES*////JUMPPLOT $

   11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   12  COND     P1,JUMPPLOT $

   13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   14  PRTMSG   PLTSETX// $

   15  PARAM    //*MPY*/PLTFLG/1/1 $

   16  PARAM    //*MPY*/PFILE/0/0 $

   17  COND     P1,JUMPPLOT $

   18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   19  PRTMSG   PLOTX1// $

   20  LABEL    P1 $

   21  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
               LUSET/S,N,NOSIMP=-1/1/S,N,NOGENL=-1/S,N,GENEL $

 23  PURGE     K4GG,GPST,OGPST,MGG,BGG,
               K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,KGGX/NOSIMP/
               OGPST/GENEL $

 24  COND      LBL1,NOSIMP $

 25  PARAM     //*ADD*/NOKGGX/1/0 $

 26  PARAM     //*ADD*/NOMGG/1/0 $

 27  PARAM     //*ADD*/NOBGG=-1/1/0 $

 28  PARAM     //*ADD*/NOK4GG/1/0 $

 29  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT,/
               S,N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/
               C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/
               C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
               V,Y,VOLUME/V,Y,SURFACE $

 30  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $

 31  COND      LBLKGGX,NOKGGX $

 32  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 33  LABEL     LBLKGGX $

 34  COND      LBLMGG,NOMGG $

 35  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 36  LABEL     LBLMGG $

 37  COND      LBLBGG,NOBGG $

 38  EMA       GPECT,BDICT,BELM/BGG, $

 39  LABEL     LBLBGG $

 40  COND      LBLK4GG,NOK4GG $

 41  EMA       GPECT,KDICT,KELM/K4GG,/NOK4GG $

 42  LABEL     LBLK4GG $

 43  PURGE     MNN,MFF,MAA/NOMGG $

 44  PURGE     BNN,BFF,BAA/NOBGG $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  COND      LBL1,GRDPNT $

 46  COND      ERROR3,NOMGG $

 47  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 48  OFP       OGPWG,,,,,//S,N,CARDNO $

 49  LABEL     LBL1  $

 50  EQUIV     KGGX,KGG/NOGENL $

 51  COND      LBL11,NOGENL $

 52  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 53  LABEL     LBL11 $

 54  PARAM     //*MPY*/NSKIP/0/0 $

 55  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
               S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
               S,Y,AUTOSPC $

 56  PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PST,QP/SINGLE $

 57  COND      LBL4,GENEL $

 58  COND      LBL4,NOSIMP $

 59  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $

 60  COND      LBL4,GPSPFLG $

 61  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $

 62  OFP       OGPST,,,,,//S,N,CARDNO $

 63  LABEL     LBL4 $

 64  EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $

 65  COND      LBL2,MPCF1 $

 66  MCE1      USET,RG/GM $

 67  MCE2      USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN  $

 68  LABEL     LBL2 $

 69  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  COND      LBL3,SINGLE $
 71  SCE1      USET,KNN,MNN,BNN,K4NN/KFF,KFS,    ,MFF,BFF,K4FF $
 72  LABEL     LBL3 $
 73  EQUIV     KFF,KAA/OMIT $
 74  EQUIV     MFF,MAA/OMIT $
 75  EQUIV     BFF,BAA/OMIT $
 76  EQUIV     K4FF,K4AA/OMIT $
 77  COND      LBL5,OMIT $
 78  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 79  COND      LBLM,NOMGG $
 80  SMP2      USET,GO,MFF/MAA $
 81  LABEL     LBLM $
 82  COND      LBLB,NOBGG $
 83  SMP2      USET,GO,BFF/BAA $
 84  LABEL     LBLB $
 85  COND      LBL5,NOK4GG $
 86  SMP2      USET,GO,K4FF/K4AA $
 87  LABEL     LBL5 $
 88  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,,
               EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/
               NOFRL/S,N,NONLFT/S,N,NOTRL/NOEED//S,N,NOUE $
 89  COND      ERROR1,NOTRL $
 90  PURGE     PNLD/NONLFT$
 91  EQUIV     GO,GOD/NOUE/GM,GMD/NOUE  $
 92  BMG       MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/
               S,N,MFACT $
 93  PARAM     //*AND*/NOFL/NOABFL/NOKBFL $
 94  PURGE     KBFL/NOKBFL/ ABFL/NOABFL $
```

```
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 95  COND      LBLFL3,NOFL $
 96  MTRXIN,   ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/
               0 $
 97  LABEL     LBLFL3 $
 98  MTRXIN    CASECC,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
               NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
 99  PARAM     //*AND*/NOM2PP/NOABFL/NOM2DPP $
100  PARAM     //*AND*/NOK2PP/NOFL  /NOK2DPP $
101  EQUIV     K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
102  COND      LBLFL2,NOFL $
103  ADD5      ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
104  COND      LBLFL2,NOABFL $
105  TRNSP     ABFL/ABFLT $
106  ADD       ABFLT,M2DPP/M2PP/MFACT $
107  LABEL     LBLFL2 $
108  PARAM     //*AND*/KDEKA/NOUE/NOK2PP $
109  PARAM     //*AND*/MDEMA/NOUE/NOM2PP $
110  PARAM     //*AND*/KDEK2/NOGENL/NOSIMP $
111  PURGE     K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
112  EQUIV     M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
               KAA,KDD/KDEKA $
113  COND      LBL16,NOGPDT $
114  GKAD      USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
               GOD,K2DD,M2DD,B2DD/*TRANRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/
               C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/NOB2PP/
               MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/
               KDEK2/-1 $
115  LABEL     LBL16 $
116  EQUIV     M2DD,MDD/NOSIMP/B2DD,BDD/NOGPDT/K2DD,KDD/KDEK2 $
117  PARAM     //*ADD*/NEVER/1/0 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


118  PARAM    //*MPY*/REPEATT/1/-1 $

119  LABEL    LBL13 $

120  PURGE    PNLD,OUDV1,OPNL1,OUDV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,
              OEF1,OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT/NEVER $

121  CASE     CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $

122  PARAM    //*MPY*/NCOL/O/1 $

123  TRLG     CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG,
              MPT/PPT,PST,PDT,PD,,TOL/S,N,NOSET/NCOL $

124  EQUIV    PPT,PDT/NOSET $

125  TRD      CASEXX,TRL,NLFT,DIT,KDD,BDD,MDD,PD/UDVT,PNLD/*DIRECT*/
              NOUE/NONCUP/S,N,NCOL/C,Y,ISTART $

126  VDR      CASEXX,EQDYN,USETD,UDVT,TOL,XYCDB,PNLD/OUDV1,OPNL1/
              *TRANRESP*/*DIRECT*/O/S,N,NOD/S,N,NOP/O $

127  COND     LBL15,NOD $

128  SDR3     OUDV1,OPNL1,,,,/OUDV2,OPNL2,,,, $

129  OFP      OUDV2,OPNL2,,,,//S,N,CARDNO $

130  XYTRAN   XYCDB,OUDV2,OPNL2,,,/XYPLTTA/*TRAN*/*DSET*/S,N,PFILE/
              S,N,CARDNO $

131  XYPLOT   XYPLTTA// $

132  LABEL    LBL15 $

133  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $

134  COND     LBL18,PJUMP $

135  EQUIV    UDVT,UPV/NOA $

136  COND     LBL17,NOA $

137  SDR1     USETD,,UDVT,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $

138  LABEL    LBL17 $

139  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,
              PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $

140  SDR3     OPP1,OQP1,OUPV1,OES1,OEF1,/
              OPP2,OQP2,OUPV2,OES2,OEF2, $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


141  OFP       OPP2,OQP2,OUPV2,OEF2,OES2,//S,N,CARDNO $

142  SCAN      CASECC,OES2,OEF2/OESF2/*RF* $

143  OFP       OESF2,,,,,//S,N,CARDNO $

144  COND      P2,JUMPPLOT $

145  PLOT      PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

146  PRTMSG    PLOTX2// $

147  LABEL     P2 $

148  XYTRAN    XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/
               S,N,PFILE/S,N,CARDNO $

149  XYPLOT    XYPLTT// $

150  LABEL     LBL18 $

151  COND      FINIS,REPEATT $

152  REPT      LBL13,100 $

153  PRTPARM   //-2/*DIRTRD* $

154  JUMP      FINIS $

155  LABEL     ERROR1 $

156  PRTPARM   //-1/*DIRTRD* $

157  LABEL     ERROR3 $

158  PRTPARM   //-3/*DIRTRD* $

159  LABEL     FINIS  $

160  PURGE     DUMMY/ALWAYS $

161  END       $
```

2.9.2 Description of Important DMAP Operations for Direct Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 87 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass, and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K^{4}_{gg}]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 157 and print Error Message No. 3 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} K_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right], \qquad [M_{gg}] = \left[\begin{array}{c|c} M_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

$$[B_{gg}] = \left[\begin{array}{c|c} B_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} K^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K^4_{nn}]$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right], \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right],$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right].$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.
74. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.
75. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.
76. Equivalence $[K^4_{ff}]$ to $[K^4_{aa}]$ if no omitted coordinates exist.
77. Go to DMAP No. 87 if no omitted coordinates exist.
78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} K_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K^1_{aa}] = [K_{aa}] + [K_{ao}][G_o]$.

79. Go to DMAP No. 81 if there is no mass matrix.
80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} M_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M^1_{aa}] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o] .$$

82. Go to DMAP No. 84 if there is no viscous damping matrix.
83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} B_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right],$$

and performs matrix reduction

$$[B^{1}_{aa}] = [B_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o]^T[B_{oo}][G_o]$$

85. Go to DMAP No. 87 if there is no structural damping matrix.

86. SMP2 partitions constrained structural damping matrix.

$$[K^4_{ff}] = \left[\begin{array}{c|c} K^4_{aa} & K^4_{ao} \\ \hline K^4_{oa} & K^4_{oo} \end{array}\right],$$

and performs matrix reduction

$$[K^4_{aa}] = [K^4_{aa}] + [K^4_{ao}][G_o] + [K^4_{ao}G_o]^T + [G^T_o][K^4_{oo}][G_o]$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamics Load Table (DLT), Nonlinear Function Table (NLFT), and Transient Response List (TRL).

89. Go to DMAP No. 63 if no potential grid point singularities exist.

91. Equivalence $[G_o]$ to $[G^d_o]$ and $[G_m]$ to $[G^d_m]$ if there are no extra points introduced for dynamic analysis.

92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

95. Go to DMAP No. 97 if no fluid-structure interface is defined.

96. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$ if a fluid-structure interface is defined. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the field.

98. MTRXIN selects the direct input matrices $[K^{2d}_{pp}]$, $[M^{2d}_{pp}]$ and $[B^2_{pp}]$.

101. Equivalence $[K^2_{pp}]$ to $[K^{2d}_{pp}]$ if no fluid-structure interface is defined and equivalence $[M^2_{pp}]$ to $[M^{2d}_{pp}]$ if there is no $[A_{b,f\ell}]$.

102. Go to DMAP No. 107 if no fluid-structure interface is defined.

103. ADD5 adds $[K_{b,f\ell}]$ and $[K^{2d}_{pp}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K^2_{pp}]$.

104. Go to DMAP No. 107 if there is no $[A_{b,f\ell}]$.

105. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

106. ADD assembles input matrix $[M^2_{pp}]$ = MFACT $[A_{b,f\ell}]^T + [M^{2d}_{pp}]$.

112. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints

are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[K_{aa}]$ to $[K_{dd}]$ if there are no direct input stiffness matrices and no extra points.

113. Go to DMAP No. 115 if only extra points are defined.

114. GKAD assembles stiffness, mass, and damping matrices for use in Direct Transient Response:

$$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] ,$$

and

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] + \frac{g}{\omega_3}[K^1_{dd}] + \frac{1}{\omega_4}[K^4_{dd}] ,$$

where

$$\left[\begin{array}{c|c} K_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [K^1_{dd}],$$

$$\left[\begin{array}{c|c} M_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [M^1_{dd}],$$

$$\left[\begin{array}{c|c} B_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [B^1_{dd}],$$

and

$$\left[\begin{array}{c|c} K^4_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [K^4_{dd}].$$

All matrices are real.

116. Equivalence $[B^2_{dd}]$ to $[B_{dd}]$ if all damping is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[K^2_{dd}]$ to $[K_{dd}]$ is all stiffness is Direct Matrix Input.

119. Beginning of loop for additional dynamic load sets.

121. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

123. TRLG generates matrices of loads versus time. $\{P^t_p\}$, $\{P^t_s\}$, and $\{P^t_d\}$ are generated with one column per output time step. $\{P_d\}$ is generated with one column per solution time step, and the Transient Output List (TØL) is a list of output time steps.

124. Equivalence $\{P^t_p\}$ to $\{P^t_d\}$ if the d and p sets are the same.

125. TRD forms the linear, $\{P_d\}$, and nonlinear, $\{P_d^{n\ell}\}$, dynamic load vectors and integrates the equations of motion (using the standard or alternate starting procedure) over specified time periods to solve for the displacements, velocities, and accelerations, using the following equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}]\{u_d\} = \{P_d\} + \{P_d^{n\ell}\} \quad .$$

126. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the solution set degrees of freedom.

127. Go to DMAP No. 132 if there is no output request for the solution set.

128. SDR3 prepares the requested output of the solution set displacements, velocities, accelerations and nonlinear load vectors sorted by point number of element number.

129. ØFP formats the tables prepared by SDR3 sorted by point number or element number and places them on the system output file for printing.

130. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.

131. XYPLØT prepares the requested X-Y plots of the solution set displacements, velocities, accelerations and nonlinear load vectors vs. time.

134. Go to DMAP No. 150 if no further output is requested.

135. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

136. Go to DMAP No. 138 if no constraints are applied.

137. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \left\{\begin{matrix} u_d \\ \hline u_o \end{matrix}\right\} = \{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_f + u_e \\ \hline u_s \end{matrix}\right\} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_n + u_e \\ \hline u_m \end{matrix}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

139. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPP1), displacement, velocity and acceleration vectors (ØUPV1) and single-point forces of constraint (ØQP1) for output and translation components of the displacement vector (PUGV) sorted by time step.

140. SDR3 prepares requested output sorted by point number of element number.

141. ØFP formats the tables prepared by SDR3 for output sorted by point number of element number and places them on the system output file for printing.

142. SCAN examines the element stresses and forces calculated by SDR3 and generates scanned output that meets the specifications set by the user.

143. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

144. Go to DMAP No. 147 if no deformed structure plots are requested.

145. PLØT prepares all requested deformed structure and contour plots.

146. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

148. XYTRAN prepares the input for requested X-Y plots.

149. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint versus time.

150. Go to DMAP No. 159 if no additional dynamic load sets need to be processed.

152. Go to DMAP No. 119 if additional dynamic load sets need to be processed.

153. Print Error Message No. 2 and terminate execution.

154. Go to DMAP No. 159 and make normal exit.

156. Print Error Message No. 1 and terminate execution.

158. Print Error Message No. 3 and terminate execution.

2.9.3 Output for Direct Transient Response

The following printed output, sorted by point number or element number (SØRT2), is available at selected multiples of the integration time step:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Nonlinear force vector for a list of SØLUTIØN points.
4. Stresses and forces in selected elements (All not allowed).
5. Scanned output of forces and elements in selected elements.

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected time intervals.
3. Contour plots of stresses and displacements for selected time intervals.
4. X-Y plot of any component of displacement, velocity, or acceleration of a PHYSICAL point or a SØLUTIØN point.
5. X-Y plot of any component of the applied load vector, nonlinear force vector, or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The data used for preapring the X-Y plots may be punched or printed in tabular form (see Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

2.9.4 Case Control Deck for Direct Transient Response

The following items relate to subcase definition and data selection for Direct Transient Response:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINEAR must be used to define a time-dependent loading condition for each subcase.
3. All constraints must be defined above the subcase level.
4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.

5. If nonzero initial conditions are desired, IC must be used to select a TIC card in the Bulk Data Deck.
6. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions. The TSTEP selections must be changed if it is desired to resume the integration at the point terminated.

2.9.5 Parameters for Direct Transient Response

The following parameters are used in Direct Transient Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. ISTART - optional. A positive value of this parameter causes the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular. The default value is -1 and causes the first starting method to be used.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in

the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.

9. W3 and W4 - optional. The real values (radians/unit time) of these parameters are used as pivotal frequencies for uniform structural damping and element structural damping, respectively (see Section 9.3.3 of the Theoretical Manual). Parameter W3 is required if uniform structural damping is desired. Parameter W4 is required if structural damping is desired for any of the structural elements. Parameter W3 should not be used for hydroelastic problems.
10. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.9.6 The CONTINUE Feature

In transient analysis, it is frequently necessary to continue the integration of the coupled equations beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previous run. The CONTINUE feature (see Section 11.4.2 of the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem.

In order to use the CONTINUE feature, the user should employ the following steps:

1. Request a checkpoint of a coupled transient analysis problem.
2. Check to ensure that the solution for at least one output time is computed in this run and that the TØL (list of output times) and UDVT (displacement - velocity - acceleration) files are successfully checkpointed.
3. Restart the problem by changing any one or more of several cards either in the Case Control Deck (DLØAD, NØNLINEAR, TSTEP cards) and/or in the Bulk Data Deck (TSTEP, DAREA, DLØAD, FØRCE, etc.) that define either the dynamic loading and/or the time step selection. Ensure that the following conditions are satisfied.
   a. The structural model and the constraint data for the restart must be the same as that used in the checkpoint run.
   b. The dynamic loading and/or the time step selection in the restart need not be the same as that used in the checkpoint run.
   c. If the user wishes to continue the integration from an intermediate (rather than from the last) output time of the checkpoint run, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NCØL to the appropriate value by

means of a PARAM statement just before the TRLG module in the DMAP sequence. (See Section 11.4.2 of the Theoretical Manual for details).

4. Note that the output of the restart does not include the solutions of the checkpoint run, but only those solutions that are computed by the restart. Also, any initial conditions specified in the data for the restart are ignored since the solution is continued by using the displacements, velocities and accelerations corresponding to the specified output time of the checkpoint run as initial conditions.

2.9.7 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Transient Response, Rigid Format 9, are ALTERed in automated substructue analyses.

Phase 1: 4, 56, 88-124, 125-153

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 109-110, 116-116, 135-149

Phase 3: 87, 92-136, 138, 151-153

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

2.9.8 Rigid Format Error Messages from Direct Transient Response

The following fatal errors are detected by the DMAP statements in the Direct Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 1 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIONS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.
The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

2.10 MODAL COMPLEX EIGENVALUE ANALYSIS

2.10.1 DMAP Sequence for Modal Complex Eigenvalue Analysis

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 10 - MODAL COMPLEX EIGENVALUE ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     GOD=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR5,NOSIMP $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    OGPST/GENEL $

 23  PARAM    //*ADD*/NOKGGX/1/0 $

 24  PARAM    //*ADD*/NOMGG/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX $

 27  COND     JMPKGGX,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGGX $

 30  COND     ERROR1,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  COND     LGPWG,GRDPNT $

 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 34  OFP      OGPWG,,,,,//S,N,CARDNO $

 35  LABEL    LGPWG $

 36  EQUIV    KGGX,KGG/NOGENL $

 37  COND     LBL11,NOGENL $

 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 39  LABEL    LBL11 $

 40  PARAM    //*MPY*/NSKIP/0/0 $

 41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 42  PARAM    //*AND*/NOSR/REACT/SINGLE $

 43  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS/SINGLE/QPC/NOSR/KLR,KRR,MLR,MRR,
              DM,MR/REACT $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 44  COND     LBL4,GENEL $
 45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/O $
 46  COND     LBL4,GPSPFLG $
 47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 48  OFP      OGPST,,,,,//S,N,CARDNO $
 49  LABEL    LBL4 $
 50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 51  COND     LBL2,MPCF1 $
 52  MCE1     USET,RG/GM $
 53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 54  LABEL    LBL2 $
 55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 56  COND     LBL3,SINGLE $
 57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 58  LABEL    LBL3 $
 59  EQUIV    KFF,KAA/OMIT $
 60  EQUIV    MFF,MAA/OMIT $
 61  COND     LBL5,OMIT $
 62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 63  SMP2     USET,GO,MFF/MAA $
 64  LABEL    LBL5 $
 65  COND     LBL6,REACT $
 66  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 67  RBMG2    KLL/LLL $
 68  RBMG3    LLL,KLR,KRR/DM $
 69  RBMG4    DM,MLL,MLR,MRR/MR $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  LABEL    LBL6 $

 71  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/
              LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/
              NOFRL/NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $

 72  COND     ERROR2,NOEED $

 73  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE  $

 74  PARAM    //*MPY*/NEIGV/1/-1 $

 75  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
              NEIGV $

 76  OFP      OEIGS,,,,,//S,N,CARDNO $

 77  COND     ERROR4,NEIGV $

 78  OFP      LAMA,,,,,//S,N,CARDNO $

 79  PARAM    //*ADD*/NEVER/1/0 $

 80  PARAM    //*MPY*/REPEATE/1/-1 $

 81  LABEL    LBL13 $

 82  PURGE    PHIH,CLAMA,OPHIH,CPHID,CPHIP,QPC,OQPC1,OCPHIP,OESC1,OEFC1,
              K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $

 83  CASE     CASECC,/CASEXX/*CEIGN*/S,N,REPEATE/S,N,NOLOOP $

 84  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $

 85  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $

 86  EQUIV    M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $

 87  GKAD     USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,
              M2DD,B2DD/*CMPLEV*/*DISP*/*MODAL*/0.0/
              0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
              MPCF1/SINGLE/OMIT/NOUE/-1/-1/
              -1/-1 $

 88  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/
              NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
              NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $

 89  CEAD     KHH,BHH,MHH,EED,CASEXX/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $

 90  OFP      OCEIGS,,,,,//S,N,CARDNO $
```

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 91  COND      LBL17,EIGVS $
 92  OFP       CLAMA,,,,,//S,N,CARDNO $
 93  VDR       CASEXX,EQDYN,USETD,PHIH,CLAMA,,/OPHIH,/*CEIGEN*/*MODAL*/
               NOSORT2/S,N,NOH/S,N,NOP/FMODE $
 94  COND      LBL16,NOH $
 95  OFP       OPHIH,,,,,//S,N,CARDNO $
 96  LABEL     LBL16 $
 97  COND      LBL17,NOP $
 98  DDR1      PHIH,PHIDH/CPHID $
 99  EQUIV     CPHID,CPHIP/NOA $
100  COND      LBLNOA,NOA $
101  SDR1      USETD,,CPHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $
102  LABEL     LBLNOA $
103  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,CLAMA,QPC,CPHIP,EST,,/
               ,OQPC1,OCPHIP,OESC1,OEFC1, /*CEIGEN* $
104  OFP       OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $
105  LABEL     LBL17 $
106  COND      FINIS,REPEATE $
107  REPT      LBL13,100 $
108  PRTPARM   //-3/*MDLCEAD* $
109  JUMP      FINIS $
110  LABEL     ERROR2 $
111  PRTPARM   //-2/*MDLCEAD* $
112  LABEL     ERROR1 $
113  PRTPARM   //-1/*MDLCEAD* $
114  LABEL     ERROR4 $
115  PRTPARM   //-4/*MDLCEAD* $
```

```
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116  LABEL    ERROR5 $

117  PRTPARM  //-5/*MDLCEAD* $

118  LABEL    FINIS $

119  PURGE    DUMMY/MINUS1 $

120  END      $
```

2.10.2 Description of Important DMAP Operations for Modal Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 116 and print Error Message No. 5 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 112 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g] \{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \;\; R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Go to DMAP No. 70 if there are no free-body supports.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

67. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||}$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

72. Go to DMAP No. 110 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

73. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for

dynamic analysis.

75. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\,\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

76. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

77. Go to DMAP No. 114 and print Error Message No. 4 if no eigenvalues were found.

78. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

81. Beginning of loop for additional sets of direct input matrices.

83. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

84. MTRXIN selects the direct input matrices for the current loop, $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

86. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied.

87. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$.

88. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Complex Eigenvalue Analysis:

$$[K_{hh}] = [k] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] \ ,$$

$$[M_{hh}] = [m] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}]$$

and $$[B_{hh}] = [b] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] \ ,$$

where m_i = modal masses ,

$$b_i = m_i \, 2\pi \, f_i \, g(f_i)$$

and $$k_i = m_i \, 4\pi^2 \, f_i^2 \ .$$

Direct input matrices may be complex.

89. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}] \{u_h\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit magnitude of a selected component
2) Unit magnitude of the largest component.

90. ØFP formats the summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places it on the system output file for printing.

91. Go to DMAP No. 105 if no complex eigenvalues were found.

92. ØFP formats the complex eigenvalues (CLAMA) prepared by CEAD and places them on the system output file for printing.

93. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.

94. Go to DMAP No. 96 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.

95. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.

97. Go to DMAP No. 105 if there is no output request involving dependent degrees of freedom or forces and stresses.

98. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$[\phi_d] = [\phi_{dh}][\phi_h] .$$

99. Equivalence $[\phi_d]$ to $[\phi_p]$ if no constraints are applied.

100. Go to DMAP No. 102 if no constraints are applied.

101. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^{\phi}]\{\phi_d\} \quad , \qquad \left\{\begin{matrix}\phi_d \\ \hline \phi_o\end{matrix}\right\} = \{\phi_f + \phi_e\} \quad ,$$

$$\left\{\begin{matrix}\phi_f + \phi_e \\ \hline \phi_s\end{matrix}\right\} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + \phi_e\} \quad ,$$

$$\left\{\begin{matrix}\phi_n + \phi_e \\ \hline \phi_m\end{matrix}\right\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$.

103. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output.

104. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

106. Go to DMAP No. 118 and make normal exit if no additional sets of direct input matrices need to be processed.

107. Go to DMAP No. 81 if additional sets of direct input matrices need to be processed.

108. Print Error Message No. 3 and terminate execution.

109. Got to DMAP No. 118 and make normal exit.

111. Print Error Message No. 2 and terminate execution.

113. Print Error Message No. 1 and terminate execution.

115. Print Error Message No. 4 and terminate execution.

117. Print Error Message No. 5 and terminate execution.

2.10.3 Output for Modal Complex Eigenvalue Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

The complex Eigenvalue Summary Table and the complex Eigenvalue Analysis Summary, as described under Direct Complex Eigenvalue Analysis (see Section 2.7.3), are automatically printed for each set of direct input matrices.

Output that may be requested is the same as that described under Direct Complex Eigenvalue Analysis. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis Rigid Format or by making a modified restart using the Normal Modes Analysis rigid format.

2.10.4 Case Control Deck for Modal Complex Eigenvalue Analysis

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Complex Eigenvalue Analysis:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

2.10.5 Parameters for Modal Complex Eigenvalue Analysis

The following parameters are used in Modal Complex Eigenvalue Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
6. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.10.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.10.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Complex Eigenvalue Analysis. See Section 2.3.7 for details.

2.10.8 Rigid Format Error Messages from Modal Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Modal Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATIØN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 different sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 5 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.11 MODAL FREQUENCY AND RANDOM RESPONSE

2.11.1 DMAP Sequence for Modal Frequency and Random Response

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OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 11 - MODAL FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     GOD=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR7,NOSIMP $
```

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 22  PURGE    OGPST/GENEL $

 23  PARAM    //*ADD*/NOKGGX/1/0 $

 24  PARAM    //*ADD*/NOMGG/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX $

 27  COND     JMPKGGX,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGGX $

 30  COND     ERROR1,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  COND     LGPWG,GRDPNT $

 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 34  OFP      OGPWG,,,,,//S,N,CARDNO $

 35  LABEL    LGPWG $

 36  EQUIV    KGGX,KGG/NOGENL $

 37  COND     LBL11,NOGENL $

 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 39  LABEL    LBL11 $

 40  PARAM    //*MPY*/NSKIP/0/0 $

 41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 42  PARAM    //*AND*/NOSR/REACT/SINGLE $

 43  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF/SINGLE/QPC/NOSR/KLR,KRR,MLR,
              MRR,DM,MR/REACT/MDD/MODACC $
```

```
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 44  COND     LBL4,GENEL $
 45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 46  COND     LBL4,GPSPFLG $
 47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 48  OFP      OGPST,,,,,//S,N,CARDNO $
 49  LABEL    LBL4 $
 50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 51  COND     LBL2,MPCF1 $
 52  MCE1     USET,RG/GM $
 53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 54  LABEL    LBL2 $
 55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 56  COND     LBL3,SINGLE $
 57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 58  LABEL    LBL3 $
 59  EQUIV    KFF,KAA/OMIT $
 60  EQUIV    MFF,MAA/OMIT $
 61  COND     LBL5,OMIT $
 62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 63  SMP2     USET,GO,MFF/MAA $
 64  LABEL    LBL5 $
 65  EQUIV    KAA,KLL/REACT $
 66  COND     LBL6,REACT $
 67  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 68  JUMP     LBL8 $
 69  LABEL    LBL6 $
```

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```
 70  COND     LBL7,MODACC $
 71  LABEL    LBL8 $
 72  RBMG2    KLL/LLL $
 73  COND     LBL7,REACT $
 74  RBMG3    LLL,KLR,KRR/DM $
 75  RBMG4    DM,MLL,MLR,MRR/MR $
 76  LABEL    LBL7 $
 77  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,
              EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/
              S,N,NOFRL/NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $
 78  COND     ERROR2,NOEED $
 79  PURGE    UEVF/NOUE $
 80  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 81  PARAM    //*MPY*/NEIGV/1/-1 $
 82  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
              NEIGV $
 83  OFP      OEIGS,,,,,//S,N,CARDNO $
 84  COND     ERROR4,NEIGV $
 85  OFP      LAMA,,,,,//S,N,CARDNO $
 86  PARAM    //*ADD*/NEVER/1/0 $
 87  PARAM    //*MPY*/REPEATF/1/-1 $
 88  LABEL    LBL13 $
 89  PURGE    OUHVC1,OUHVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,
              OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,K2PP,M2PP,
              B2PP,K2DD,M2DD,B2DD,OPPCA,IQP1,IPHIP1,IES1,IEF1,OPPCB,IQP2,
              IPHIP2,IES2,IEF2,ZQPC2,ZUPVC2,ZESC2,ZEFC2,ZQPC1,ZUPVC1,ZESC1,
              ZEFC1/NEVER $
 90  CASE     CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
 91  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
```

```
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 92  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $

 93  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $

 94  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $

 95  GKAD     USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP/,,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/*FREQRESP*/*DISP*/*MODAL*/0.0/
              0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
              MPCF1/SINGLE/OMIT/NOUE/-1/-1/
              1/V,Y,MODACC = -1 $

 96  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/
              NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
              NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $

 97  COND     ERROR5,NOFRL $

 98  COND     ERROR6,NODLT $

 99  FRRD     CASEXX,USETD,DLT,FRL,GMD,GOD,KHH,BHH,MHH,PHIDH,DIT/UHVF,PSF,
              PDF,PPF/*DISP*/*MODAL*/LUSETD/MPCF1/SINGLE/
              OMIT/NONCUP/S,N,FRQSET $

100  EQUIV    PPF,PDF/NOSET $

101  VDR      CASEXX,EQDYN,USETD,UHVF,PPF,XYCDB,/OUHVC1,/*FREQRESP*/
              *MODAL*/S,N,NOSORT2/S,N,NOH/S,N,NOP/FMODE $

102  COND     LBL16,NOH $

103  COND     LBL16A,NOSORT2 $

104  SDR3     OUHVC1,,,,,/OUHVC2,,,,, $

105  OFP      OUHVC2,,,,,//S,N,CARDNO $

106  XYTRAN   XYCDB,OUHVC2,,,,/XYPLTFA/*FREQ*/*HSET*/S,N,PFILE/
              S,N,CARDNO $

107  XYPLOT   XYPLTFA // $

108  JUMP     LBL16 $

109  LABEL    LBL16A $

110  OFP      OUHVC1,,,,,//S,N,CARDNO $

111  LABEL    LBL16 $

112  COND     LBL14,NOP $
```

```
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113  PARAM    //*NOT*/NOMOD/V,Y,MODACC $

114  COND     LBDDRM,MODACC $

115  DDR1     UHVF,PHIDH/UDV1F $

116  DDR2     USETD,UDV1F,PDF,K2DD,B2DD,MDD,PPF,LLL,DM/UDV2F,UEVF,PAF/
              *FREQRESP*/NOUE/REACT/FRQSET $

117  EQUIV    UDV2F,UDV1F/NOMOD $

118  EQUIV    UDV1F,UPVC/NOA $

119  COND     LBLNOA,NOA $

120  SDR1     USETD,,UDV1F,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $

121  LABEL    LBLNOA $

122  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,
              XYCDB,PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUGV/*FREQ*/
              S,N,NOSORT2 $

123  COND     LBL18,NOSORT2 $

124  SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,
              OEFC2, $

125  JUMP     P2A $

126  LABEL    LBDDRM $

127  SDR1     USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $

128  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,LAMA,QPH,PHIPH,EST,XYCDB,/
              ,IQP1,IPHIP1,IES1,IEF1,/*MMREIG*/S,N,NOSORT2 $

129  SDR2     CASEXX,,,,EQDYN,SILD,,,,PPF,,,,XYCDB,PPF/OPPCA,,,,,/*FREQ* $

130  EQUIV    OPPCA,OPPC1/MODACC $

131  COND     LBLSORT,NOSORT2 $

132  SDR3     IQP1,IPHIP1,IES1,IEF1,OPPCA,/IQP2,IPHIP2,IES2,IEF2,OPPCB, $

133  EQUIV    OPPCB,OPPC2/MODACC $

134  DDRMM    CASEXX,UHVF,PPF,IPHIP2,IQP2,IES2,IEF2,XYCDB,EST,MPT,DIT/
              ZUPVC2,ZQPC2,ZESC2,ZEFC2,  $

135  EQUIV    ZUPVC2,OUPVC2/MODACC/ZQPC2,OQPC2/MODACC/ZESC2,OESC2/MODACC/
              ZEFC2,OEFC2/MODACC $
```

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```
136  JUMP     P2A $
137  LABEL    LBLSORT $
138  DDRMM    CASEXX,UHVF,PPF,IPHIP1,IQP1,IES1,IEF1,,EST,MPT,DIT/
              ZUPVC1,ZQPC1,ZESC1,ZEFC1, $
139  EQUIV    ZUPVC1,OUPVC1/MODACC/ZQPC1,OQPC1/MODACC/ZESC1,OESC1/MODACC/
              ZEFC1,OEFC1/MODACC $
140  JUMP     LBL18 $
141  LABEL    P2A $
142  OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $
143  XYTRAN   XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/
              S,N,PFILE/S,N,CARDNO $
144  XYPLOT   XYPLTF// $
145  COND     LBL21,JUMPPLOT $
146  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
147  PRTMSG   PLOTX2// $
148  LABEL    LBL21 $
149  COND     LBL14,NOPSDL $
150  RANDOM   XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
              S,N,NORD $
151  COND     LBL14,NORD $
152  XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/
              S,N,CARDNO $
153  XYPLOT   XYPLTR// $
154  JUMP     LBL14 $
155  LABEL    LBL18 $
156  OFP      OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $
157  LABEL    LBL14 $
158  COND     FINIS,REPEATF $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
159  REPT     LBL13,100 $
160  PRTPARM  //-3/*MDLFRRD* $
161  JUMP     FINIS $
162  LABEL    ERROR2 $
163  PRTPARM  //-2/*MDLFRRD* $
164  LABEL    ERROR1 $
165  PRTPARM  //-1/*MDLFRRD* $
166  LABEL    ERROR4 $
167  PRTPARM  //-4/*MDLFRRD* $
168  LABEL    ERROR5 $
169  PRTPARM  //-5/*MDLFRRD* $
170  LABEL    ERROR6 $
171  PRTPARM  //-6/*MDLFRRD* $
172  LABEL    ERROR7 $
173  PRTPARM  //-7/*MDLFRRD* $
174  LABEL    FINIS $
175  PURGE    DUMMY/MINUS1 $
176  END      $
```

2.11.2 Description of Important DMAP Operations for Modal Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 172 and print Error Message No. 7 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 164 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \text{ and } \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \text{ and } \qquad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamic Loads Table (DLT), Power Spectral Density List (PSDL), Frequency Response List (FRL), and Eigenvalue Extraction Data (EED).

78. Go to DMAP No. 162 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} \frac{D\phi_{ro}}{\phi_{ro}} \end{bmatrix} ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

84. Go to DMAP No. 166 and print Error Message No. 4 if no eigenvalues were found.

85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

88. Beginning of loop for additional sets of direct input matrices.

90. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

91. MTRXIN selects the direct input matrices for the current loop, $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$.

94. Equivalence $[M_{pp}^2]$ to $[M_{dd}^2]$, $[B_{pp}^2]$ to $[B_{dd}^2]$ and $[K_{pp}^2]$ to $[K_{dd}^2]$ if no constraints are applied, and $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points introduced for dynamic analysis.

95. GKAD applies constraints to direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$, forming $[K_{dd}^2]$, $[M_{dd}^2]$ and $[B_{dd}^2]$.

96. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Frequency Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

and

$$[B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where

m_i = modal masses ,

$b_i = m_i \, 2\pi \, f_i \, g(f_i)$

and $k_i = m_i 4\pi^2 f_i^2$.

Direct input matrices may be complex.

97. Go to DMAP No. 168 and print Error Message No. 5 if there is no Frequency Response List.

98. Go to DMAP No. 170 and print Error Message No. 6 if there is no Dynamic Loads Table.

99. FRRD forms the dynamic load vectors $\{P_h\}$ and solves for the displacements using the following equation

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K_{hh}]\{u_h\} = \{P_h\}.$$

100. Equivalence $\{P_p\}$ to $\{P_d\}$ if no constraints are applied.

101. VDR prepares displacements (ØUHVC1), sorted by frequency, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).

102. Go to DMAP No. 111 if there is no output request for solution points.

103. Go to DMAP No. 109 if there is no output request for solution points sorted by extra point or mode number.

104. SDR3 sorts the solution point displacements by extra point or mode number.

105. ØFP formats the requested solution point displacements prepared by SDR3 and places them on the system output file for printing.

106. XYTRAN prepares the input for requested X-Y plots of the solution point displacements vs. frequency.

107. XYPLØT prepares the requested X-Y plots of the solution point displacements vs. frequency.

108. Go to DMAP No. 111.

110. ØFP formats the requested solution point displacements prepared by VDR and places them on the system output file for printing.

112. Go to DMAP No. 157 if there is no output request involving dependent degrees of freedom or forces and stresses.

114. Go to DMAP No. 126 if the mode acceleration technique is not requested.

115. DDR1 transforms the solution vector of displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} .$$

116. DDR2 calculates an improved displacement vector using the mode acceleration technique.

117. Equivalence $\{u_d\}$ to the improved displacement vector. (Flag NØMØD is negative since the mode acceleration technique is requested).

118. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

119. Go to DMAP No. 121 if no constraints are applied.

120. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_a\} \quad , \qquad \left\{\begin{matrix} u_d \\ \hline u_o \end{matrix}\right\} = \{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_f + u_e \\ \hline u_s \end{matrix}\right\} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} u_n + u_e \\ \hline u_m \end{matrix}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

122. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1) and single-point forces of constraint (ØQPC1) for output and translation components of the displacement vector (PUGV), sorted by frequency.

123. Go to DMAP No. 155 if there are no requests for output sorted by point number or element number.

124. SDR3 prepares the requested output sorted by point number of element number.

125. Go to DMAP No. 141.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_n\} \quad , \qquad \left\{\begin{matrix} \phi_n \\ \hline \phi_o \end{matrix}\right\} = \{\phi_f + u_e\} \quad ,$$

$$\left\{\begin{matrix} \phi_f + u_e \\ \hline \phi_s \end{matrix}\right\} = \{\phi_n + u_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + u_e\} \quad ,$$

$$\left\{\begin{matrix} \phi_n + u_e \\ \hline \phi_m \end{matrix}\right\} = \{\phi_g + u_e\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by frequency.

129. SDR2 prepares load vectors for output (ØPPCA) sorted by frequency.

130. Equivalence ØPPCA to ØPPC1. (Flag MØDACC is negative since the mode acceleration technique is not requested).

131. Go to DMAP No. 137 if there are no requests for output sorted by point number or element number.

132. SDR3 prepares the requested output sorted by point number or element number.

133. Equivalence ØPPCB to ØPPC2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

134. DDRMM prepares a subset of the element forces (ZEFC2) and stresses (ZESC2), and displacement vectors (ZUPVC2) and single-point forces of constraint (ZQPC2) for output sorted by point number or element number.

135. Equivalence ZUPVC2 to ØUPVC2, ZQPC2 to ØQPC2, ZESC2 to ØESC2, and ZEFC2 to ØEFC2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

136. Go to DMAP No. 141.

138. DDRMM prepares a subset of the element forces (ZEFC1) and stresses (ZESC1), and displacement vectors (ZUPVC1) and single-point forces of constraint (ZQPC1) for output sorted by frequency.

139. Equivalence ZUPVC1 to ØUPVC1, ZQPC1 to ØQPC1, ZESC1 to ØESC1, and ZEFC1 to ØEFC1. (Flag MØDACC is negative since the mode acceleration technique is not requested).

140. Go to DMAP No. 155.

142. ØFP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.

143. XYTRAN prepares the input for requested X-Y plots.

144. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.

145. Go to DMAP No. 148 if no deformed structure plots are requested.

146. PLØT generates all requested deformed structure and contour plots.

147. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

149. Go to DMAP No. 157 if no power spectral density functions or autocorrelation functions are requested.

150. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

151. Go to DMAP No. 157 if no X-Y plots of RANDØM calculations are requested.

152. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

153. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

154. Go to DMAP No. 157.

156. ØFP formats the frequency response output requests prepared by SDR2 (with mode acceleration) or DDRMM (no mode acceleration) and places them on the system output file for printing.

158. Go to DMAP No. 174 and make normal exit if no additional sets of direct input matrices need to be processed.

159. Go to DMAP No. 88 if additional sets of direct input matrices need to be processed.

160. Print Error Message No. 3 and terminate execution.

161. Go to DMAP No. 174 and make normal exit.

163. Print Error Message No. 2 and terminate execution.

165. Print Error Message No. 1 and terminate execution.

167. Print Error Message No. 4 and terminate execution.

169. Print Error Message No. 5 and terminate execution.

171. Print Error Message No. 6 and terminate execution.

173. Print Error Message No. 7 and terminate execution.

2.11.3 Output for Modal Frequency and Random Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Frequency and Random Response. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis rigid format or by making a modified restart using the Normal Modes Analysis rigid format.

2.11.4 Case Control Deck for Modal Frequency and Random Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Frequency and Random Response:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

2.11.5 Parameters for Modal Frequency and Random Response

The following parameters are used in Modal Frequency and Random Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
6. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
7. MØDACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.
8. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.11.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.11.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Frequency and Random Response. See Section 2.3.7 for details.

2.11.8 Rigid Format Error Messages from Modal Frequency and Random Response

The following fatal errors are detected by the Modal Frequency and Random Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATIØN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 5 - FREQUENCY RESPØNSE LIST REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ, FREQ1 or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 6 - DYNAMIC LØADS TABLE REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLØAD1 or RLØAD2 card in the Bulk Data Deck and DLØAD in the Case Control Deck must select a dynamic load set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 7 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.12 MODAL TRANSIENT RESPONSE

2.12.1 DMAP Sequence for Modal Transient Response

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 12 - MODAL TRANSIENT RESPONSE ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     LAMA=APPEND/PHIA=APPEND/UHVT=APPEND/TOL=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR6,NOSIMP $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    OGPST/GENEL $

 23  PARAM    //*ADD*/NOKGGX/1/0 $

 24  PARAM    //*ADD*/NOMGG/1/0 $

 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 26  PURGE    KGGX,GPST/NOKGGX $

 27  COND     JMPKGGX,NOKGGX $

 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL    JMPKGGX $

 30  COND     ERROR1,NOMGG $

 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  COND     LGPWG,GRDPNT $

 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 34  OFP      OGPWG,,,,,//S,N,CARDNO $

 35  LABEL    LGPWG $

 36  EQUIV    KGGX,KGG/NOGENL $

 37  COND     LBL11,NOGENL $

 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 39  LABEL    LBL11 $

 40  PARAM    //*MPY*/NSKIP/0/0 $

 41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 42  PARAM    //*AND*/NOSR/REACT/SINGLE $

 43  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PST/SINGLE/QP/NOSR/KLR,KRR,MLR,MR,
              MRR,DM/REACT $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 44  COND     LBL4,GENEL $
 45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 46  COND     LBL4,GPSPFLG $
 47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 48  OFP      OGPST,,,,,//S,N,CARDNO $
 49  LABEL    LBL4 $
 50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 51  COND     LBL2,MPCF1 $
 52  MCE1     USET,RG/GM $
 53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 54  LABEL    LBL2 $
 55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 56  COND     LBL3,SINGLE $
 57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 58  LABEL    LBL3 $
 59  EQUIV    KFF,KAA/OMIT $
 60  EQUIV    MFF,MAA/OMIT $
 61  COND     LBL5,OMIT $
 62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 63  SMP2     USET,GO,MFF/MAA $
 64  LABEL    LBL5 $
 65  EQUIV    KAA,KLL/REACT $
 66  COND     LBL6,REACT $
 67  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 68  JUMP     LBL8 $
 69  LABEL    LBL6 $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  COND     LBL7,MODACC $

 71  LABEL    LBL8 $

 72  RBMG2    KLL/LLL $

 73  COND     LBL7,REACT $

 74  RBMG3    LLL,KLR,KRR/DM $

 75  RBMG4    DM,MLL,MLR,MRR/MR $

 76  LABEL    LBL7 $

 77  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,
              EED ,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/
              NOFRL/S,N,NONLFT/S,N,NOTRL/S,N,NOEED//S,N,NOUE $

 78  COND     ERROR2,NOEED $

 79  PURGE    UEVT/NOUE/PNLH/NONLFT $

 80  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE  $

 81  PARAM    //*MPY*/NEIGV/1/-1 $

 82  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
              NEIGV $

 83  OFP      OEIGS,,,,,//S,N,CARDNO $

 84  COND     ERROR4,NEIGV $

 85  OFP      LAMA,,,,,//S,N,CARDNO $

 86  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $

 87  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $

 88  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $

 89  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $

 90  GKAD     USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP/,,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/*TRANRESP*/*DISP*/*MODAL*/0.0/
              0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
              MPCF1/SINGLE/OMIT/NOUE/-1/-1/
              1/V,Y,MODACC = -1 $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

 91  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
              NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
              NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $

 92  COND     ERROR5,NOTRL $

 93  PARAM    //*ADD*/NEVER/1/0 $

 94  PARAM    //*MPY*/REPEATT/1/-1 $

 95  LABEL    LBL13 $

 96  PURGE    PNLH,OUHV1,OPNL1,OUHV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,OEF1,
              OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT,OPPA,IQP1,IPHIP1,IES1,
              IEF1,OPPB,IQP2,IPHIP2,IES2,IEF2,ZQP2,ZUPV2,ZES2,ZEF2/NEVER $

 97  CASE     CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $

 98  PARAM    //*MPY*/NCOL/0/1 $

 99  TRLG     CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,PHIDH,
              EST,MGG,/PPT,PST,PDT,PD,PH,TOL/S,N,NOSET/NCOL $

100  EQUIV    PPT,PDT/NOSET $

101  TRD      CASEXX,TRL,NLFT,DIT,KHH,BHH,MHH,PH/UHVT,PNLH/*MODAL*/
              NOUE/NONCUP/S,N,NCOL/C,Y,ISTART $

102  VDR      CASEXX,EQDYN,USETD,UHVT,TOL,XYCDB,PNLH/OUHV1,OPNL1/
              *TRANRESP*/*MODAL*/0/S,N,NOH/S,N,NOP/FMODE $

103  COND     LBL16,NOH $

104  SDR3     OUHV1,OPNL1,,,,/OUHV2,OPNL2,,,, $

105  OFP      OUHV2,OPNL2,,,,//S,N,CARDNO $

106  XYTRAN   XYCDB,OUHV2,OPNL2,,,/XYPLTTA/*TRAN*/*HSET*/S,N,PFILE/
              S,N,CARDNO $

107  XYPLOT   XYPLTTA// $

108  LABEL    LBL16 $

109  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $

110  COND     LBL15,PJUMP $

111  PARAM    //*NOT*/NOMOD/V,Y,MODACC $

112  PARAM    //*AND*/MPJUMP/V,Y,MODACC/JUMPPLOT $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


113  COND      LBDDRM,MPJUMP $

114  DDR1      UHVT,PHIDH/UDV1T $

115  COND      LBLMOD,MODACC $

116  DDR2      USETD,UDV1T,PDT,K2DD,B2DD,MDD,,LLL,DM/UDV2T,UEVT,PAF/
               *TRANRESP*/NOUE/REACT/0 $

117  EQUIV     UDV2T,UDV1T/NOMOD $

118  LABEL     LBLMOD $

119  EQUIV     UDV1T,UPV/NOA $

120  COND      LBL14,NOA $

121  SDR1      USETD,,UDV1T,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $

122  LABEL     LBL14 $

123  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,
               PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $

124  SDR3      OPP1,OQP1,OUPV1,OES1,OEF1,/OPP2,OQP2,OUPV2,OES2,OEF2, $

125  JUMP      P2A $

126  LABEL     LBDDRM $

127  SDR1      USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $

128  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,LAMA,QPH,PHIPH,EST,XYCDB,/
               ,IQP1,IPHIP1,IES1,IEF1,/*MMREIG* $

129  SDR2      CASEXX,,,,EQDYN,SILD,,,,TOL,,,,XYCDB,PPT/OPPA,,,,,/
               *TRANRESP* $

130  SDR3      OPPA,IQP1,IPHIP1,IES1,IEF1,/OPPB,IQP2,IPHIP2,IES2,IEF2, $

131  EQUIV     OPPB,OPP2/MODACC $

132  DDRMM     CASEXX,UHVT,TOL,IPHIP2,IQP2,IES2,IEF2,,EST,MPT,DIT/
               ZUPV2,ZQP2,ZES2,ZEF2, $

133  EQUIV     ZUPV2,OUPV2/MODACC/ZQP2,OQP2/MODACC/ZEF2,OEF2/MODACC/ZES2,OES2/
               MODACC $

134  LABEL     P2A $

135  OFP       OUPV2,OPP2,OQP2,OEF2,OES2,//S,N,CARDNO $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 12

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


136  SCAN     CASECC,OES2,OEF2/OESF2/*RF* $
137  OFP      OESF2,,,,,//S,N,CARDNO $
138  COND     P2,JUMPPLOT $
139  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/PLOTX2/
              NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
140  PRTMSG   PLOTX2// $
141  LABEL    P2 $
142  XYTRAN   XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/
              S,N,PFILE/S,N,CARDNO $
143  XYPLOT   XYPLTT// $
144  LABEL    LBL15 $
145  COND     FINIS,REPEATT $
146  REPT     LBL13,100 $
147  PRTPARM  //-3/*MDLTRD* $
148  JUMP     FINIS $
149  LABEL    ERROR2 $
150  PRTPARM  //-2/*MDLTRD* $
151  LABEL    ERROR1 $
152  PRTPARM  //-1/*MDLTRD* $
153  LABEL    ERROR4 $
154  PRTPARM  //-4/*MDLTRD* $
155  LABEL    ERROR5 $
156  PRTPARM  //-5/*MDLTRD* $
157  LABEL    ERROR6 $
158  PRTPARM  //-6/*MDLTRD* $
159  LABEL    FINIS $
160  PURGE    DUMMY/MINUS1 $
161  END      $
```

2.12.2 Description of Important DMAP Operations for Modal Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 157 and print Error Message No. 6 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 151 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \quad .$$

65. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \text{ and } \qquad [M_{aa}] = \begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array} \quad .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} \quad .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamic Loads Table (DLT), Nonlinear Function Table (NLFT), Transient Response List (TRL).

78. Go to DMAP Nc. 149 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 \quad ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \hline \phi_{ro} \end{bmatrix} ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

84. Go to DMAP No. 153 and print Error Message No. 4 if no eigenvalues were found.

85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

86. MTRXIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

89. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied, and $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points introduced for dynamic analysis.

90. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$.

91. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Transient Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K^2_{dd}][\phi_{dh}] ,$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M^2_{dd}][\phi_{dh}]$$

and

$$[B_{hh}] = [b] + [\phi_{dh}^T][B^2_{dd}][\phi_{dh}] ,$$

where m_i = modal masses ,

$b_i = m_i \, 2\pi \, f_i \, g(f_i)$

and $k_i = m_i \, 4\pi^2 \, f_i^2$.

All matrices are real.

92. Go to DMAP No. 155 and print Error Message No. 5 if there is no Transient Response List.

95. Beginning of loop for additional dynamic load sets.

97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

99. TRLG generates matrices of loads versus time. $\{P_p^t\}$, $\{P_s^t\}$ and $\{P_d^t\}$ are generated with one column per output time step. $\{P_d\}$ and $\{P_h\}$ are generated with one column per solution time step, and the Transient Output List (TØL) is a list of output time steps.

100. Equivalence $\{P_d^t\}$ to $\{P_p^t\}$ if the d and p sets are the same.

101. TRD forms the linear, $\{P_d\}$, and nonlinear, $\{P_d^{n\ell}\}$, dynamic load vectors and integrates the equations of motion over specified time periods to solve for the displacements, velocities and accelerations, using the following equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}]\{u_h\} = \{P_h\} + \{P_h^{n\ell}\} \quad .$$

102. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).

103. Go to DMAP No. 108 if there is no output request for the solution points.

104. SDR3 sorts the solution point displacements, velocities, accelerations and nonlinear load vectors by extra point or mode number.

105. ØFP formats the requested solution point displacements, velocities, accelerations and nonlinear load vectors prepared by SDR3 and places them on the system output file for printing.

106. XYTRAN prepares the input for X-Y plotting of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.

107. XYPLØT prepares the requested X-Y plots of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.

110. Go to DMAP No. 144 if there is no output request involving dependent degrees of freedom, forces and stresses, or deformed structure plots.

113. Go to DMAP No. 126 if the mode acceleration technique is not requested and if there are no requests for deformed structure plots.

114. DDR1 transforms the solution vector displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} \quad .$$

115. Go to DMAP No. 118 if the mode acceleration technique is not requested.

116. DDR2 calculates an improved displacement vector using the mode acceleration technique.

117. Equivalence $\{u_d\}$ to the improved displacement vector. (Flag NØMØD is negative since the mode acceleration technique is requested).

119. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

120. Go to DMAP No. 122 if no constraints are applied.

121. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \left\{\frac{u_d}{u_o}\right\} = \{u_f + u_e\} \quad ,$$

$$\left\{\frac{u_f + u_e}{u_s}\right\} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\left\{\frac{u_n + u_e}{u_m}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

123. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPP1), displacement, velocity and acceleration vectors (ØUPV1) and single-point forces of constraint (ØQP1) for output and translation components of the displacement vector (PUGV), sorted by time step.

124. SDR3 prepares requested output sorted by point number or element number.

125. Go to DMAP No. 134.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_n\} \quad , \qquad \left\{\frac{\phi_h}{\phi_o}\right\} = \{\phi_f + u_e\} \quad ,$$

$$\left\{\frac{\phi_f + u_e}{\phi_s}\right\} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + u_e\} \quad ,$$

$$\left\{\frac{\phi_n + u_e}{\phi_m}\right\} = \{\phi_g + u_e\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by time step.

129. SDR2 prepares load vectors for output (ØPPA) sorted by time step.

130. SDR3 prepares the requested output sorted by point number or element number.

131. Equivalence ØPPB to ØPP2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

132. DDRMM prepares a subset of the element forces (ZEF2) and stresses (ZES2), and displacement vectors (ZUPV2) and single-point forces of constraint (ZQP2) for output sorted by point number or element number.

133. Equivalence ZUPV2 to ØUPV2, ZQP2 to ØQP2, ZES2 to ØES2 and ZEF2 to ØEF2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

135. ØFP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.

136. SCAN examines the element stresses and forces calculated by SDR3 or DDRMM and generates scanned output that meets the specifications set by the user.

137. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

138. Go to DMAP No. 141 if no deformed structure plots are requested.

139. PLØT prepares all requested deformed structure and contour plots.

140. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

142. XYTRAN prepares the input for requested X-Y plots.

143. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint vs. time.

145. Go to DMAP No. 159 and make normal exit if no additional dynamic load sets need to be processed.

146. Go to DMAP No. 95 if additional dynamic load sets need to be processed.

147. Print Error Message No. 3 and terminate execution.

148. Go to DMAP No. 159 and make normal exit.

150. Print Error Message No. 2 and terminate execution.

152. Print Error Message No. 1 and terminate execution.

154. Print Error Message No. 4 and terminate execution.

156. Print Error Message No. 5 and terminate execution.

158. Print Error Message No. 6 and terminate execution.

2.12.3 Output for Modal Transient Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Transient Response. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis rigid format or by making a modified restart using the Normal Modes Analysis rigid format.

2.12.4 Case Control Deck for Modal Transient Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Transient Response:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

2.12.5 Parameters for Modal Transient Response

The following parameters are used in Modal Transient Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. ISTART - optional. A positive value of this parameter causes the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular. The default value is -1 and causes the first starting method to be used.
6. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
7. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
8. MØDACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.
9. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
11. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.12.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.12.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Transient Response. See Section 2.3.7 for details.

2.12.8 The CONTINUE Feature

The CONTINUE feature can be used for coupled transient analysis in Modal Transient Response. See Section 2.9.6 for details.

2.12.9 Rigid Format Error Messages from Modal Transient Response

The following fatal errors are detected by the DMAP statements in the Modal Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number can be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 5 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIØNS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.13 NORMAL MODES WITH DIFFERENTIAL STIFFNESS

2.13.1 DMAP Sequence for Normal Modes With Differential Stiffness

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 13

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 13 - NORMAL MODES WITH DIFFERENTIAL STIFFNESS-APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     LAMA=APPEND/PHIA=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10  COND     P1,JUMPPLOT $

   11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   12  PRTMSG   PLTSETX// $

   13  PARAM    //*MPY*/PLTFLG/1/1 $

   14  PARAM    //*MPY*/PFILE/0/0 $

   15  COND     P1,JUMPPLOT $

   16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17  PRTMSG   PLOTX1// $

   18  LABEL    P1 $

   19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $

   20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   21  COND     ERROR1,NOSIMP $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 13

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 22  PURGE    OGPST/GENEL $
 23  PARAM    //*ADD*/NOKGGX/1/0 $
 24  PARAM    //*ADD*/NOMGG/1/0 $
 25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $
 26  PURGE    KGGX,GPST/NOKGGX $
 27  COND     JMPKGG,NOKGGX $
 28  EMA      GPECT,KDICT,KELM/KGGX,GPST $
 29  LABEL    JMPKGG $
 30  COND     ERROR5,NOMGG $
 31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 32  COND     LBL1,GRDPNT $
 33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
 34  OFP      OGPWG,,,,,//S,N,CARDNO $
 35  LABEL    LBL1 $
 36  EQUIV    KGGX,KGG/NOGENL $
 37  COND     LBL11,NOGENL $
 38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 39  LABEL    LBL11 $
 40  PARAM    //*MPY*/NSKIP/0/0 $
 41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $
 42  COND     ERROR6,NOL $
 43  PARAM    //*AND*/NOSR/SINGLE/REACT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 13

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

 44  PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS/SINGLE/
              QG/NOSR $
 45  COND     LBL4D,REACT $
 46  JUMP     ERROR2 $
 47  LABEL    LBL4D $
 48  COND     LBL4,GENEL $
 49  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 50  COND     LBL4,GPSPFLG $
 51  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 52  OFP      OGPST,,,,,//S,N,CARDNO $
 53  LABEL    LBL4 $
 54  EQUIV    KGG,KNN/MPCF1 $
 55  COND     LBL2,MPCF1 $
 56  MCE1     USET,RG/GM $
 57  MCE2     USET,GM,KGG,,,/KNN,, $
 58  LABEL    LBL2 $
 59  EQUIV    KNN,KFF/SINGLE $
 60  COND     LBL3,SINGLE $
 61  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
 62  LABEL    LBL3 $
 63  EQUIV    KFF,KAA/OMIT $
 64  COND     LBL5,OMIT $
 65  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 66  LABEL    LBL5 $
 67  RBMG2    KAA/LLL $
 68  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/1 $
```

```
RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 13

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 69  EQUIV    PG,PL/NOSET $

 70  COND     LBL10,NOSET $

 71  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $

 72  LABEL    LBL10 $

 73  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              1/S,N,EPSI $

 74  COND     LBL9,IRES $

 75  MATGPR   GPL,USET,SIL,RULV//*L* $

 76  MATGPR   GPL,USET,SIL,RUOV//*O* $

 77  LABEL    LBL9 $

 78  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/
              *BKLO* $

 79  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKLO* $

 80  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $

 81  SCAN     CASECC,OES1,OEF1/OESF1/C,N,*RF* $

 82  OFP      OESF1,,,,,//S,N,CARDNO $

 83  COND     P2,JUMPPLOT $

 84  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

 85  PRTMSG   PLOTX2// $

 86  LABEL    P2 $

 87  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/
              NOSIMP/0/NOGENL/GENEL $

 88  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/
              S,N,DSCOSET $

 89  EQUIV    KDGG,KDNN/MPCF2 / MGG,MNN/MPCF2 $

 90  COND     LBL2D,MPCF2 $

 91  MCE2     USET,GM,KDGG,MGG,,/KDNN,MNN,, $
```

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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 13

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 92  LABEL    LBL2D $
 93  EQUIV    KDNN,KDFF/SINGLE / MNN,MFF/SINGLE $
 94  COND     LBL3D,SINGLE $
 95  SCE1     USET,KDNN,MNN,,/KDFF,KDFS,KDSS,MFF,, $
 96  LABEL    LBL3D $
 97  EQUIV    KDFF,KDAA/OMIT / MFF,MAA/OMIT $
 98  COND     LBL5D,OMIT $
 99  SMP2     USET,GO,KDFF/KDAA $
100  SMP2     USET,GO,MFF/MAA $
101  LABEL    LBL5D $
102  PARAM    //*ADD*/DSCOSET/-1/0 $
103  EQUIV    PL,PBL/DSCOSET/PS,PBS/DSCOSET/YS,YBS/DSCOSET/UOOV,UBOOV/
              DSCOSET $
104  PARAM    //*MPY*/NDSKIP/0/0 $
105  DSMG2    MPT,KAA,KDAA,KFS,KDFS,KSS,KDSS,PL,PS,YS,UOOV/KBLL,KBFS,KBSS,
              PBL,PBS,YBS,UBOOV/S,N,NDSKIP/S,N,REPEATD/DSCOSET $
106  RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $
107  PRTPARM  //0/*DET* $
108  PRTPARM  //0/*POWER* $
109  SSG3     LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/
              S,N,EPSI $
110  COND     LBL9D,IRES $
111  MATGPR   GPL,USET,SIL,RUBLV//*L* $
112  LABEL    LBL9D $
113  SDR1     USET,,UBLV,UBOOV,YBS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/NDSKIP/
              *DS1* $
114  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/,
              OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $
```

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RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 13

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


115  OFP       OQBG1,OUBGV1,OESB1,OEFB1,,//S,N,CARDNO $

116  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/
               LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
               NONLFT/NOTRL/S,N,NOEED//NOUE $

117  COND      ERROR3,NOEED $

118  PARAM     //*MPY*/NEIGV/1/-1 $

119  READ      KBLL,MAA,,,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/
               S,N,NEIGV/3 $

120  OFP       OEIGS,,,,,//S,N,CARDNO $

121  COND      ERROR4,NEIGV $

122  OFP       LAMA,,,,,//S,N,CARDNO $

123  SDR1      USET,,PHIA,,,GO,GM,,KDFS,,/PHIG,,BQG/1/*REIG* $

124  CASE      CASECC,/CASEXX/*TRANRESP*/KEPEAT=3/LOOP $

125  SDR2      CASEXX,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,BQG,PHIG,EST,,/,
               OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*REIG* $

126  OFP       OPHIG,OBQG1,OBEF1,OBES1,,//S,N,CARDNO $

127  COND      P3,JUMPPLOT $

128  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,
               OBES1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/
               S,N,PFILE $

129  PRTMSG    PLOTX3// $

130  LABEL     P3 $

131  JUMP      FINIS $

132  LABEL     ERROR1 $

133  PRTPARM   //-1/*NMDS* $

134  LABEL     ERROR2 $

135  PRTPARM   //-2/*NMDS* $

136  LABEL     ERROR3 $

137  PRTPARM   //-3/*NMDS* $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 13

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
138  LABEL    ERROR4 $
139  PRTPARM  //-4/*NMDS* $
140  LABEL    ERROR5 $
141  PRTPARM  //-5/*NMDS* $
142  LABEL    ERROR6 $
143  PRTPARM  //-6/*NMDS* $
144  LABEL    FINIS $
145  PURGE    DUMMY/MINUS1 $
146  END      $
```

2.13.2 Description of Important DMAP Operations for Normal Modes with Differential Stiffness

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 132 and print Error Message No. 1 if no structural elements have been defined.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 140 and print Error Message No. 5 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

37. Go to DMAP No. 39 if there are no general elements.

38. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

42. Go to DMAP No. 142 and print Error Message No. 6 if no independent degrees of freedom are defined.

45. Go to DMAP No. 47 if there are no support cards.

46. Go to DMAP No. 134 and print Error Message No. 2.

48. Go to DMAP No. 53 if general elements are present.

50. Go to DMAP No. 53 if no potential grid point singularities exist.

51. GPSP generates a table of potential grid point singularities.

52. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

54. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

55. Go to DMAP No. 58 if no multipoint constraints exist.

56. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

57. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

59. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

60. Go to DMAP No. 62 if no single-point constraints exist.

61. SCE1 partitions out single-point constraints

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

63. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

64. Go to DMAP No. 66 if no omitted coordinates exist.

65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

67. RBMG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. SSG1 generates static load vectors $\{P_g\}$.

69. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

70. Go to DMAP No. 72 if no constraints are applied.

71. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c}\bar{P}_n \\ \hline P_m\end{array}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c}P_a \\ \hline P_o\end{array}\right\} \text{ and } \qquad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

73. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}} ,$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

74. Go to DMAP No. 77 if residual vectors are not to be printed.

75. MATGPR prints the residual vector for independent coordinates (RULV).

76. MATGPR prints the residual vector for omitted coordinates (RUØV).

78. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \ ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} \ , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} \ .$$

79. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

80. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

81. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

82. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

83. Go to DMAP No. 86 if no static solution deformed structure plots are requested.

84. PLØT generates all requested static solution deformed structure and contour plots.

85. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.

87. TA1 generates element tables for use in differential stiffness matrix assembly.

88. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

89. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

90. Go to DMAP No. 92 if no multipoint constraints exist.

91. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{array}{c|c} \bar{K}_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

93. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

94. Go to DMAP No. 96 if no single-point constraints exist.

95. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right] \text{ and } \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

97. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

98. Go to DMAP No. 101 if no omitted coordinates exist.

99. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right]$$

and performs matrix reduction $[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{ao}][G_o]$.

100. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M^T_{oa}][G_o] + [G^T_o][M_{oa}] + [G^T_o][M_{oo}][G_o]$$

103. Equivalence $\{P_\ell\}$ to $\{P^b_\ell\}$, $\{P_s\}$ to $\{P^b_s\}$, $\{Y_s\}$ to $\{Y^b_s\}$ and $\{u^o_o\}$ to $\{u^{ob}_o\}$ if a scale factor is not specified on a DSFACT card.

105. DSMG2 adds partitions of stiffness matrix to similar partitions of differential stiffness matrix

$$[K^b_{\ell\ell}] = [K_{aa}] + \beta[K^d_{aa}] ,$$

$$[K^b_{fs}] = [K_{fs}] + \beta[K^d_{fs}] \text{ and}$$

$$[K^b_{ss}] = [K_{ss}] + \beta[K^d_{ss}]$$

and multiplies partitions of load vectors and displacement vectors by the value of the differential stiffness scale factor (β)

$$\{P^b_\ell\} = \beta\{P_\ell\} , \qquad \{P^b_s\} = \beta\{P_s\} ,$$

$$\{Y^b_s\} = \beta\{Y_s\} \text{ and} \qquad \{u^{bo}_o\} = \beta\{u^o_o\} .$$

106. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K^b_{\ell\ell}] = [L^b_{\ell\ell}][U^b_{\ell\ell}].$$

107. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

108. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and the elastic stiffness matrix.

109. SSG3 solves for displacements of independent coordinates for the value of differential stiffness scale factor (β)

$$\{u^b_\ell\} = [K^b_{\ell\ell}]^{-1}\{P^b_\ell\}$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P^b_\ell\} = \{P^b_\ell\} - [K^b_{\ell\ell}]\{u^b_\ell\} \quad ,$$

$$\varepsilon^b_\ell = \frac{\{u^b_\ell\}^T\{\delta P^b_\ell\}}{\{P^b_\ell\}^T\{u^b_\ell\}} \quad .$$

110. Go to DMAP No. 112 if the residual vector for current differential stiffness load factor is not to be printed.

111. MATGPR prints the residual vector for current differential stiffness load factor.

113. SDR1 recovers dependent displacements for the current differential stiffness scale factor

$$\{u^b_o\} = [G_o]\{u^b_\ell\} + \{u^{ob}_o\} \quad , \qquad \left\{\begin{array}{c} u^b_\ell \\ \hline u^b_o \end{array}\right\} = \{u^b_f\} \quad ,$$

$$\left\{\begin{array}{c} u^b_f \\ \hline \gamma^b_s \end{array}\right\} = \{u^b_n\} \quad , \qquad \{u^b_m\} = [G_m]\{u^b_n\} \quad ,$$

$$\left\{\begin{array}{c} u^b_n \\ \hline u^b_m \end{array}\right\} = \{u^b_g\}$$

and recovers single-point forces of constraint for the current differential stiffness scale factor

$$\{q^b_s\} = -\{P^b_s\} + [K^b_{sf}]\{u^b_f\} + [K^b_{ff}]\{\gamma^b_s\} \quad .$$

114. SDR2 calculates element forces (ØEFB1) and stresses (ØESB1) and prepares displacement vectors (ØUBGV1) and single-point forces of constraint (ØQBG1) for output and translation components of the displacement vector (PUBGV1) for the differential stiffness solution.

115. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

116. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

117. Go to DMAP No. 136 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.

119. READ extracts real eigenvalues and eigenvectors from the equation

$$[K^{b}_{\ell\ell} - \lambda M_{aa}]\{u_a\} = 0 \quad ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi^{T}_{ro}][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} -D\phi_{ro}- \\ \phi_{ro} \end{bmatrix} ,$$

calculates modal mass matrix

$$[m] = [\phi^{T}_{a}][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

120. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

121. Go to DMAP No. 138 and print Error Message No. 4 if no eigenvalues were found.

122. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

123. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \begin{Bmatrix} -\phi_a- \\ \phi_o \end{Bmatrix} = \{\phi_f\} \quad ,$$

$$\begin{Bmatrix} -\phi_f- \\ \phi_s \end{Bmatrix} = \{\phi_n\} \quad , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \quad ,$$

$$\begin{Bmatrix} -\phi_n- \\ \phi_m \end{Bmatrix} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

124. CASE copies the record corresponding to the third subcase from CASECC into CASEXX.

125. SDR2 calculates element forces (ØBEF1) and stresses (ØBES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØBQG1) for output and translation components of the eigenvectors (PPHIG) for the normal mode solution.

126. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

127. Go to DMAP No. 130 if no real eigenvalue solution deformed structure plots are requested.

128. PLØT generates all requested real eigenvalue solution deformed structure and contour plots.

129. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

131. Go to DMAP No. 144 and make normal exit.

133. Print Error Message No. 1 and terminate execution.

135. Print Error Message No. 2 and terminate execution.

137. Print Error Message No. 3 and terminate execution.

139. Print Error Message No. 4 and terminate execution.

141. Print Error Message No. 5 and terminate execution.

143. Print Error Message No. 6 and terminate execution.

2.13.3 Output for Normal Modes with Differential Stiffness

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is also automatically printed.

The following output may be requested:

1. Nonzero components of the applied static load for the linear solution at selected grid points.
2. Displacement and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Deformed and undeformed plots with and without differential stiffness.
2. Contour plots of stresses and displacements with and without differential stiffness.

The following output may be requested for the eigenvector solution subcase:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected modes.
5. Contour plots of stresses and displacements for selected modes.

2.13.4 Case Control Deck for Normal Modes with Differential Stiffness

The following items relate to subcase definition and data selection for Normal Modes with Differential Stiffness:

1. The Case Control Deck must contain three subcases. Output selections may be made above the subcase level and within the individual subcases.
2. The linear solution is output from the first subcase. The static differential stiffness solution is output from the second subcase. The eigenvector solution is output from the third subcase.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.

4. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
5. DSCØEFFICIENT must appear in the second subcase, either to select a DSFACT set from the Bulk Data Deck, or to explicitly select the DEFAULT value of unity.
6. METHØD must appear in the third subcase to select an EIGR bulk data card.

2.13.5 Parameters for Normal Modes with Differential Stiffness

The following parameters are used in Normal Modes with Differential Stiffness:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
6. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.13.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.13.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes with Differential Stiffness. See Section 2.3.7 for details.

2.13.8 Rigid Format Error Messages from Normal Modes with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Normal Modes with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUE FØUND.

No eigenvalues were found in the frequency range specified by the user.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

2.14 STATIC ANALYSIS USING CYCLIC SYMMETRY

2.14.1 DMAP Sequence for Static Analysis Using Cyclic Symmetry

```
  RIGID FORMAT DMAP LISTING
  APRIL 1986 RELEASE

  DISPLACEMENT APPROACH, RIGID FORMAT 14

       LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 14 - STATIC ANALYSIS WITH CYCLIC SYMMETRY - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     KKK=SAVE/PK=SAVE $

    4  FILE     UXV=APPEND $

    5  PARAM    //*MPY*/CARDNO/0/0 $

    6  PARAM    //*NOP*/V,Y,CYCIO=1 $

    7  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    8  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    9  GP2      GEOM2,EQEXIN/ECT $

   10  PARAML   PCDB//*PRES*////JUMPPLOT $

   11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   12  COND     P1,JUMPPLOT $

   13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   14  PRTMSG   PLTSETX// $

   15  PARAM    //*MPY*/PLTFLG/1/1 $

   16  PARAM    //*MPY*/PFILE/0/0 $

   17  COND     P1,JUMPPLOT $

   18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE  $

   19  PRTMSG   PLOTX1// $

   20  LABEL    P1 $

   21  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 14

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $

 23  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
              LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

 24  PARAM    //*AND*/NOELMT/NOGENL/NOSIMP $

 25  COND     ERROR4,NOELMT $

 26  PURGE    GPST/NOSIMP/OGPST/GENEL $

 27  COND     LBL1,NOSIMP $

 28  PARAM    //*ADD*/NOKGGX/1/0 $

 29  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/
              C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 30  PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $

 31  COND     JMPKGG,NOKGGX $

 32  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 33  LABEL    JMPKGG $

 34  COND     JMPMGG,NOMGG $

 35  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 36  LABEL    JMPMGG $

 37  COND     LBL1,GRDPNT $

 38  COND     ERROR2,NOMGG $

 39  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $

 40  OFP      OGPWG,,,,,//S,N,CARDNO $

 41  LABEL    LBL1 $

 42  EQUIV    KGGX,KGG/NOGENL $

 43  COND     LBL11A,NOGENL $

 44  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 45  LABEL    LBL11A $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 14

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 46  PARAM    //*MPY*/NSKIP/0/0 $

 47  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 48  COND     ERROR3,NOL $

 49  PARAM    //*NOT*/REACDATA/REACT $

 50  COND     ERROR6,REACDATA $

 51  PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE $

 52  GPCYC    GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $

 53  COND     ERROR7,NOGO $

 54  COND     LBL4,GENEL $

 55  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

 56  COND     LBL4,GPSPFLG $

 57  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $

 58  OFP      OGPST,,,,,//S,N,CARDNO $

 59  LABEL    LBL4 $

 60  EQUIV    KGG,KNN/MPCF1 $

 61  COND     LBL2,MPCF1 $

 62  MCE1     USET,RG/GM $

 63  MCE2     USET,GM,KGG,,,/KNN,,, $

 64  LABEL    LBL2 $

 65  EQUIV    KNN,KFF/SINGLE $

 66  COND     LBL3,SINGLE $

 67  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $

 68  LABEL    LBL3 $

 69  EQUIV    KFF,KAA/OMIT $

 70  COND     LBL5,OMIT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 14

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 71  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

 72  LABEL    LBL5 $

 73  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/NSKIP $

 74  EQUIV    PG,PL/NOSET $

 75  COND     LBL9,NOSET $

 76  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $

 77  COND     LBL9,OMIT $

 78  SSG3     LOO,KOO,PO,,,/UOOV,,RUOV,/-1/V,Y,IRES=-1 $

 79  COND     LBL9,IRES $

 80  MATGPR   GPL,USET,SIL,RUOV//*0* $

 81  LABEL    LBL9 $

 82  EQUIV    PL,PX/CYC10 $

 83  COND     LBL10,CYC10 $

 84  CYCT1    PL/PX,GCYCF/V,Y,CTYPE/*FORE*/V,Y,NSEGS=-1/S,Y,KMAX=-1/V,Y,
              NLOAD=1/S,N,NOGO $

 85  LABEL    LBL10 $

 86  COND     ERROR7,NOGO $

 87  PARAM    //*ADD*/KINDEX/0/0 $

 88  LABEL    LBL11 $

 89  CYCT2    CYCD,KAA,,PX,,/KKK,,PK,,/*FORE*/V,Y,NSEGS/KINDEX/V,Y,
              CYCSEQ=-1/V,Y,NLOAD/S,N,NOGO $

 90  COND     ERROR7,NOGO $

 91  RBMG2    KKK/LKK $

 92  SSG3     LKK,KKK,PK,,,/UKV,,RUKV,/-1/V,Y,IRES $

 93  CYCT2    CYCD,,,UKV,RUKV,/,,UXV,RUXV,/*BACK*/V,Y,NSEGS/KINDEX/
              V,Y,CYCSEQ/V,Y,NLOAD/S,N,NOGO $

 94  COND     ERROR7,NOGO $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 14

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 95  COND      LBL14,IRES $
 96  MATGPR    GPL,USET,SIL,RUXV//*A* $
 97  LABEL     LBL14 $
 98  PARAM     //*ADD*/KINDEX/KINDEX/1 $
 99  PARAM     //*SUB*/DONE/V,Y,KMAX/KINDEX $
100  COND      LBL15,DONE $
101  REPT      LBL11,360 $
102  JUMP      ERROR1 $
103  LABEL     LBL15 $
104  EQUIV     UXV,ULV/CYC10 $
105  COND      LBL16,CYC10 $
106  CYCT1     UXV/ULV,GCYCB/V,Y,CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/V,Y,NLOAD/
               S,N,NOGO $
107  COND      ERROR7,NOGO $
108  LABEL     LBL16 $
109  SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/NSKIP/
               *STATICS* $
110  COND      NOMPCF,GRDEQ $
111  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/
               OQM1/V,Y,OPT=0/V,Y,GRDEQ/NSKIP $
112  OFP       OQM1,,,,,//S,N,CARDNO $
113  LABEL     NOMPCF $
114  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
               OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $
115  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
116  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $
117  OFP       OESF1,,,,,//S,N,CARDNO $
118  COND      P2,JUMPPLOT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 14

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


119  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

120  PRTMSG   PLOTX2// $

121  LABEL    P2 $

122  JUMP     FINIS $

123  LABEL    ERROR1 $

124  PRTPARM  //-1/*CYCSTATICS* $

125  LABEL    ERROR2 $

126  PRTPARM  //-2/*CYCSTATICS* $

127  LABEL    ERROR3 $

128  PRTPARM  //-3/*CYCSTATICS* $

129  LABEL    ERROR4 $

130  PRTPARM  //-4/*CYCSTATICS* $

131  LABEL    ERROR6 $

132  PRTPARM  //-6/*CYCSTATICS* $

133  LABEL    ERROR7 $

134  PRTPARM  //-7/*CYCSTATICS* $

135  LABEL    FINIS $

136  PURGE    DUMMY/MINUS1 $

137  END      $
```

2.14.2 Description of Important DMAP Operations for Static Analysis Using Cyclic Symmetry

7. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

8. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Static Loads Table and Grid Point Temperature Table.

23. TA1 generates element tables for use in matrix assembly and stress recovery.

25. Go to DMAP No. 129 and print Error Message No. 4 if no elements have been defined.

27. Go to DMAP No. 41 if there are no structural elements.

29. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 41 if no weight and balance information is requested.

38. Go to DMAP No. 125 and print Error Message No. 2 if no mass matrix exists.

39. GPWG generates weight and balance information.

40. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

42. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

43. Go to DMAP No. 45 if there are no general elements.

44. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

47. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

48. Go to DMAP No. 127 and print Error Message No. 3 if no independent degrees of freedom are defined.

50. Go to DMAP No. 131 and print Error Message No. 6 if free-body supports are present.

52. GPCYC prepares segment boundary table (CYCD).

53. Go to DMAP No. 133 and print Error Message No. 7 if CYJØIN data is inconsistent.

54. Go to DMAP No. 59 if general elements are present.

56. Go to DMAP No. 59 if no potential grid point singularities exist.

57. GPSP generates a table of potential grid point singularities.

58. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

60. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

61. Go to DMAP No. 64 if no multipoint constraints exist.

62. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

63. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

65. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

66. Go to DMAP No. 68 if no single-point constraints exist.

67. SCE1 partitions out single-point constraints

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

69. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

70. Go to DMAP No. 72 if no omitted coordinates exist.

71. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

73. SSG1 generates static load vectors $\{P_g\}$.

74. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

75. Go to DMAP No. 81 if no constraints are applied.

76. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c}\bar{P}_n \\ \hline P_m\end{array}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c}\bar{P}_a \\ \hline P_o\end{array}\right\} , \qquad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\begin{array}{c}P_\ell \\ \hline P_r\end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

77. Go to DMAP No. 81 if no omitted coordinates exist.

78. SSG3 solves for displacements of omitted coordinates (these are not transformed)

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

79. Go to DMAP No. 81 if residual vectors are not to be printed.

80. MATGPR prints the residual vector for omitted coordinates (RUØV).

82. Equivalence $\{P_\ell\}$ to $\{P_x\}$ if symmetric components of loads have been input.

83. Go to DMAP No. 85 if symmetric conponents of loads have been input.

84. CYCT1 transforms loads on analysis points to symmetric components by the equation

$$\{P_x\} = [G]\{P_\ell\} .$$

86. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT1 error was found.

88. Beginning of loop for cyclic index (KINDEX) values.

89. CYCT2 transforms matrices and loads from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}[G_2] \ ,$$

where $G_1 = G_c$ (cosine) and $G_2 = G_s$ (sine) for rotational symmetry,

and $G_1 = G_S$ (Symmetric) and $G_2 = G_A$ (Antisymmetric) for dihedral symmetry,

$$\{P_k\} = [G_c^T]\{P_c\} + [G_s^T]\{P_s\} \text{ for rotational symmetry,}$$

$$\{P_k^1\} = [G_S^T]\{P_{cS}\} + [G_A^T]\{P_{sA}\} \ ,$$

and $\{P_k^2\} = [G_A^T]\{P_{cA}\} + [G_S^T]\{P_{sS}\}$ for dihedral symmetry.

90. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT2 error was found.

91. RBMG2 decomposes constrained stiffness matrix for solution set

$$[K_{kk}] = [L_{kk}][U_{kk}]$$

92. SSG3 solves for displacements of solution set coordinates

$$\{u_k\} = [K_{kk}]^{-1}\{P_k\}$$

and calculates residual vector (RUKV) and residual vector error ratio for solution set coordinates

$$\{\delta P_k\} = \{P_k\} - [K_{kk}]\{u_k\} \ ,$$

$$\varepsilon_k = \frac{\{u_k^T\}\{\delta P_k\}}{\{P_k^T\}\{u_k\}} \ .$$

93. CYCT2 finds symmetric components of displacement from solution set data and appends to output for each KINDEX.

94. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT2 error was found.

95. Go to DMAP No. 97 if residual vectors are not to be printed.

96. MATGPR prints the residual vector for solution set coordinates (RUXV).

100. Go to DMAP No. 103 if all cyclic index (KINDEX) values are complete.

101. Go to DMAP No. 88 if additional cyclic index values are needed.

102. Go to DMAP No. 123 and print Error Message No. 1 if number of loops exceeds 360.

104. Equivalence $\{u_x\}$ to $\{u_\ell\}$ if output of symmetric components was requested.

105. Go to DMAP No. 108 if output of symmetric components was requested.

106. CYCT1 transforms displacements from symmetric components to physical components.

107. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT1 error was found.

109. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \ ,$$

$$\left\{\begin{matrix} u_a \\ \hline u_o \end{matrix}\right\} = \{u_f\} \ , \qquad \left\{\begin{matrix} u_f \\ \hline Y_s \end{matrix}\right\} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} \ .$$

110. Go to DMAP No. 113 if no multipoint constraint force balance is requested.

111. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

112. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

114. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

115. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

116. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

117. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

118. Go to DMAP No. 121 if no deformed structure plots are requested.

119. PLØT generates all requested deformed structure and contour plots.

120. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

122. Go to DMAP No. 135 and make normal exit.

124. Print Error Message No. 1 and terminate execution.

126. Print Error Message No. 2 and terminate execution.

128. Print Error Message No. 3 and terminate execution.

130. Print Error Message No. 4 and terminate execution.

132. Print Error Message No. 6 and terminate execution.

134. Print Error Message No. 7 and terminate execution.

2.14.3 Output for Static Analysis Using Cyclic Symmetry

The following printed output, for each loading condition and each symmetric segment or index, may be requested for Static Analysis Using Cyclic Symmetry:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and streses in selected elements.
3. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model (1 segment).
2. Contour plots of stresses and displacements (1 segment).
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point.
4. X-Y plot of any stress or force component for an element.

2.14.4 Case Control Deck for Static Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Static Analysis Using Cyclic Symmetry:

1. A separate group of subcases must be defined for each symmetric segment. For dihedral symmetry, a separate group of subcases must be defined for each half. There may be up to 360 subcases corresponding to 1° segments.
2. The different loading conditions are defined within each group of subcases. The loads on each symmetric segment and the selected output requests may be independent. The number of loading cases is specified on the PARAM card NLØAD.
3. The SPC and MPC request must appear above the subcase level and may not be changed.
4. An alternate loading method is to define a separate group of subcases for each harmonic index, k. The parameter CYCIØ is included and the load components for each index are defined directly within each group for the various loading conditions.

2.14.5 Parameters for Static Analysis Using Cyclic Symmetry

The following parameters are used in Static Analysis Using Cyclic Symmetry:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

2. AUTØSPC - reserved for future optional use. The default value is -1.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:

   (1) RØT - rotational symmetry

   (2) DRL - dihedral symmetry, using right and left halves

   (3) DSA - dihedral symmetry, using symmetric and antisymmetric components

5. CYCIØ - optional. The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. The default value is +1.

6. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.

7. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. The default value is -1.

8. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

9. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.

10. KMAX - optional. The integer value of this parameter specifies the maximum value of the harmonic index. The default value is ALL which implies NSEGS/2 for NSEGS even and (NSEGS - 1)/2 for NSEGS odd.

11. NLØAD - optional. The integer value of this parameter is the number of static loading conditions. The default value is 1.

12. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.

13. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
14. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
16. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.14.6 Rigid Format Error Messages from Static Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Static Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 cyclic index (KINDEX) values. This number may be increased by ALTERing the REPT instruction in the DMAP.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis Using Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 7 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

2.15 NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

2.15.1 DMAP Sequence for Normal Modes Analysis Using Cyclic Symmetry

```
  RIGID FORMAT DMAP LISTING
  APRIL 1986 RELEASE

  DISPLACEMENT APPROACH, RIGID FORMAT 15

       LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 15 NORMAL MODES ANALYSIS WITH CYCLIC SYMMETRY-APR. 1986 $

    2  PRECHK   ALL $

    3  PARAM    //*MPY*/CARDNO/0/0 $

    4  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                NOGPDT/MINUS1=-1 $

    5  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    6  GP2      GEOM2,EQEXIN/ECT $

    7  PARAML   PCDB//*PRES*////JUMPPLOT $

    8  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

    9  COND     P1,JUMPPLOT $

   10  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/
                S,N,JUMPPLOT $

   11  PRTMSG   PLTSETX// $

   12  PARAM    //*MPY*/PLTFLG/1/1 $

   13  PARAM    //*MPY*/PFILE/0/0 $

   14  COND     P1,JUMPPLOT $

   15  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE  $

   16  PRTMSG   PLOTX1//$

   17  LABEL    P1 $

   18  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   19  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   20  COND     ERROR6,NOSIMP $

   21  PURGE    OGPST/GENEL $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PARAM    //*ADD*/NOKGGX/1/0 $

 23  PARAM    //*ADD*/NOMGG/1/0 $

 24  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
              S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/
              C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/
              C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
              V,Y,VOLUME/V,Y,SURFACE $

 25  PURGE    KGGX,GPST/NOKGGX $

 26  COND     JMPKGG,NOKGGX $

 27  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 28  LABEL    JMPKGG $

 29  COND     ERROR1,NOMGG $

 30  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 31  COND     LGPWG,GRDPNT $

 32  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $

 33  OFP      OGPWG,,,,,//S,N,CARDNO $

 34  LABEL    LGPWG $

 35  EQUIV    KGGX,KGG/NOGENL $

 36  COND     LBL11,NOGENL $

 37  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 38  LABEL    LBL11 $

 39  PARAM    //*MPY*/NSKIP/0/0 $

 40  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/
              LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 41  COND     ERROR3,NOL $

 42  PARAM    //*NOT*/REACDATA/REACT $

 43  COND     ERROR4,REACDATA $

 44  PURGE    GM/MPCF1/GO/OMIT/KFS,QG/SINGLE $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  GPCYC    GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $
 46  COND     ERROR5,NOGO $
 47  COND     LBL4,GENEL $
 48  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 49  COND     LBL4,GPSPFLG $
 50  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 51  OFP      OGPST,,,,,//S,N,CARDNO $
 52  LABEL    LBL4 $
 53  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 54  COND     LBL2,MPCF1 $
 55  MCE1     USET,RG/GM $
 56  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 57  LABEL    LBL2 $
 58  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 59  COND     LBL3,SINGLE $
 60  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 61  LABEL    LBL3  $
 62  EQUIV    KFF,KAA/OMIT $
 63  EQUIV    MFF,MAA/OMIT $
 64  COND     LBL5,OMIT $
 65  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 66  SMP2     USET,GO,MFF/MAA $
 67  LABEL    LBL5 $
 68  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/
              LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
              NONLFT/NOTRL/S,N,NOEED//NOUE $
 69  COND     ERROR2,NOEED $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  CYCT2     CYCD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS=-1/V,Y,KINDEX=-1/
               V,Y,CYCSEQ=-1/1/S,N,NOGO $

 71  COND      ERROR5,NOGO $

 72  READ      KKK,MKK,,,EED,,CASECC/LAMK,PHIK,MI,OEIGS/*MODES*/S,N,NEIGV $

 73  OFP       OEIGS,,,,,//S,N,CARDNO $

 74  COND      FINIS,NEIGV $

 75  OFP       LAMK,,,,,//S,N,CARDNO $

 76  CYCT2     CYCD,,,,PHIK,LAMK/,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,KINDEX/
               V,Y,CYCSEQ/1/S,N,NOGO $

 77  COND      ERROR5,NOGO $

 78  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $

 79  COND      NOMPCF,GRDEQ $

 80  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/
               OQM1/V,Y,OPT=0/V,Y,GRDEQ/-1 $

 81  OFP       OQM1,,,,,//S,N,CARDNO $

 82  LABEL     NOMPCF $

 83  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/,
               OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $

 84  OFP       OPHIG,OQG1,OEF1,OES1,,//S,N,CARDNO $

 85  SCAN      CASECC,OES1,OEF1/OESF1/*RF* $

 86  OFP       OESF1,,,,,//S,N,CARDNO $

 87  COND      P2,JUMPPLOT $

 88  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

 89  PRTMSG    PLOTX2// $

 90  LABEL     P2 $

 91  JUMP      FINIS $

 92  LABEL     ERROR1 $

 93  PRTPARM   //-1/*CYCMODES* $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 94  LABEL    ERROR2 $
 95  PRTPARM  //-2/*CYCMODES* $
 96  LABEL    ERROR3 $
 97  PRTPARM  //-3/*CYCMODES* $
 98  LABEL    ERROR4 $
 99  PRTPARM  //-4/*CYCMODES* $
100  LABEL    ERROR5 $
101  PRTPARM  //-5/*CYCMODES* $
102  LABEL    ERROR6 $
103  PRTPARM  //-6/*CYCMODES* $
104  LABEL    FINIS $
105  PURGE    DUMMY/MINUS1 $
106  END      $
```

2.15.2 Description of Important DMAP Operations for Normal Modes Analysis Using Cyclic Symmetry

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

5. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

6. GP2 generates Element Connection Table with internal indices.

9. Go to DMAP No. 17 if there are no structure plot requests.

10. PLTSET transforms user input into a form used to drive the structure plotter.

11. PRTMSG prints error messages associated with the structure plotter.

14. Go to DMAP No. 17 if no undeformed structure plots are requested.

15. PLØT generates all requested undeformed structure plots.

16. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

18. GP3 generates Static Loads Table and Grid Point Temperature Table.

19. TA1 generates element tables for use in matrix assembly and stress recovery.

20. Go to DMAP No. 102 and print Error Message No. 6 if no structural elements have been defined.

24. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

26. Go to DMAP No. 28 if no stiffness matrix is to be assembled.

27. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

29. Go to DMAP No. 92 and print Error Message No. 1 if no mass matrix is to be assembled.

30. EMA assembles mass matrix $[M_{gg}]$.

31. Go to DMAP No. 34 if no weight and balance information is requested.

32. GPWG generates weight and balance information.

33. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

35. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

36. Go to DMAP No. 38 if there are no general elements.

37. SMA3 adds general elements to $[K^{x}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

40. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

41. Go to DMAP No. 96 and print Error Message No. 3 if no independent degrees of freedom are defined.

43. Go to DMAP No. 98 and print Error Message No. 4 if free-body supports are present.

45. GPCYC prepares segment boundary table (CYCD).

46. Go to DMAP No. 100 and print Error Message No. 5 if CYJØIN data is inconsistent.

47. Go to DMAP No. 52 if general elements are present.

49. Go to DMAP No. 52 if no potential grid point singularities exist.

50. GPSP generates a table of potential grid point singularities.

51. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

53. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

54. Go to DMAP No. 57 if no multipoint constraints exist.

55. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

56. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad .$$

58. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

59. Go to DMAP No. 61 if no single-point constraints exist.

60. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

62. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

63. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

64. Go to DMAP No. 67 if no omitted coordinates exist.

65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

66. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \quad .$$

68. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

69. Go to DMAP No. 94 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

70. CYCT2 transforms matrices from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}[G_2] ,$$

and

$$[M_{kk}] = [G_1^T][M_{aa}][G_1] + [G_2^T][M_{aa}[G_2] ,$$

where $G_1 = G_c$ (cosine) and $G_2 = G_s$ (sine) for rotational symmetry,

and $G_1 = G_S$ (Symmetric) and $G_2 = G_A$ (Antisymmetric) for dihedral symmetry.

71. Go to DMAP No. 100 and print Error Message No. 5 if a CYCT2 error was found.

72. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{kk} - \lambda M_{kk}]\{u_k\} = 0 \quad ,$$

calculates modal mass matrix

$$[m] = [\phi_k^T][M_{kk}][\phi_k]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

73. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

74. Go to DMAP No. 104 and make normal exit if no eigenvalues were found.

75. ØFP formats the eigenvalues (LAMK) prepared by READ and places them on the system output file for printing.

76. CYCT2 finds symmetric components of eigenvectors from solution set eigenvectors.

77. Go to DMAP No. 100 and print Error Message No. 5 if a CYCT2 error was found.

78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \left\{\frac{\phi_a}{\phi_o}\right\} = \{\phi_f\} \quad ,$$

$$\left\{\frac{\phi_f}{\phi_s}\right\} = \{\phi_n\} \quad , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \quad ,$$

$$\left\{\frac{\phi_n}{\phi_m}\right\} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.

80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

83. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØQG1) for output and translation components of the eigenvectors (PPHIG).

84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

85. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.

86. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

87. Go to DMAP No. 90 if no deformed structure plots are requested.

88. PLØT generates all requested deformed structure and contour plots.

89. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

91. Go to DMAP No. 104 and make normal exit.

93. Print Error Message No. 1 and terminate execution.

95. Print Error Message No. 2 and terminate execution.

97. Print Error Message No. 3 and terminate execution.

99. Print Error Message No. 4 and terminate execution.

101. Print Error Message No. 5 and terminate execution.

103. Print Error Message No. 6 and terminate execution.

2.15.3 Output for Normal Modes Analysis Using Cyclic Symmetry

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

Each NASTRAN run calculates modes for only one symmetry index, k. The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected modes.
2. Contour plots of stresses and displacements for selected modes.

2.15.4 Case Control Deck for Normal Modes Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Normal Modes Analysis Using Cyclic Symmetry:

1. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
2. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
3. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.

2.15.5 Parameters for Normal Modes Analysis Using Cyclic Symmetry

The following parameters are used in Normal Modes Analysis Using Cyclic Symmetry:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
   (1) RØT - rotational symmetry
   (2) DRL - dihedral symmetry, using right and left halves
   (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
5. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.
6. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. The default value is -1.
7. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
8. KINDEX - required. The integer value of this parameter specifies a single value of the harmonic index.
9. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.
10. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
11. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.

12. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
13. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

2.15.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.15.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes Analysis Using Cyclic Symmetry. See Section 2.3.7 for details.

2.15.8 Rigid Format Error Messages from Normal Modes Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Normal Modes Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHOD in the Case Control Deck must select an EIGR set.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT, or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes Analysis Using Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 5 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

2.16 STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESORS

2.16.1 DMAP Sequence for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    DISP 16 - STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS-APR. 1986 $

    2  PRECHK   ALL $

    3  PARAM    //*MPY*/CARDNO/0/0 $

    4  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/S,N,
                NOGPDT/MINUS1=-1 $

    5  COND     ERROR3,NOGPDT $

    6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  PARAMR   //*COMPLEX*//V,Y,SIGN/0.0/CSIGN $

   10  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   11  COND     P1,JUMPPLOT $

   12  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/S,N,
                JUMPPLOT $

   13  PRTMSG   PLTSETX// $

   14  PARAM    //*MPY*/PLTFLG/1/1 $

   15  PARAM    //*MPY*/PFILE/0/0 $

   16  COND     P1,JUMPPLOT $

   17  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   18  PRTMSG   PLOTX1// $

   19  LABEL    P1 $

   20  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $

   21  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,
               NOSIMP/1/S,N,NOGENL/S,N,GENEL $

 23  COND      ERROR1,NOSIMP $

 24  PURGE     OGPST/GENEL $

 25  PARAM     //*ADD*/NOKGGX/1/0 $

 26  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
               S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
               CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,
               CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $

 27  COND      JMPKGG,NOKGGX $

 28  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 29  LABEL     JMPKGG $

 30  COND      JMPMGG,NOMGG $

 31  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $

 32  LABEL     JMPMGG $

 33  COND      LBL1,GRDPNT $

 34  COND      ERROR4,NOMGG $

 35  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $

 36  OFP       OGPWG,,,,,//S,N,CARDNO $

 37  LABEL     LBL1 $

 38  EQUIV     KGGX,KGG/NOGENL $

 39  COND      LBL11,NOGENL $

 40  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $

 41  LABEL     LBL11 $

 42  PARAM     //*MPY*/NSKIP/0/0 $

 43  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,YS,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
               NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,
               AUTOSPC $

 44  COND      ERROR5,NOL $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE/
              PBS,KBFS,KBSS,KDFS,KDSS/SINGLE $

 46  COND     LBL4D,REACT $

 47  JUMP     ERROR2 $

 48  LABEL    LBL4D $

 49  COND     LBL4,GENEL $

 50  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

 51  COND     LBL4,GPSPFLG $

 52  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $

 53  OFP      OGPST,,,,,//S,N,CARDNO $

 54  LABEL    LBL4 $

 55  EQUIV    KGG,KNN/MPCF1 $

 56  COND     LBL2,MPCF2 $

 57  MCE1     USET,RG/GM $

 58  MCE2     USET,GM,KGG,,,/KNN,,, $

 59  LABEL    LBL2 $

 60  EQUIV    KNN,KFF/SINGLE $

 61  COND     LBL3,SINGLE $

 62  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $

 63  LABEL    LBL3 $

 64  EQUIV    KFF,KAA/OMIT $

 65  COND     LBL5,OMIT $

 66  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

 67  LABEL    LBL5 $

 68  RBMG2    KAA/LLL $

 69  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PGNA,,,,/
              LUSET/1 $
```

RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 70  PARAM    //*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $
 71  COND     NOAL,ALOAD $
 72  ALG      CASECC,,EQEXIN,,ALGDB,,/CASECCA1,GEOM3A1/S,Y,APRESS/S,Y,
              ATEMP/-1/-1/V,Y,IPRTC1/S,N,IFAIL $
 73  COND     FINIS,IFAIL $
 74  PARAM    //*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $
 75  COND     NOAL,ALOAD $
 76  GP3      GEOM3A1,EQEXIN,GEOM2/SLTA1,GPTTA1/NOGRAV $
 77  SSG1     SLTA1,BGPDT,CSTM,SIL,EST,MPT,GPTTA1,EDT,MGG,CASECCA1,DIT,/
              PGA1,,,,/LUSET/1 $
 78  ADD      PGNA,PGA1/PG $
 79  LABEL    NOAL $
 80  EQUIV    PGNA,PG/ALOAD $
 81  EQUIV    PG,PL/NOSET $
 82  COND     LBL10,NOSET $
 83  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
 84  LABEL    LBL10 $
 85  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              1/S,N,EPSI $
 86  COND     LBL9,IRES $
 87  MATGPR   GPL,USET,SIL,RULV//*L* $
 88  MATGPR   GPL,USET,SIL,RUOV//*O* $
 89  LABEL    LBL9 $
 90  SDR1     USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/1/*DSO* $
 91  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*DSO* $
 92  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
 93  COND     P2,JUMPPLOT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 94  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $

 95  PRTMSG   PLOTX2// $

 96  LABEL    P2 $

 97  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/
              NOSIMP/0/NOGENL/GENEL $

 98  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/
              DSCOSET$

 99  COND     NOALO,ALOAD $

100  EQUIV    PGNA,PG $

101  LABEL    NOALO $

102  PARAM    //*ADD*/SHIFT/-1/0 $

103  PARAM    //*ADD*/COUNT/ALWAYS=-1/NEVER=1 $

104  PARAMR   //*ADD*/DSEPS1/0.0/0.0 $

105  PARAML   YS//*NULL*////NOYS $

106  LABEL    OUTLPTOP $

107  EQUIV    PG,PG1/NOYS $

108  PARAM    //*KLOCK*/TO $

109  EQUIV    KDGG,KDNN/MPCF2 $

110  COND     LBL2D,MPCF2 $

111  MCE2     USET,GM,KDGG,,,/KDNN,,, $

112  LABEL    LBL2D $

113  EQUIV    KDNN,KDFF/SINGLE $

114  COND     LBL3D,SINGLE $

115  SCE1     USET,KDNN,,,/KDFF,KDFS,KDSS,,, $

116  LABEL    LBL3D $

117  EQUIV    KDFF,KDAA/OMIT $

118  COND     LBL5D,OMIT $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


119  SMP2     USET,GO,KDFF/KDAA $
120  LABEL    LBL5D $
121  ADD      KAA,KDAA/KBLL/(1.0,0.0)/CSIGN $
122  ADD      KFS,KDFS/KBFS/(1.0,0.0)/CSIGN $
123  ADD      KSS,KDSS/KBSS/(1.0,0.0)/CSIGN $
124  COND     PGOK,NOYS $
125  MPYAD    KBSS,YS,/PSS/O $
126  MPYAD    KBFS,YS,/PFS/O $
127  UMERGE   USET,PFS,PSS/PN/*N*/*F*/*S* $
128  EQUIV    PN,PGX/MPCF2 $
129  COND     LBL6D,MPCF2 $
130  UMERGE   USET,PN,/PGX/*G*/*N*/*M* $
131  LABEL    LBL6D $
132  ADD      PGX,PG/PGG/(-1.0,0.0) $
133  EQUIV    PGG,PG1/ALWAYS $
134  LABEL    PGOK $
135  ADD      PG1,/PGO/ $
136  COPY     UGV/AUGV $
137  RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $
138  PRTPARM  //O/*DET* $
139  PRTPARM  //O/*POWER* $
140  LABEL    INLPTOP $
141  PARAM    //*KLOCK*/TI $
142  COND     NOAL1,ALOAD $
143  ALG      CASECC,EDT,EQEXIN,AUGV,ALGDB,CSTM,BGPDT/CASECCA,GEOM3A/S,Y,
              APRESS/S,Y,ATEMP/-1/-1/V,Y,IPRTCL/S,N,IFAIL/V,Y,SIGN/V,
              Y,ZORIGN/V,Y,FXCOOR/V,Y,FYCOOR/V,Y,FZCOOR $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


144  COND      DONE,IFAIL $

145  PARAM     //*MPY*/V,Y,IPRTCL/0 $

146  PARAM     //*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $

147  COND      NOAL1,ALOAD $

148  GP3       GEOM3A,EQEXIN,GEOM2/SLTA,GPTTA/NOASL/NOGRAV/NOATL $

149  SSG1      SLTA,BGPDT,CSTM,SIL,EST,MPT,GPTTA,EDT,MGG,CASECCA,DIT,/PGA,,,,/
               LUSET/1 $

150  ADD       PG1,PGA/PG2 $

151  LABEL     NOAL1 $

152  EQUIV     PG1,PG2/ALOAD $

153  SSG2      USET,GM,YS,KDFS,GO,,PG2/,PBO,PBS,PBL $

154  SSG3      LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/S,N,
               EPSI $

155  COND      LBL9D,IRES $

156  MATGPR    GPL,USET,SIL,RUBLV//*L* $

157  LABEL     LBL9D $

158  SDR1      USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/1/*DS1* $

159  COND      NOAL2,ALOAD $

160  EQUIV     UBGV,AUGV $

161  LABEL     NOAL2 $

162  ADD       UBGV,UGV/DUGV/(-1.0,0.0) $

163  DSMG1     CASECC,GPTT,SIL,EDT,DUGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/V,N,
               DSCOSET $

164  MPYAD     DKDGG,UBGV,PGO/PG11/0 $

165  ADD       PG11,PGA/PG12 $

166  DSCHK     PG2,PG12,UBGV//C,Y,EPSIO=1.E-5/S,N,DSEPSI/C,Y,NT=10/
               TO/TI/S,N,DONE/S,N,SHIFT/S,N,COUNT/C,Y,BETA=4 $

167  COND      DONE,DONE $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


168  COND      SHIFT,SHIFT $

169  EQUIV     PG,PG1/NEVER $

170  EQUIV     PG11,PG1/ALWAYS $

171  EQUIV     PG1,PG11/NEVER $

172  REPT      INLPTOP,1000 $

173  TABPT     PG11,PG1,PG,,// $

174  LABEL     SHIFT $

175  ADD       DKDGG,KDGG/KDGG1/(-1.0,0.0) $

176  EQUIV     UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $

177  EQUIV     KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $

178  REPT      OUTLPTOP,1000 $

179  TABPT     KDGG1,KDGG,UGV,,// $

180  LABEL     DONE $

181  PARAM     //*NOP*/V,Y,KTOUT=-1 $

182  COND      JMPKTOUT,KTOUT $

183  ADD       KGG,KDGG/KTOTAL/(1.0,0.0)/CSIGN $

184  OUTPUT1   KTOTAL,,,,//C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $

185  OUTPUT1,  ,,,,//-3/0 $

186  LABEL     JMPKTOUT $

187  ALG       CASECC,EDT,EQEXIN,UBGV,ALGDB,CSTM,BGPDT/CASECCB,GEOM3B/
               -1/-1/V,Y,STREAML/V,Y,PGEOM/V,Y,IPRTCF/S,N,IFAIL/V,Y,SIGN/
               V,Y,ZORIGN/V,Y,FXCOOR/V,Y,FYCOOR/V,Y,FZCOOR $

188  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/,
               OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $

189  OFP       OUBGV1,OQBG1,OEFB1,OESB1,,//S,N,CARDNO $

190  SDR1      USET,PG2,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/AUBGV,APGG,AQBG/
               1/*DS1* $

191  GPFDR     CASECC,AUBGV,KELM,KDICT,ECT,EQEXIN,GPECT,APGG,AQBG/ONRGY1,
               OGPFB1/*STATICS* $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


192  OFP       ONRGY1,OGPFB1,,,,//S,N,CARDNO $
193  COND      P3,JUMPPLOT $
194  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUBGV1,,GPECT,
               OESB1/PLOTX3/NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $
195  PRTMSG    PLOTX3// $
196  LABEL     P3 $
197  JUMP      FINIS $
198  LABEL     ERROR1 $
199  PRTPARM   //-1/*ASTA* $
200  LABEL     ERROR2 $
201  PRTPARM   //-2/*ASTA* $
202  LABEL     ERROR3 $
203  PRTPARM   //-3/*ASTA* $
204  LABEL     ERROR4 $
205  PRTPARM   //-4/*ASTA* $
206  LABEL     ERROR5 $
207  PRTPARM   //-5/*ASTA* $
208  LABEL     FINIS $
209  PURGE     DUMMY/MINUS1 $
210  END       $
```

2.16.2 Description of Important DMAP Operations for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

5. Go to DMAP No. 202 and print Error Message No. 3 if there is no Grid Point Definition Table.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

9. PARAMR sets CSIGN=(SIGN, 0.0), where SIGN = +1.0 for analysis type run and SIGN = -1.0 for design type run.

11. Go to DMAP No. 19 if there are no structure plot requests.

12. PLTSET transforms user input into a form used to drive the structure plotter.

13. PRTMSG prints error messages associated with the structure plotter.

16. Go to DMAP No. 19 if no undeformed structure plots are requested.

17. PLØT generates all requested undeformed structure plots.

18. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

20. GP3 generates Static Loads Table and Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

23. Go to DMAP No. 198 and print Error Message No. 1 if there are no structural elements.

26. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 32 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

33. Go to DMAP No. 37 if no weight and balance information is requested.

34. Go to DMAP No. 204 and print Error Message No. 4 if no mass matrix exists.

35. GPWG generates weight and balance information.

36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

38. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if no general elements exist.

39. Go to DMAP No. 41 if no general elements exist.

40. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

43. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

44. Go to DMAP No. 206 and print Error Message No. 5 if no independent degrees of freedom are defined.

46. Go to DMAP No. 48 if no free-body supports are supplied.

47. Go to DMAP No. 200 and print Error Message No. 2.

49. Go to DMAP No. 54 if general elements are present.

51. Go to DMAP No. 54 if no potential grid point singularities exist.

52. GPSP generates a table of potential grid point singularities.

53. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

55. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

56. Go to DMAP No. 59 if no multipoint constraints exist.

57. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

58. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

60. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

61. Go to DMAP No. 63 if no single-point constraints exist.

62. SCE1 partitions out single-point constraints

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

64. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

65. Go to DMAP No. 67 if no omitted coordinates exist.

66. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

68. RMBG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

69. SSG1 generates non-aerodynamic static load vectors $\{P_g^{NA}\}$.

71. Go to DMAP No. 79 if no aerodynamic loads exist.

72. ALG generates aerodynamic load data.

77. SSG1 generates aerodynamic load vector $\{P_g^A\}$.

78. Add $\{P_g^{NA}\}$ and $\{P_g^A\}$ to form total load vector $\{P_g\}$.

80. Equivalence $\{P_g\}$ to $\{P_g^{NA}\}$ if no aerodynamic loads exist.

81. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

82. Go to DMAP No. 84 if no constraints are applied.

83. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \begin{array}{c} \bar{P}_n \\ \hline P_m \end{array} \right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{ \begin{array}{c} \bar{P}_f \\ \hline P_s \end{array} \right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{ \begin{array}{c} P_a \\ \hline P_o \end{array} \right\} , \text{ and} \qquad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

85. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{aa}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{aa}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} \quad .$$

86. Go to DMAP No. 89 if residual vectors are not to be printed.

87. MATGPR prints the residual vector for independent coordinates (RULV).

88. MATGPR prints the residual vector for omitted coordinates (RUØV).

90. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \quad ,$$

$$\left\{\frac{u_a}{u_o}\right\} = \{u_f\} \quad , \qquad \left\{\frac{u_f}{Y_s}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \left\{\frac{u_n}{u_m}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

91. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

92. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

93. Go to DMAP No. 96 if no deformed static solution structure plots are requested.

94. PLØT generates all requested static solution deformed structure and contour plots.

95. PRTMSG prints plotter data, engineering data, and contour data for each deformed static solution plot generated.

97. TA1 generates element tables for use in differential stiffness matrix assembly.

98. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

99. Go to DMAP No. 101 if no aerodynamic loads exist.

100. Equivalence $\{P_g^{NA}\}$ to $\{P_g\}$ to remove aerodynamic loads from total load vector before entering the differential stiffness loop. New aerodynamic loads will be generated in the loop.

106. Beginning of outer (stiffness adjustment) loop for differential stiffness iteration.

107. Equivalence $\{P_g\}$ to $\{P_{g1}\}$ if no enforced displacements are specified.

109. Equivalence $[K^d_{gg}]$ to $[K^d_{nn}]$ if no multipoint constraints exist.

110. Go to DMAP No. 112 if no multipoint constraints exist.

111. MCE2 partitions differential stiffness matrix

$$[K^d_{gg}] = \left[\begin{array}{c|c} \bar{K}^d_{nn} & K^d_{nm} \\ \hline K^d_{mn} & K^d_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K^d_{nn}] = [\bar{K}^d_{nn}] + [G^T_m][K^d_{mn}] + [K^d_{mn}][G_m] + [G^T_m][K^d_{mm}][G_m].$$

113. Equivalence $[K^d_{nn}]$ to $[K^d_{ff}]$ if no single-point constraints exist.

114. Go to DMAP No. 116 if no single-point constraints exist.

115. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right].$$

117. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ if no omitted coordinates exist.

118. Go to DMAP No. 120 if no omitted coordinates exist.

119. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right].$$

and performs matrix reduction

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{oa}]^T[G_o] + [G_o]^T[K^d_{oa}] + [G_o]^T[K^d_{oo}][G_o].$$

121. ADD $[K_{aa}]$ and $[K^d_{aa}]$ to form $[K^b_{\ell\ell}]$.

122. ADD $[K_{fs}]$ and $[K^\phi_{fs}]$ to form $[K^\beta_{fs}]$.

123. ADD $[K_{ss}]$ and $[K^d_{ss}]$ to form $[K^b_{ss}]$.

124. Go to DMAP No. 134 if no enforced displacements are specified.

125. MPYAD multiplies $[K^b_{ss}]$ and $\{Y_s\}$ to form $\{P_{ss}\}$.

126. MYPAD multiplies $[K^b_{fs}]$ and $\{Y_s\}$ to form $\{P_{fs}\}$.

127. UMERGE combines $\{P_{fs}\}$ and $\{P_{ss}\}$ to form $\{P_n\}$.

128. Equivalence $\{P_n\}$ to $\{P_g^X\}$ if no multipoint constraints exist.

129. Go to DMAP No. 131 if no multipoint constraints exist.

130. UMERGE expands $\{P_n\}$ to form $\{P_g^X\}$.

132. ADD $-\{P_g^X\}$ and $\{P_g\}$ to form $\{P_{gg}\}$.

133. Equivalence $\{P_{gg}\}$ to $\{P_{g1}\}$.

135. ADD $\{P_{g1}\}$ and nothing to create $\{P_{go}\}$.

136. Copy $\{u_g\}$ to $\{u_g^A\}$ to initialize aerodynamic displacements.

137. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K_{\ell\ell}^b] = [L_{\ell\ell}^b][U_{\ell\ell}^b].$$

138. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

139. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

140. Beginning of inner (load correction) loop for differential stiffness iteration.

142. Go to DMAP No. 151 if no aerodynamic loads exist.

143. ALG generates aerodynamic load data.

144. Go to DMAP No. 180 if ALG fails to converge while generating aerodynamic load data.

149. SSG1 generates aerodynamic load vector $\{P_g^A\}$.

150. ADD $\{P_{g1}\}$ to $\{P_g^A\}$ to form total load vector $\{P_{g2}\}$.

153. SSG2 applies constraints to static load vectors

$$\{P_{g1}\} = \begin{Bmatrix} \bar{P}_n^b \\ \hline P_m^b \end{Bmatrix}, \qquad \{P_n^b\} = \{\bar{P}_n^b\} + [G_m^T]\{P_m^b\},$$

$$\{P_n^b\} = \begin{Bmatrix} \bar{P}_f^b \\ \hline P_s^b \end{Bmatrix}, \qquad \{P_f\} = \{\bar{P}_f^b\} - [K_{fs}^d]\{Y_s\},$$

$$\{P_f^b\} = \begin{Bmatrix} \bar{P}_a^b \\ \hline P_o^b \end{Bmatrix} \quad \text{and} \quad \{P_\ell^b\} = \{P_a^b\} + [G_o^T]\{P_o^b\}.$$

154. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u_\ell^b\} = [K_{\ell\ell}^b]^{-1}\{P_\ell^b\} \quad ,$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P_\ell^b\} = \{P_\ell^b\} - [K_{\ell\ell}^b]\{u_\ell^b\} \quad ,$$

$$\varepsilon_\ell^b = \frac{\{u_\ell^b\}^T\{\delta P_\ell^b\}}{\{P_\ell^b\}^T\{u_\ell^b\}}$$

155. Go to DMAP No. 157 if the residual vector for current differential stiffness solution is not to be printed.

156. MATGPR prints the residual vector for current differential stiffness solution.

158. SDR1 recovers dependent displacements for the current differential stiffness solution

$$\{u_o^b\} = [G_o]\{u_\ell^b\} + \{u_o^{ob}\} \quad , \qquad \left\{\begin{array}{c} u_\ell^b \\ \hline u_o^b \end{array}\right\} = \{u_f\} \quad ,$$

$$\left\{\begin{array}{c} u_f^b \\ \hline Y_s^b \end{array}\right\} = \{u_n^b\} \quad , \qquad \{u_m^b\} = [G_m]\{u_n^b\} \quad ,$$

$$\left\{\begin{array}{c} u_n^b \\ \hline u_m^b \end{array}\right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b]\{u_f^b\} + [K_{ff}^b]\{Y_s^b\} \ .$$

159. Go to DMAP No. 161 if no aerodynamic loads exist.

160. Equivalence $\{u_g^B\}$ and $\{u_g^A\}$.

162. ADD $-\{U_g^b\}$ and $\{U_g\}$ to form $\{U_g^d\}$.

163. DSMG1 generates differential stiffness matrix $[\delta K_{gg}^d]$.

164. MYPAD forms the load vector for inner loop iteration

$$\{P_{g_{I1}}\} = [\delta K^{d}_{gg}]\{U^{b}_{g}\} + \{P_{go}\}.$$

165. ADD $\{P_{gI1}\}$ and $\{P^{A}_{g}\}$ to form $\{P_{gI2}\}$.

166. DSCHK performs differential stiffness convergence checks.

167. Go to DMAP No. 180 if differential stiffness iteration is complete.

168. Go to DMAP No. 174 if additional differential stiffness matrix changes are necessary for further iteration.

169. Break the previous equivalence of $\{P_g\}$ and $\{P_{g1}\}$.

170. Equivalence $\{P_{gI1}\}$ to $\{P_{g1}\}$.

171. Break the previous equivalence of $\{P_{g1}\}$ to $\{P_{gI1}\}$.

172. Go to DMAP No. 140 for an additional inner loop differential stiffness iteration.

173. TABPT table prints vectors $\{P_{g_{I1}}\}$, $\{P_{g1}\}$, and $\{P_g\}$.

175. ADD $-[\delta K^{d}_{gg}]$ and $[K^{d}_{gg}]$ to form $[K^{d}_{gg1}]$.

176. Equivalence $\{U^{b}_{g}\}$ to $\{U_g\}$ and $[K^{d}_{gg1}]$ to $[K^{d}_{gg}]$.

177. Break the previous equivalence of $[K^{d}_{gg}]$ to $[K^{d}_{gg1}]$ and $\{U_g\}$ to $\{U^{b}_{g}\}$.

178. Go to DMAP No. 106 for an additional outer loop differential stiffness iteration.

179. TABPT table prints $[K^{d}_{gg1}]$, $[K^{d}_{gg}]$, and $\{U_g\}$.

182. Go to DMAP No. 186 if the total stiffness matrix [KTØTAL] is not to be saved on an external file.

183. ADD $[K_{gg}]$ and $[K^{d}_{gg}]$ to form [KTØTAL].

184. ØUTPUT1 outputs [KTØTAL] to an external file.

185. ØUTPUT1 prints the names of the data blocks on the external file.

187. ALG generates final aerodynamic results and generates GRID and STREAML2 bulk data cards on the system punch file, if requested.

188. SDR2 calculates element forces (ØEFB1) and stresses (ØESB1) and prepares displacement vectors (ØUBGV1) and single-point forces of constraint (ØQBG1) for output and translation components of the displacement vector (PUBGV1) for the differential stiffness solution.

189. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

190. SDR1 recovers dependent displacements after differential stiffness loop for grid point force balance.

191. GPFDR calculates for requested sets the grid point force balance and element strain energy for output.

192. ØFP formats the tables prepared by GPFDR and places them on the system output file for printing.

193. Go to DMAP No. 196 if no differential stiffness solution deformed plots are requested.

194. PLØT generates all requested differential stiffness solution deformed structure and contour plots.

195. PRTMSG prints plotter data, engineering data, and contour data for each differential stiffness solution deformed plot generated.

197. Go to DMAP No. 208 and make normal exit.

199. Print Error Message No. 1 and terminate execution.

201. Print Error Message No. 2 and terminate execution.

203. Print Error Message No. 3 and terminate execution.

205. Print Error Message No. 4 and terminate execution.

207. Print Error Message No. 5 and terminate execution.

2.16.3 Output for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is automatically printed for each differential stiffness loading condition.

Iterative differential stiffness computations are terminated for one of five reasons. Iteration termination reasons are automatically printed in an information message. These reasons have the following meanings:

1. REASON 0 means the iteration procedure was incomplete at the time of exit. This is caused by either an unexpected interruption of the iteration procedure (i.e., system abort) or termination is not scheduled (for the other four reasons) at the completion of the current iteration.
2. REASON 1 means the iteration procedure converged to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
3. REASON 2 means the iteration procedure is diverging from the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
4. REASON 3 means insufficient time remaining to achieve convergence to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
5. REASON 4 means the number of iterations supplied by the user on a PARAM bulk data card has been met. (The default number of iterations is 10.)

Parameter values at the time of exit are automatically output as follows:

1. Parameter DØNE: -1 is normal; + N is the estimate of the number of iterations required to achieve convergence.
2. Parameter SHIFT: +1 indicates a return to the top of the inner loop was scheduled; -1 indicates a return to top of the outer loop was scheduled following the current iteration.
3. Parameter DSEPSI: the value of the ratio of energy error to total energy at the time of exit.

The following output may be requested:

1. Nonzero Components of the applied static load for the linear solution at selected grid points.
2. Displacements and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.

4. Undeformed and deformed plots of the structural model.
5. Contour plots of stresss and displacements.

2.16.4 Case Control Deck for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following items relate to subcase definition and data selection for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors:

1. The Case Control Deck must contain two subcases.
2. A static loading condition must be defined above the subcase level with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.
4. Output requests that apply only to the linear solution must appear in the first subcase.
5. Output requests that apply only to the solution with differential stiffness must be placed in the second subcase.
6. Output requests that apply to both solutions, with and without differential stiffness, may be placed above the subcase level.

2.16.5 Parameters for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following parameters are used in Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors:

1. APRESS - optional. A positive integer value causes the generation of aerodynamic pressure loads. A negative integer value suppresses the generation of these loads. The default value is -1.
2. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
3. ATEMP - optional. A positive integer value causes the generation of aerodynamic temperature loads. A negative integer value suppresses the generation of these loads. The default value is -1.
4. AUTØSPC - reserved for future optional use. The default value is -1.

5. BETAD - optional. The integer value of this parameter is the number of iterations allowed for computing the load correction in the inner (load) loop before shifting to the outer (stiffness) loop, which adjusts the differential stiffness. The default value is 4 iterations.
6. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
7. EPSIØ - optional. The real value of this parameter is used to test the convergence of the iterated differential stiffness. The default value is 10^{-5}.
8. FXCØØR, FYCØØR and FZCØØR - optional. The real values of these parameters are the fractions of the displacements used to redefine the blade geometry. The default values are: FXCØØR = 1.0, FYCØØR = 1.0 and FZCØØR = 1.0.
9. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
10. IPRTCI, IPRTCL and IPRTCF - optional. If IPRTi is a positive integer, then intermediate print will be generated in the ALG module based on the print option in the ALGDB data table. If IPRTi = 0 (the default), no intermediate print will be generated.
11. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
12. KTØUT - optional. A positive integer value of this parameter indicates that the user wants to save the total stiffness matrix on an external file (GINØ file INPT) via the ØUTPUT1 module in the rigid format. The default value is -1 when not needed.
13. LØCATIØN and INPTUNIT - required when using the KTØUT parameter. See Section 5.5 for a description of these parameters which are required by the ØUTPUT1 module. The default values for LØCATIØN and INPTUNIT are -1 and 0, respectively.
14. NT - optional. The integer value of this parameter limits the cumulative number of iterations in both loops. The default value is 10 iterations.
15. PGEØM - optional. The integer value of this parameter specifies the punching of various bulk data cards. PGEØM = 1 causes the punching of GRID bulk data cards. PGEØM = 2 causes the punching of GRID, CTRIA2 and PTRIA2 bulk data cards. PGEØM = 3 causes the

punching of GRID cards and the modified ALGDB table on DTI cards. The default value of -1 suppresses the punching of any of these cards.

16. SIGN - optional. The real value of this parameter controls the type of run being performed. SIGN = 1.0 specifies a standard analysis type run. SIGN = -1.0 specifies a design type run. The default value is 1.0.
17. STREAML - optional. The integer value of this parameter specifies the punching of various bulk data cards. STREAML = 1 causes the punching of STREAML1 bulk data cards. STREAML = 2 causes the punching of STREAML2 bulk data cards. STREAML = 3 causes both STREAML1 and STREAML2 cards to be punched. The default value of -1 suppresses the punching of any of these cards.
18. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
19. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
20. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

2.16.6 Rigid Format Error Messages from Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following fatal errors are detected by the DMAP statements in the Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

AERØTHERMØELASTIC ERRØR NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

AERØTHERMØELASTIC ERRØR NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

AERØTHERMØELASTIC ERRØR NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED.

No points have been defined with GRID or SPØINT cards.

AERØTHERMØELASTIC ERRØR NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

AERØTHERMØELASTIC ERRØR NØ. 5 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

3.1 STATIC HEAT TRANSFER ANALYSIS

3.1.1 DMAP Sequence for Static Heat Transfer Analysis

```
RIGID FORMAT DMAP LISTING
APRIL 1985 RELEASE

HEAT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1   BEGIN    HEAT 01 - STATIC HEAT TRANSFER ANALYSIS - APR. 1985 $

    2   PRECHK   ALL $

    3   FILE     HQG=APPEND/HPGG=APPEND/HUGV=APPEND/HGM=SAVE/HKNN=SAVE $

    4   PARAM    //*MPY*/CARDNO/0/0 $

    5   GP1      GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/
                 NOGPDT/MINUS1=-1 $

    6   PLTTRAN  BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $

    7   GP2      GEOM2,HEQEXIN/ECT $

    8   PARAML   PCDB//*PRES*////JUMPPLOT $

    9   PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   10   COND     HP1,JUMPPLOT $

   11   PLTSET   PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/
                 S,N,JUMPPLOT $

   12   PRTMSG   PLTSETX// $

   13   PARAM    //*MPY*/PLTFLG/1/1 $

   14   PARAM    //*MPY*/PFILE/0/0 $

   15   COND     HP1,JUMPPLOT $

   16   PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/
                 HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   17   PRTMSG   PLOTX1// $

   18   LABEL    HP1 $

   19   GP3      GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $

   20   TA1      ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/
                 HLUSET/S,N,NOSIMP/1/NOGENL/GENEL $

   21   COND     ERROR4,NOSIMP $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1985 RELEASE

HEAT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    HKGG,GPST/NOSIMP $
 23  COND     HLBL1,NOSIMP $
 24  PARAM    //*ADD*/HNOKGG/1/0 $
 25  EMG      HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,,,/S,N,HNOKGG $
 26  PURGE    HKGG,GPST/HNOKGG $
 27  COND     HLBL1,HNOKGG $
 28  EMA      HGPECT,HKDICT,HKELM/HKGG,GPST $
 29  LABEL    HLBL1 $
 30  PARAM    //*MPY*/NSKIP/0/0 $
 31  LABEL    HLBL11 $
 32  GP4      CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,HUSET,HASET/
              HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,HREPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $
 33  COND     ERROR3,NOL $
 34  PARAM    //*AND*/NOSR/SINGLE/REACT $
 35  PURGE    HKRR,HKLR,HQR,HDM/REACT/GM/MPCF1/HGO,HKOO,HLOO,HPO,HUOOV,
              HRUOV/OMIT/HPS,HKFS,HKSS/SINGLE/HQG/NOSR $
 36  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 37  COND     HLBL4,GPSPFLG $
 38  GPSP     GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $
 39  OFP      OGPST,,,,,//S,N,CARDNO $
 40  LABEL    HLBL4 $
 41  EQUIV    HKGG,HKNN/MPCF1 $
 42  COND     HLBL2,MPCF1 $
 43  MCE1     HUSET,RG/GM $
 44  MCE2     HUSET,GM,HKGG,,,/HKNN,,, $
 45  LABEL    HLBL2 $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1985 RELEASE

HEAT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 46  EQUIV    HKNN,HKFF/SINGLE $
 47  COND     HLBL3,SINGLE $
 48  SCE1     HUSET,HKNN,,,/HKFF,HKFS,HKSS,,, $
 49  LABEL    HLBL3 $
 50  EQUIV    HKFF,HKAA/OMIT $
 51  COND     HLBL5,OMIT $
 52  SMP1     HUSET,HKFF,,,/HGO,HKAA,HKOO,HLOO,,,,, $
 53  LABEL    HLBL5 $
 54  EQUIV    HKAA,HKLL/REACT $
 55  COND     HLBL6,REACT $
 56  RBMG1    HUSET,HKAA,/HKLL,HKLR,HKRR,,, $
 57  LABEL    HLBL6 $
 58  RBMG2    HKLL/HLLL $
 59  COND     HLBL7,REACT $
 60  RBMG3    HLLL,HKLR,HKRR/HDM $
 61  LABEL    HLBL7 $
 62  SSG1     HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASECC,DIT,/
              HPG,,,,SCR/HLUSET/NSKIP $
 63  EQUIV    HPG,HPL/NOSET $
 64  COND     HLBL10,NOSET $
 65  SSG2     HUSET,GM,YS,HKFS,HGO,HDM,HPG/HQR,HPO,HPS,HPL $
 66  LABEL    HLBL10 $
 67  SSG3     HLLL,HKLL,HPL,HLOO,HKOO,HPO/HULV,HUOOV,HRULV,HRUOV/OMIT/
              V,Y,IRES=-1/NSKIP/S,N,EPS1 $
 68  COND     HLBL9,IRES $
 69  MATGPR   GPL,HUSET,HSIL,HRULV//*L* $
 70  MATGPR   GPL,HUSET,HSIL,HRUOV//*O* $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 71  LABEL    HLBL9 $

 72  SDR1     HUSET,HPG,HULV,HUOOV,YS,HGO,GM,HPS,HKFS,HKSS,HQR/HUGV,HPGG,
              HQG/NSKIP/*HSTATICS* $

 73  COND     HLBL8,HREPEAT $

 74  REPT     HLBL11,100 $

 75  JUMP     ERROR1 $

 76  PARAM    //*NOT*/HTEST/HREPEAT $

 77  COND     ERROR5,HTEST $

 78  LABEL    HLBL8 $

 79  SDR2     CASECC,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,
              HEST,,HPGG/HOPG1,HOQG1,HOUGV1,,HOEF1,HPUGV1/*STATICS* $

 80  OFP      HOUGV1,HOPG1,HOQG1,HOEF1,,//S,N,CARDNO $

 81  COND     HP2,JUMPPLOT $

 82  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIP,HPUGV1,,HGPECT,
              /PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/
              S,N,PFILE $

 83  PRTMSG   PLOTX2// $

 84  LABEL    HP2 $

 85  JUMP     FINIS $

 86  LABEL    ERROR1 $

 87  PRTPARM  //-1/*HSTA* $

 88  LABEL    ERROR3 $

 89  PRTPARM  //-3/*HSTA* $

 90  LABEL    ERROR4 $

 91  PRTPARM  //-4/*HSTA* $

 92  LABEL    ERROR5 $

 93  PRTPARM  //-5/*HSTA* $

 94  LABEL    FINIS $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 1

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 95  PURGE    DUMMY/MINUS1 $

 96  END      $
```

3.1.2 Description of Important DMAP Operations for Static Heat Transfer Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

6. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go To DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no boundary and structure (heat conduction) element plots are requested.

16. PLØT generates all requested boundary and heat conduction element plots.

17. PRTMSG prints plotter data and engineering data for each plot generated.

19. GP3 generates applied Static (Thermal) Loads Table (HSLT) and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.

21. Go to DMAP No. 90 and print Error Message No. 4 if no elements have been defined.

23. Go to DMAP No. 29 if there are no heat conduction elements.

25. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no heat conduction matrix is to be assembled.

28. EMA assembles heat conduction matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

31. Beginning of loop for additional constraint sets.

32. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

33. Go to DMAP No. 88 and print Error Message No. 3 if no independent degrees of freedom are defined.

37. Go to DMAP No. 40 if no potential grid point singularities exist.

38. GPSP generates a table of potential grid point singularities.

39. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

41. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

42. Go to DMAP No. 45 if no multipoint constraints exist.

43. MCE1 partitions multipoint constraint equations $[R_g] = [R_m | R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

44. MCE2 partitions heat conduction matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

46. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

47. Go to DMAP No. 49 if no single-point constraints exist.

48. SCE1 partitions out single-point constraints

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

50. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

51. Go to DMAP No. 53 if no omitted coordinates exist.

52. SMP1 partitions constrained heat conduction matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

54. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

55. Go to DMAP No. 57 if no free-body supports exist.

56. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right].$$

58. RBMG2 decomposes constrained heat conduction matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

59. Go to DMAP No. 61 if no free-body supports exist.

60. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] \quad ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} \quad .$$

62. SSG1 generates static thermal load vectors $\{P_g\}$.

63. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

64. Go to DMAP No. 66 if no constraints are applied.

65. SSG2 applies constraints to static thermal load vectors

$$\{P_g\} = \left\{\begin{array}{c}\bar{P}_n \\ \hline P_m\end{array}\right\} \quad , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} \quad ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} \quad , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} \quad ,$$

$$\{P_f\} = \left\{\begin{array}{c}\bar{P}_a \\ \hline P_o\end{array}\right\} \quad , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} \quad ,$$

$$\{P_a\} = \left\{\begin{array}{c}P_\ell \\ \hline P_r\end{array}\right\}$$

and calculates determinate thermal powers $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

67. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} \quad ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} \quad ,$$

calculates residual vector (HRULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} \quad ,$$

$$\varepsilon_{\ell} = \frac{\{u_{\ell}^T\}\{\delta P_{\ell}\}}{\{P_{\ell}^T\}\{u_{\ell}\}}$$

and calculates residual vector (HRUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} \quad ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

68. Go to DMAP No. 71 if residual vectors are not to be printed.

69. MATGPR prints the residual vector for independent coordinates (HRULV).

70. MATGPR prints the residual vector for omitted coordinates (HRUØV).

72. SDR1 recovers dependent temperatures

$$\left\{\begin{matrix} u_{\ell} \\ \hline u_r \end{matrix}\right\} = \{u_a\} \quad , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \quad ,$$

$$\left\{\begin{matrix} u_a \\ \hline u_o \end{matrix}\right\} = \{u_f\} \quad , \qquad \left\{\begin{matrix} u_f \\ \hline Y_s \end{matrix}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \left\{\begin{matrix} u_n \\ \hline u_m \end{matrix}\right\} = \{u_g\}$$

and recovers single-point powers of sustained thermal constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

73. Go to DMAP No. 78 if all constraint sets have been processed.

74. Go to DMAP No. 31 if additional sets of constraints need to be processed.

75. Go to DMAP No. 86 and print Error Message No. 1 as the number of constraint sets exceeds 100.

77. Go to DMAP No. 92 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

79. SDR2 calculates conduction and boundary element heat flows and gradients (HØEF1) and prepares thermal load vectors (HØPG1), temperature vectors (HØUGV1) and single-point powers of constraint (HØQG1) for output and components of the temperature vector (HPUGV1).

80. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

81. Go to DMAP No. 84 if no temperature profile plots are requested.

82. PLØT generates all requested temperature profile and thermal contour plots.

83. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

85. Go to DMAP No. 94 and make normal exit.

87. Print Error Message No. 1 and terminate execution.

89. Print Error Message No. 3 and terminate execution.

91. Print Error Message No. 4 and terminate execution.

93. Print Error Message No. 5 and terminate execution.

3.1.3 Output for Static Heat Transfer Analysis

The following output may be requested for Static Heat Transfer Analysis:

1. Temperatures (THERMAL) and nonzero components of static loads (ØLØAD) and constrained heat flow (SPCFØRCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELFØRCE) in selected elements.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

3.1.4 Case Control Deck for Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Static Heat Transfer Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD selection, unless all loading is specified with grid point temperatures on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless all constraints are specified on GRID cards or Scalar Connection cards.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases, in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

3.1.5 Parameters for Static Heat Transfer Analysis

The following parameters are used in Static Heat Transfer Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following each execution of the SSG3 module.

3.1.6 Rigid Format Error Messages from Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

3.2 NONLINEAR STATIC HEAT TRANSFER ANALYSIS

3.2.1 DMAP Sequence for Nonlinear Static Heat Transfer Analysis

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    HEAT 03 - NONLINEAR STATIC HEAT TRANSFER ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  PARAM    //*MPY*/CARDNO/0/0 $

    4  GP1      GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/
                NOGPDT/MINUS1=-1 $

    5  PLTTRAN  BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $

    6  GP2      GEOM2,HEQEXIN/ECT $

    7  PARAML   PCDB//*PRES*////JUMPPLOT $

    8  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

    9  COND     HP1,JUMPPLOT $

   10  PLTHBDY  GEOM2,ECT,EPT,HSIL,HEQEXIN,BGPDT/PECT,PSIL,PEQEXIN,PBGPDT/
                NHBDY/V,Y,MESH=NO $

   11  EQUIV    ECT,PECT/NHBDY/HSIL,PSIL/NHBDY/HEQEXIN,PEQEXIN/NHBDY/
                BGPDT,PBGPDT/NHBDY $

   12  PLTSET   PCDB,PEQEXIN,PECT/PLTSETX,HPLTPAR,HGPSETS,HELSETS/S,N,HNSIL/
                S,N,JUMPPLOT $

   13  PRTMSG   PLTSETX// $

   14  PARAM    //*MPY*/PLTFLG/1/1 $

   15  PARAM    //*MPY*/PFILE/0/0 $

   16  COND     HP1,JUMPPLOT $

   17  PLOT     HPLTPAR,HGPSETS,HELSETS,CASECC,PBGPDT,PEQEXIN,PSIL,,,,/PLOTX1/
                HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   18  PRTMSG   PLOTX1// $

   19  LABEL    HP1 $

   20  GP3      GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $
```

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HEAT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 21  SETVAL   //S,N,REPEATH/-1 $

 22  LABEL    LOOPTOP $

 23  CASE     CASECC,/CASEXX/*TRANRESP*/S,N,REPEATH/S,N,NOLOOP $

 24  PARAML   CASEXX//*DTI*/1/8//S,N,TEMPMATE $

 25  PARAM    //*STSR*/V,N,TEMPMATE/-10 $

 26  TA1      ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/
              HLUSET/S,N,NOSIMP/1/NOGENL/HXYZ $

 27  COND     ERROR2,NOSIMP $

 28  PARAM    //*ADD*/HNOKGG/1/0 $

 29  EMG      HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,,,/S,N,HNOKGG $

 30  PURGE    HKGG,GPST/HNOKGG $

 31  COND     JMPKGGX,HNOKGG $

 32  EMA      HGPECT,HKDICT,HKELM/HKGGX,GPST $

 33  LABEL    JMPKGGX $

 34  RMG      HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKGG/C,Y,TABS/C,Y,SIGMA=0.0/
              S,N,HNLR/HLUSET $

 35  EQUIV    HKGGX,HKGG/HNLR $

 36  PURGE    HQGE,HRGG/HNLR $

 37  GP4      CASEXX,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,HUSET,HASET/
              HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/
              S,N,NSKIP/S,N,REPEATH/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 38  COND     ERROR1,NOL $

 39  PURGE    GM/MPCF1/HPS,HKFS,HKSS,HKSF,HRSN,HQG/SINGLE $

 40  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

 41  COND     HLBL5,GPSPFLG $

 42  GPSP     GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $

 43  OFP      OGPST,,,,,//S,N,CARDNO $

 44  LABEL    HLBL5 $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 45  EQUIV    HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1 $
 46  COND     HLBL1,MPCF1 $
 47  MCE1     HUSET,RG/GM $
 48  MCE2     HUSET,GM,HKGG,HRGG,,/HKNN,HRNN,, $
 49  LABEL    HLBL1 $
 50  EQUIV    HKNN,HKFF/SINGLE/HRNN,HRFN/SINGLE $
 51  COND     HLBL2,SINGLE $
 52  VEC      HUSET/VFS/*N*/*F*/*S* $
 53  PARTN    HKNN,VFS,/HKFF,HKSF,HKFS,HKSS $
 54  PARTN    HRNN,,VFS/HRFN,HRSN,,/1 $
 55  LABEL    HLBL2 $
 56  DECOMP   HKFF/HLLL,HULL/0/0/MDIAG/DET/PWR/S,N,KSING $
 57  COND     ERROR3,KSING $
 58  SSG1     HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASEXX,DIT,/
              HPG,,,,SCR/HLUSET/NSKIP $
 59  EQUIV    HPG,HPF/NOSET $
 60  COND     HLBL3,NOSET $
 61  SSG2     HUSET,GM,,HKFS,,,HPG/,,HPS,HPF  $
 62  LABEL    HLBL3 $
 63  SSGHT    HUSET,HSIL,GPTT,GM,HEST,MPT,DIT,HPF,HPS,HKFF,HKFS,HKSF,
              HKSS,HRFN,HRSN,HLLL,HULL/HUGV,HQG,HRULV/HNNLK=1/HNLR/
              C,Y,EPSHT=.001/C,Y,TABS=0.0/C,Y,MAXIT=4/V,Y,IRES/
              MPCF1/SINGLE $
 64  COND     HLBL4,IRES $
 65  MATGPR   GPL,HUSET,HSIL,HRULV//*F* $
 66  LABEL    HLBL4 $
 67  SDR2    CASEXX,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,HEST,,
              HPG/HOPG1,HOQG1,HOUGV1,HOES1,HOEF1,HPUGV1/*STATICS* $
 68  OFP      HOUGV1,HOPG1,HOQG1,,,//S,N,CARDNO $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

HEAT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 69  SDRHT    HSIL,HUSET,HUGV,HOEF1,HSLT,HEST,DIT,HQGE,,/HOEF1X/C,Y,TABS/
              HNLR $

 70  OFP      HOEF1X,,,,,//S,N,CARDNO $

 71  COND     HP2,JUMPPLOT $

 72  PLTSET   PCDB,HEQEXIN,ECT/PSMES,DPLTPAR,DGPSETS,DELSETS/S,N,DSIL/DJ $

 73  PLOT     DPLTPAR,DGPSETS,DELSETS,CASEXX,BGPDT,HEQEXIN,HSIP,HPUGV1,,
              HGPECT,HOES1/PLOTX2/DSIL/HLUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

 74  PRTMSG   PLOTX2// $

 75  LABEL    HP2 $

 76  COND     FINIS,REPEATH $

 77  REPT     LOOPTOP,100 $

 78  JUMP     FINIS$

 79  LABEL    ERROR1 $

 80  PRTPARM  //-1/*HNL1* $

 81  LABEL    ERROR2 $

 82  PRTPARM  //-2/*HNL1* $

 83  LABEL    ERROR3 $

 84  PRTPARM  //-3/*HNL1* $

 85  LABEL    FINIS$

 86  PURGE    DUMMY/MINUS1 $

 87  END      $
```

3.2.2 Description of Important DMAP Operations for Nonlinear Static Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

6. GP2 generates the Element Connection Table with internal indices.

9. Go to DMAP No. 19 if there are no structure plot requests.

10. PLTHBDY modifies the data in the ECT, HSIL, HEQEXIN and BGPDT tables to permit the plotting of HBDY (thermal boundary) elements.

11. Equivalence PECT to ECT, PSIL to HSIL, PEQEXIN to HEQEXIN and PBGPDT to BGPDT if there are no HBDY elements.

12. PLTSET transforms user input into a form used to drive the structure plotter.

13. PRTMSG prints error messages associated with the structure plotter.

16. Go to DMAP No. 19 if no boundary and structure (heat conduction) element plots are requested.

17. PLØT generates all requested boundary and heat conduction element plots.

18. PRTMSG prints plotter and engineering data for each generated plot.

20. GP3 generates applied Static (Heat Flux) Loads Table (HSLT) and the Grid Point Temperature Table.

23. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it to CASEXX.

24. PARAML extracts the 8^{th} word in the data record of CASEXX (representing the thermal material set ID) and stores its value in the parameter TEMPMATE.

25. PARAM stores the value of the parameter TEMPMATE in the 10^{th} word of CØMMØN /SYSTEM/.

26. TA1 generates element tables for use in matrix assembly, load generation, and heat flux data recovery.

27. Go to DMAP No. 81 and print Error Message No. 2 if no elements have been defined.

29. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no heat conduction matrix is to be assembled.

32. EMA assembles heat conduction matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

34. RMG generates the radiation matrix, $[R_{gg}]$, and adds the estimated linear component of radiation to the heat conduction matrix. The element radiation flux matrix, $[Q_{ge}]$, is also generated for use in recovery data for the HBDY elements.

35. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if there is no linear component of radiation.

37. GP4 generates flags defining members of various displacement sets (HUSET) and forms multipoint constraint equations $[R_g]\{u_g\} = \{0\}$.

38. Go to DMAP No. 79 and print Error Message No. 1 if no independent degrees of freedom are defined.

41. Go to DMAP No. 44 if no potential grid point singularities exist.

42. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.

43. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

45. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[R_{gg}]$ to $[R_{nn}]$ if no multipoint constraints exist.

46. Go to DMAP No. 49 if no multipoint constraints exist.

47. MCE1 partitions the multipoint constraint equation matrix $[R_g] = [R_m \mid R_n]$ and solves for the multipoint constraint transformation matrix

$$[G_m] = -[R_m]^{-1}\,[R_n]\ .$$

48. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [R_{gg}] = \left[\begin{array}{c|c} \bar{R}_{nn} & R_{nm} \\ \hline R_{mn} & R_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[R_{nn}] = [\bar{R}_{nn}] + [G_m^T][R_{mn}] + [R_{mn}^T][G_m] + [G_m^T][R_{mm}][G_m].$$

50. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[R_{nn}]$ to $[R_{fn}]$ if no single-point constraints exist.

51. Go to DMAP No. 55 if no single-point constraints exist.

52. VEC generates a partitioning vector $\{u_n\} \rightarrow \{u_f\} + \{u_s\}$.

53. PARTN partitions the heat conduction matrix

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

54. PARTN partitions the radiation matrix

$$[R_{nn}] = \left[\begin{array}{c} R_{fn} \\ \hline R_{sn} \end{array}\right] .$$

56. DECØMP decomposes the potentially unsymmetric matrix $[K_{ff}]$ into upper and lower triangular factors $[U_{\ell\ell}]$ and $[L_{\ell\ell}]$.

57. Go to DMAP No. 83 and print Error Message No. 3 if the matrix is singular.

58. SSG1 generates the input heat flux vector $\{P_g\}$.

59. Equivalence $\{P_g\}$ to $\{P_f\}$ if no constraints are applied.

60. Go to DMAP No. 62 if no constraints of any kind exist.

61. SSG2 reduces the heat flux vector

$$\{P_g\} = \begin{Bmatrix} \bar{P}_n \\ \hline P_m \end{Bmatrix},$$

$$\{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\}$$

and

$$\{P_n\} = \begin{Bmatrix} P_f \\ \hline P_s \end{Bmatrix}.$$

63. SSGHT solves the nonlinear heat transfer problem by an iteration technique which is limited by parameters EPSHT and MAXIT. The output data blocks are: $\{u_g\}$, the solution temperature vector, $\{q_g\}$, the heat flux due to single-point constraints, and $\{\delta P_\ell\}$, the matrix of residual heat fluxes at each iteration step.

64. Go to DMAP No. 66 if residual vectors are not to be printed.

65. MATGPR prints the residual vectors for independent coordinates (HRULV).

67. SDR2 calculates the heat flux due to conduction and convection in the elements (HØEF1) and prepares the temperature vector (HØUGV1), the load vector (HØPG1), and the power of constraint (HØQG1) for output and components of the temperature vector (HPUGV1).

68. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

69. SDRHT processes the HBDY elements to produce heat flux into the elements (HØEF1X) due to convection, radiation, and applied flux.

70. ØFP formats the element flux table prepared by SDRHT and places it on the system output file for printing.

71. Go to DMAP No. 75 if no temperature profile plots are requested.

72. PLTSET transforms user input into a form used to drive the structure plotter.

73. PLØT generates all requested temperature profile and thermal contour plots.

74. PRIMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

76. Go to DMAP No. 85 and make normal exit if all constraint sets have been processed.

77. Go to DMAP No. 22 if additional constraint sets need to be processed.

78. Go to DMAP No. 85 and make normal exit.

80. Print Error Message No. 1 and terminate execution.

82. Print Error Message No. 2 and terminate execution.

74. Print Error Message No. 3 and terminate execution.

3.2.3 Output for Nonlinear Static Heat Transfer Analysis

The following output may be requested for the last iteration in Nonlinear Static Heat Transfer Analysis:

1. Temperature (THERMAL) and nonzero components of static loads (ØLØAD) and constrained heat flow (SPCFØRCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELFØRCE) in selected elements. In the case of CHBDY elements, a flux density summary is produced that includes applied flux, radiation flux, and convective flux.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

3.2.4 Case Control Deck for Nonlinear Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Nonlinear Static Heat Transfer Analysis:

1. A separate subcase must be defined for each unique combination of constraints and loading conditions.
2. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP(MATERIAL) request for each subcase. Temperatures for constrained components are taken from these TEMP cards and entries on SPC cards are ignored.

3.2.5 Parameters for Nonlinear Static Heat Transfer Analysis

The following parameters are used in Nonlinear Static Heat Transfer Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. EPSHT - optional. The real value of this parameter is used to test the convergence of the nonlinear heat transfer solution (see Section 8.4.1 of the Theoretical Manual). The default value is 0.001.
4. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSGHT module for each iteration.

5. MAXIT - optional. The integer value of this parameter limits the maximum number of iterations. The default value is 4 iterations.
6. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.
7. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

3.2.6 Rigid Format Error Messages from Nonlinear Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Nonlinear Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - NØ SIMPLE STRUCTURAL ELEMENTS.

No structural elements have been defined with Connection Cards.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 3 - STIFFNESS MATRIX SINGULAR.

The heat conduction matrix is singular due to unspecified grid point temperatures.

3.3 TRANSIENT HEAT TRANSFER ANALYSIS

3.3.1 DMAP Sequence for Transient Heat Transfer Analysis

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    HEAT 09 - TRANSIENT HEAT TRANSFER ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  PARAM    //*MPY*/CARDNO/0/0 $

    4  GP1      GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/
                S,N,NOGPDT/MINUS1=-1 $

    5  PLTTRAN  BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $

    6  PURGE    HUSET,GM,HGO,HKAA,HBAA,HPSO,HKFS,HQP,HEST/NOGPDT $

    7  COND     HLBL5,NOGPDT $

    8  GP2      GEOM2,HEQEXIN/ECT $

    9  PARAML   PCDB//*PRES*////JUMPPLOT $

   10  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

   11  COND     HP1,JUMPPLOT $

   12  PLTSET   PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/
                S,N,JUMPPLOT $

   13  PRTMSG   PLTSETX// $

   14  PARAM    //*MPY*/PLTFLG/1/1 $

   15  PARAM    //*MPY*/PFILE/0/0 $

   16  COND     HP1,JUMPPLOT$

   17  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/
                HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

   18  PRTMSG   PLOTX1// $

   19  LABEL    HP1 $

   20  GP3      GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/1 $

   21  TA1      ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/
                HLUSET/S,N,NOSIMP=-1/1/123/123 $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 22  PURGE    HKGG,GPST,HBGG/NOSIMP $

 23  COND     HLBL1,NOSIMP $

 24  PARAM    //*ADD*/NOKGGX/1/0 $

 25  PARAM    //*ADD*/NOBGG/1/0 $

 26  EMG      HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,HBELM,HBDICT,/S,N,
              NOKGGX//S,N,NOBGG $

 27  PURGE    HKGGX,GPST/NOKGGX $

 28  COND     JMPKGGX,NOKGGX $

 29  EMA      HGPECT,HKDICT,HKELM/HKGGX,GPST $

 30  LABEL    JMPKGGX $

 31  COND     JMPHBGG,NOBGG $

 32  EMA      HGPECT,HBDICT,HBELM/HBGG, $

 33  LABEL    JMPHBGG $

 34  PURGE    HBNN,HBFF,HBAA,HBGG/NOBGG $

 35  LABEL    HLBL1 $

 36  RMG      HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKGG/C,Y,TABS/C,Y,SIGMA=0.0/
              S,N,HNLR/HLUSET $

 37  EQUIV    HKGGX,HKGG/HNLR $

 38  PURGE    HRGG,HRNN,HRFF,HRAA,HRDD/HNLR $

 39  GP4      CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,HUSET,ASET/
              HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/
              S,N,REACT/0/123/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/
              S,Y,AUTOSPC $

 40  PURGE    GM,GMD/MPCF1/HGO,HGOD/OMIT/HKFS,HPSO,HQP/SINGLE $

 41  COND     HLBL2,NOSIMP $

 42  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

 43  COND     HLBL2,GPSPFLG $

 44  GPSP     GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $

 45  OFP      OGPST,,,,,//S,N,CARDNO $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 46  LABEL    HLBL2 $
 47  EQUIV    HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1/HBGG,HBNN/MPCF1 $
 48  COND     HLBL3,MPCF1 $
 49  MCE1     HUSET,RG/GM $
 50  MCE2     HUSET,GM,HKGG,HRGG,HBGG,/HKNN,HRNN,HBNN, $
 51  LABEL    HLBL3 $
 52  EQUIV    HKNN,HKFF/SINGLE/HRNN,HRFF/SINGLE/HBNN,HBFF/SINGLE $
 53  COND     HLBL4,SINGLE $
 54  SCE1     HUSET,HKNN,HRNN,HBNN,/HKFF,HKFS,,HRFF,HBFF, $
 55  LABEL    HLBL4 $
 56  EQUIV    HKFF,HKAA/OMIT $
 57  EQUIV    HRFF,HRAA/OMIT $
 58  EQUIV    HBFF,HBAA/OMIT $
 59  COND     HLBL5,OMIT $
 60  SMP1     HUSET,HKFF,,,/HGO,HKAA,HKOO,HLOO,,,,, $
 61  COND     HLBLR,HNLR $
 62  SMP2     HUSET,HGO,HRFF/HRAA $
 63  LABEL    HLBLR $
 64  COND     HLBL5,NOBGG $
 65  SMP2     HUSET,HGO,HBFF/HBAA $
 66  LABEL    HLBL5 $
 67  DPD      DYNAMICS,GPL,HSIL,HUSET/GPLD,HSILD,HUSETD,TFPOOL,HDLT,,,
              HNLFT,HTRL,,HEQDYN/HLUSET/S,N,HLUSETD/123 /S,N,NODLT/
              123/123/S,N,NONLFT/S,N,NOTRL/123//S,N,NOUE $
 68  COND     ERROR1,NOTRL $
 69  EQUIV    HGO,HGOD/NOUE/GM,GMD/NOUE $
 70  PURGE    HPPO,HPSO,HPDO,HPDT/NODLT $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 71  MTRXIN   CASECC,MATPOOL,HEQDYN,,TFPOOL/HK2PP,,HB2PP/HLUSETD/
              S,N,NOK2PP/123/S,N,NOB2PP $

 72  PARAM    //*AND*/KDEKA/NOUE/NOK2PP $

 73  PURGE    HK2DD/NOK2PP/HB2DD/NOB2PP $

 74  EQUIV    HKAA,HKDD/KDEKA/HB2PP,HB2DD/NOA/HK2PP,HK2DD/NOA/HRAA,HRDD/
              NOUE $

 75  COND     HLBL6,NOGPDT $

 76  GKAD     HUSETD,GM,HGO,HKAA,HBAA,HRAA,,HK2PP,,HB2PP/HKDD,HBDD,
              HRDD,GMD,HGOD,HK2DD,,HB2DD/*TRANRESP*/*DISP*/
              *DIRECT*/C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/-1/
              NOB2PP/MPCF1/SINGLE/OMIT/NOUE/
              -1/NOBGG/NOSIMP/-1 $

 77  LABEL    HLBL6 $

 78  EQUIV    HK2DD,HKDD/NOSIMP/HB2DD,HBDD/NOGPDT $

 79  PARAM    //*MPY*/REPEATT/1/-1 $

 80  LABEL    HLBL10 $

 81  CASE     CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $

 82  TRLG     CASEXX,HUSETD,HDLT,HSLT,BGPDT,HSIL,CSTM,HTRL,DIT,GMD,HGOD,,
              HEST,,/HPPO,HPSO,HPDO,HPDT,,HTOL/S,N,NOSET $

 83  EQUIV    HPPO,HPDO/NOSET $

 84  TRHT     CASEXX,HUSETD,HNLFT,DIT,GPTT,HKDD,HBDD,HRDD,HPDT,HTRL/
              HUDVT,HPNLD/C,Y,BETA=.55/C,Y,TABS=0.0/HNLR/C,Y,RADLIN=-1/
              C,Y,SIGMA=0.0 $

 85  VDR      CASEXX,HEQDYN,HUSETD,HUDVT,HTOL,XYCDB,HPNLD/HOUDV1,HOPNL1/
              *TRANRESP*/*DIRECT*/0/S,N,NOD/S,N,NOP/0 $

 86  COND     HLBL7,NOD $

 87  SDR3     HOUDV1,HOPNL1,,,,/HOUDV2,HOPNL2,,,, $

 88  OFP      HOUDV2,HOPNL2,,,,//S,N,CARDNO $

 89  XYTRAN   XYCDB,HOUDV2,HOPNL2,,,/HXYPLTTA/*TRAN*/*DSET*/S,N,HPFILE/
              S,N,HCARDNO $

 90  XYPLOT   HXYPLTTA// $

 91  LABEL    HLBL7 $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 92  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $

 93  COND     HLBL9,PJUMP $

 94  EQUIV    HUDVT,HUPV/NOA $

 95  COND     HLBL8,NOA $

 96  SDR1     HUSETD,,HUDVT,,,HGOD,GMD,HPSO,HKFS,,/HUPV,,HQP/1/
              *DYNAMICS* $

 97  LABEL    HLBL8 $

 98  SDR2     CASEXX,CSTM,MPT,DIT,HEQDYN,HSILD,,,BGPDP,HTOL,HQP,HUPV,HEST,
              XYCDB,HPPO/HOPP1,HOQP1,HOUPV1,HOES1,HOEF1,HPUGV/*TRANRESP* $

 99  SDRHT    HSILD,HUSETD,HUPV,HOEF1,HSLT,HEST,DIT,HQGE,HDLT,/HOEF1X/C,Y,
              TABS/HNLR $

100  EQUIV    HOEF1X,HOEF1/MINUS1 $

101  SDR3     HOPP1,HOQP1,HOUPV1,HOES1,HOEF1,/HOPP2,HOQP2,HOUPV2,HOES2,
               HOEF2, $

102  OFP      HOPP2,HOQP2,HOUPV2,HOEF2,HOES2,//S,N,CARDNO $

103  COND     HP2,JUMPPLOT $

104  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,HEQEXIN,HSIP,,HPUGV,
              HGPECT,/PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/
              S,N,PFILE $

105  PRTMSG   PLOTX2// $

106  LABEL    HP2 $

107  XYTRAN   XYCDB,HOPP2,HOQP2,HOUPV2,HOES2,HOEF2/HXYPLTT/*TRAN*/*PSET*/S,N,
              PFILE/S,N,CARDNO $

108  XYPLOT   HXYPLTT// $

109  LABEL    HLBL9 $

110  COND     FINIS,REPEATT $

111  REPT     HLBL10,100 $

112  PRTPARM  //-2/*HTRD* $

113  JUMP     FINIS $

114  LABEL    ERROR1 $
```

```
RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


115  PRTPARM  //-1/*HTRD* $

116  LABEL    FINIS$

117  PURGE    DUMMY/MINUS1 $

118  END      $
```

3.3.2 Description of Important DMAP Operations for Transient Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

7. Go to DMAP No. 66 if there is no Grid Point Definition Table.

8. GP2 generates the Element Connection Table with internal indices.

11. Go to DMAP No. 19 if there are no structure plot requests.

12. PLTSET transforms user input into a form used to drive the structure plotter.

13. PRTMSG prints error messages associated with the structure plotter.

16. Go to DMAP No. 19 if no boundary and structure (heat conduction) element plots are requested.

17. PLØT generates all requested boundary and heat conduction element plots.

18. PRTMSG prints plotter data and engineering data for each generated plot.

20. GP3 generates applied Static (Heat Flux) Load Tables (HSLT) and the Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.

23. Go to DMAP No. 35 if no heat conduction or boundary elements exist.

26. EMG generates element heat conduction and capacitance matrix tables and dictionaries for later assembly by the EMA module.

28. Go to DMAP No. 30 if no heat conduction matrix is to be assembled.

29. EMA assembles heat conduction matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

31. Go to DMAP No. 33 if no heat capacitance matrix is to be assembled.

32. EMA assembles heat capacitance matrix $[B_{gg}]$.

36. RMG generates the radiation matrix, $[R_{gg}]$, and adds the estimated linear component of radiation to the conductivity matrix. The element-radiation flux matrix, $[Q_{ge}]$, is also generated for use in data recovery.

37. Equivalence the linear heat transfer matrix, $[K_{gg}]$, to the heat conduction matrix if no radiation exists.

39. GP4 generates flags defining members of various displacement sets (HUSET) and forms the multipoint constraint equations, $[R_g]\{u_g\} = 0$.

41. Go to DMAP No. 46 if no simple elements exist.

43. Go to DMAP No. 46 if no potential grid point singularities exist.

44. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.

45. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

47. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[R_{gg}]$ to $[R_{nn}]$, and $[B_{gg}]$ to $[B_{nn}]$ if no multipoint constraints exist.

48. Go to DMAP No. 51 if no multipoint constraints exist.

49. MCE1 partitions the multipoint constraint equation matrix, $[R_g] = [R_m \mid R_n]$, and solves for the multipoint constraint transformation matrix,

$$[G_m] = -[R_m]^{-1} [R_n] .$$

50. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \left[\begin{array}{c|c} K_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] ,$$

$$[R_{gg}] = \left[\begin{array}{c|c} R_{nn} & R_{nm} \\ \hline R_{mn} & R_{mm} \end{array}\right] ,$$

$$[B_{gg}] = \left[\begin{array}{c|c} B_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] ,$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}][G_m] + [G_m^T][K_{mm}][G_m] .$$

The same equation is applied to $[R_{nn}]$ and $[B_{nn}]$.

52. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$, and $[R_{nn}]$ to $[R_{ff}]$ if no single-point constraints exist.

53. Go to DMAP No. 55 if no single-point constraints exist.

54. SCE1 partitions the matrices as follows:

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

$[R_{nn}]$ and $[B_{nn}]$ are partitioned in the same manner, except that only the ff partitions are saved.

56. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

57. Equivalence $[R_{ff}]$ to $[R_{aa}]$ if no omitted coordinates exist.

58. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.

59. Go to DMAP No. 66 if no omitted coordinates exist.

60. SMP1 partitions the heat conduction matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for the transformation matrix $[G_o]$:

$$[K_{oo}]\,[G_o] = -[K_{oa}] ,$$

and solves for the reduced heat conduction matrix $[K_{aa}]$:

$$[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}]\,[G_o] .$$

61. Go to DMAP No. 63 if no radiation matrix exists.

62. SMP2 partitions constrained radiation matrix

$$[R_{ff}] = \left[\begin{array}{c|c} \bar{R}_{aa} & R_{ao} \\ \hline R_{oa} & R_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[R_{aa}] = [\bar{R}_{aa}] + [R_{oa}^T]\,[G_o] + [G_o^T]\,[R_{oa}] + [G_o^T]\,[R_{oo}]\,[G_o].$$

64. Go to DMAP No. 66 if no heat capacitance matrix, $[B_{ff}]$, exists.

65. SMP2 calculates a reduced heat capacitance matrix, $[B_{aa}]$, with the same equation as DMAP No. 62.

67. DPD generates the table defining the displacement sets each degree of freedom belongs to (HUSETD), including extra points. It prepares the Transfer Function Pool, the Dynamics Load Table, the Nonlinear Function Table, and the Transient Response List.

68. Go to DMAP No. 114 and print Error Message No. 1 if there is no Transient Response List.

69. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if no extra points were defined.

71. MTRXIN selects the direct input matrices $[K_{pp}^2]$ and $[B_{pp}^2]$.

74. Equivalence $[K_{aa}]$ to $[K_{dd}^1]$ if there are no direct input stiffness matrices and no extra points; $[B_{pp}]$ to $[B_{dd}^2]$ and $[K_{pp}]$ to $[K_{dd}^2]$ if only extra points are used; and $[R_{aa}]$ to $[R_{dd}]$ if no extra points are used.

75. Go to DMAP No. 77 if there is no Grid Point Definition Table.

76. GKAD expands the matrices to include extra points and assembles heat conduction, capacitance, and radiation matrices for use in the transient analysis:

$$[K^1_{dd}] = \left[\begin{array}{c|c} K_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

$$[B^1_{dd}] \qquad \left[\begin{array}{c|c} B_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

$$[R_{dd}] \qquad \left[\begin{array}{c|c} R_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

and $$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] ,$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

(Nonzero values of the parameters W4, G, and W3 (see the PARAM bulk data card) are not recommended for use in heat transfer analysis and therefore do not appear in the above equations.)

78. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ and $[B^2_{dd}]$ to $[B_{dd}]$ if no matrices were generated from the element heat conduction and capacitance assemblers.

80. Beginning of loop for additional dynamic load sets.

81. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

82. TRLG generates matrices of heat flux loads versus time. $\{P^o_p\}$, $\{P^o_s\}$, and $\{P^o_d\}$ are generated with one column per output time step. $\{P^t_d\}$ is generated with one column per solution time step, and the Transient Output List is a list of output time steps.

83. Equivalence $\{P^o_p\}$ to $\{P^o_d\}$ if the d and p sets are the same.

84. TRHT integrates the equation of motion:

$$[B_{dd}] \{\dot{u}\} + [K_{dd}] \{u\} = \{P_d\} + \{N_d\} ,$$

where $\{u\}$ is a vector of temperatures at any time,

$\{\dot{u}\}$ is the time derivative of $\{u\}$ ("velocity"),

$\{P_d\}$ is the applied heat flux at any time step, and

$\{N_d\}$ is the total nonlinear heat flux from radiation and/or NØLINi data, extrapolated from the previous solution vector.

The output consists of the $[u^t_d]$ matrix containing temperature vectors and temperature "velocity" vectors for the output time steps.

85. VDR prepares the solution set temperatures, temperature "velocities", and nonlinear loads, sorted by time step, for output.

86. Go to DMAP No. 91 if there is no output request for the solution set.

87. SDR3 prepares the requested output of the solution set temperatures, temperature "velocities", and nonlinear loads sorted by point number or element number.

88. ØFP formats the tables prepared by SDR3 for output sorted by point number or element number and places them on the system output file for printing.

89. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.

90. XYPLØT prepares the requested X-Y plots of the solution set temperatures, "velocities" and nonlinear loads versus time.

93. Go to DMAP No. 109 if no further output is requested.

94. Equivalence $\{u_d\}$ to $\{u_p\}$ if no structure points were input.

95. Go to DMAP No. 97 if no structure points were input.

96. SDR1 recovers the dependent temperatures:

$$\{u_o\} = [G_o^d]\,\{u_d\} \quad ,$$

$$\begin{Bmatrix} u_d \\ \hline u_o \end{Bmatrix} = \{u_f\} \quad ,$$

$$\begin{Bmatrix} u_f + u_e \\ \hline u_s \end{Bmatrix} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m^d]\,\{u_f + u_e\}$$

and

$$\begin{Bmatrix} u_n + u_e \\ \hline u_m \end{Bmatrix} = \{u_p\} \quad .$$

The module also recovers the heat flux into the points having single-point constraints:

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\,\{u_f\} \; .$$

98. SDR2 calculates requested heat flux transfer in the elements and prepares temperatures, "velocities", and heat flux loads for output sorted by time step.

99. SDRHT modifies the HØEF1 data block by combining the heat flow data from different sources for the HBDY elements and writes the results on the HØEF1X output data block.

100. Equivalence HØEF1 data block to the HØEF1X data block.

101. SDR3 prepares requested output sorted by point number or element number.

102. ØFP formats the tables prepared by SDR3 for output and places them on the system output file for printing.

103. Go to DMAP No. 106 if no temperature profile plots are requested.

104. PLØT generates all requested temperature profile plots and thermal contours for specified times.

105. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

107. XYTRAN prepares the input for requested X-Y plots.

108. XYPLØT prepares the requested X-Y plots of temperatures, "velocities", element flux, and applied heat loads versus time.

110. Go to DMAP No. 116 if no additional dynamic load sets need to be processed.

111. Go to DMAP No. 80 if additional dynamic load sets need to be processed.

112. Print Error Message No. 2 and terminate execution.

113. Go to DMAP No. 116 and make normal exit.

115. Print Error Message No. 1 and terminate execution.

3.3.3 Output for Transient Heat Transfer Analysis

The following printed output, sorted by point number or element number (SØRT2), is available at selected multiples of the integration time step:

1. Temperatures (THERMAL) and derivatives of temperatures (VELØCITY) for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SDISPLACEMENT and SVELØCITY for SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector (ØLØAD) and constrained heat flow (SPCFØRCE) for a list of PHYSICAL points.
3. Nonlinear load vector for a list of SØLUTIØN points.
4. Flux density (ELFØRCE) in selected elements.

The following plotter output is available:

1. Plot of the Structural model.
2. Temperature profiles and thermal contours for selected time intervals.
3. X-Y plot of temperature or derivative of temperature for a PHYSICAL point or a SØLUTIØN point.
4. X-Y plot of the applied load vector, nonlinear load vector, or constrained heat flow.
5. X-Y plot of flux density for an element.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Volume I, Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

3.3.4 Case Control Deck for Transient Heat Transfer Analysis

The following items relate to subcase definition and data selection for Transient Heat Transfer Analysis:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINEAR must be used to define a time-dependent loading condition for each subcase. The static load cards (QVECT, QVØL, QHBDY, QBDY1, and QBDY2) can also be used to define a dynamic load by using these cards with, or instead of, the DAREA cards. The set identification number on the static load cards (field 2) is used in the same manner as the set identification number on the DAREA cards (field 2).
3. All constraints must be defined above the subcase level.

4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.
5. If nonzero initial conditions are desired, IC must be used to select a TEMP set in the Bulk Data Deck.
6. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP (MATERIAL) request if radiation effects are included.
7. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions.

3.3.5 Parameters for Transient Heat Transfer Analysis

The following parameters are used in Transient Heat Transfer Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. BETA - optional. The real value of this parameter is used as a factor in the integration algorithm (see Section 8.4.2 of the Theoretical Manual). The default value is 0.55.
4. RADLIN - optional. A positive integer value of this parameter causes some of the radiation efffects to be linearized (see Equation 2, Section 8.4.2 of the Theoretical Manual). The default value is -1.
5. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.
6. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

3.3.6 Rigid Format Error Messages from Transient Heat Transfer Analysis

The following fatal errors are detected by the DMAP instructions in the Transient Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional material, including suggestions for remedial action.

TRANSIENT HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIØNS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

TRANSIENT HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

4.1 BLADE CYCLIC MODAL FLUTTER ANALYSIS

4.1.1 DMAP Sequence for Blade Cyclic Modal Flutter Analysis

```
RIGID FORMAT DMAP LISTING
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    AERO 09 - COMPRESSOR BLADE MODAL FLUTTER ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     PHIHL=APPEND/AJJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/CLAMAL=
                APPEND/OVG=APPEND/QHHL=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/S,N,
                NOGPDT/MINUS1=-1 $

    6  COND     ERROR5,NOGPDT $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

    9  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,
                NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   10  COND     ERROR5,NOSIMP $

   11  PURGE    OGPST/GENEL $

   12  PARAM    //*ADD*/NOKGGX/1/0 $

   13  PARAM    //*ADD*/NOMGG/1/0 $

   14  PARAM    //*NOP*/V,Y,KGGIN=-1 $

   15  COND     JMPKGGIN,KGGIN $

   16  PARAM    //*ADD*/NOKGGX/-1/0 $

   17  INPUTT1  /KTOTAL,,,,/C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $

   18  EQUIV    KTOTAL,KGGX $

   19  LABEL    JMPKGGIN $

   20  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/S,
                N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
                CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,
                CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
```

```
RIGID FORMAT DMAP LISTING
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 21  COND      JMPKGGX,NOKGGX $
 22  EMA       GPECT,KDICT,KELM/KGGX,GPST $
 23  LABEL     JMPKGGX $
 24  COND      ERROR1,NOMGG $
 25  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 26  COND      LGPWG,GRDPNT $
 27  GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 28  OFP       OGPWG,,,,,//S,N,CARDNO $
 29  LABEL     LGPWG $
 30  EQUIV     KGGX,KGG/NOGENL $
 31  COND      LBL11,NOGENL $
 32  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 33  LABEL     LBL11 $
 34  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,,USET,ASET/
               LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/O/
               S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,
               AUTOSPC $
 35  PARAM     //*NOT*/REACDATA/REACT $
 36  COND      ERROR6,REACDATA $
 37  PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,QPC/SINGLE $
 38  GPCYC     GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $
 39  COND      ERROR7,NOGO $
 40  COND      LBL4,GENEL $
 41  PARAM     //*EQ*/GPSPFLG/AUTOSPC $
 42  COND      LBL4,GPSPFLG $
 43  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 44  OFP       OGPST,,,,,//S,N,CARDNO $
 45  LABEL     LBL4 $
```

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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 46  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 47  COND     LBL2,MPCF1 $
 48  MCE1     USET,RG/GM $
 49  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
 50  LABEL    LBL2 $
 51  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 52  COND     LBL3,SINGLE $
 53  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
 54  LABEL    LBL3 $
 55  EQUIV    KFF,KAA/OMIT/MFF,MAA/OMIT $
 56  COND     LBL5,OMIT $
 57  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 58  SMP2     USET,GO,MFF/MAA $
 59  LABEL    LBL5 $
 60  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/
              LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
              NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $
 61  COND     ERROR2,NOEED $
 62  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 63  CYCT2    CYCD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS=-1/V,Y,
              KINDEX=-1/V,Y,CYCSEQ=-1/1/S,N,NOGO $
 64  COND     ERROR7,NOGO $
 65  READ     KKK,MKK,,,EED,,CASECC/LAMK,PHIK,  ,OEIGS/*MODES*/S,N,
              NEIGV $
 66  OFP      OEIGS,LAMK,,,,//S,N,CARDNO $
 67  COND     ERROR4,NEIGV $
 68  CYCT2    CYCD,,,,PHIK,LAMK/,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,
              KINDEX/V,Y,CYCSEQ/1/S,N,NOGO $
 69  COND     ERROR7,NOGO $
```

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AERO APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 70  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,/1/*REIG* $

 71  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,,PHIG,EST,,/,,
               OPHIG,,,PPHIG/*REIG* $

 72  OFP       OPHIG,,,,,//S,N,CARDNO $

 73  PARAML    PCDB//*PRES*////JUMPPLOT $

 74  PURGE     PLTSETZ,PLTPARZ,GPSETSZ,ELSETSZ/JUMPPLOT $

 75  COND      PZZ,JUMPPLOT $

 76  PLTSET    PCDB,EQEXIN,ECT/PLTSETZ,PLTPARZ,GPSETSZ,ELSETSZ/
               S,N,NSILZ/S,N,JUMPZ=-1 $

 77  PRTMSG    PLTSETZ// $

 78  COND      PZZ,JUMPZ $

 79  PLOT      PLTPARZ,GPSETSZ,ELSETSZ,CASECC,BGPDT,EQEXIN,SIL,,PPHIG,,/
               PLOTZ/NSILZ/LUSET/JUMPZ/PLTFLGZ=-1/S,N,PFILEZ=0 $

 80  PRTMSG    PLOTZ// $

 81  LABEL     PZZ $

 82  APDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,FLIST,GTKA,PVECT/
               S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/V,Y,MTYPE/
               NEIGV/V,Y,KINDEX=-1 $

 83  PARTN     PHIA,PVECT,/PHIAX,,,/1 $

 84  SMPYAD    PHIAX,MAA,PHIAX,,,/MI/3/1/1/0/1 $

 85  MTRXIN    CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
               NOK2PP/S,N,NOM2PP/S,N,NOB2PP $

 86  PURGE     K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $

 87  EQUIV     M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $

 88  GKAD      USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/
               *CMPLEV*/*DISP*/*MODAL*/0.0/0.0/0.0/NOK2PP/
               NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/
               -1/-1/-1/-1 $

 89  GKAM      USETD,PHIAX,MI,LAMK,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,
               PHIDH/NOUE/C,Y,LMODES=999999/C,Y,LFREQ=0.0/C,Y,HFREQ=0.0/
               NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,
               KDAMP=-1 $
```

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RIGID FORMAT DMAP LISTING
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 90  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $

 91  COND      P2,JUMPPLOT $

 92  PLTSET    PCDB,EQDYN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL1/S,N,
               JUMPPLOT $

 93  PRTMSG    PLTSETX//$

 94  PARAM     //*MPY*/PLTFLG/1/1 $

 95  PARAM     //*MPY*/PFILE/0/0 $

 96  COND      P2,JUMPPLOT $

 97  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQDYN,,,,,/PLOTX1/NSIL1/
               LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

 98  PRTMSG    PLOTX1//$

 99  LABEL     P2 $

100  PARAM     //*ADD*/DESTRY/0/1 $

101  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $

102  PURGE     D1JE,D2JE/NODJE $

103  COND      NODJE,NODJE $

104  INPUTT2   /D1JE,D2JE,,,/C,Y,POSITION=-1/C,Y,UNITNUM=11/C,Y,USRLABEL=
               TAPEID $

105  LABEL     NODJE $

106  PARAM     //*ADD*/XQHHL/1/0 $

107  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,,/
               NOUE/S,N,XQHHL $

108  PARAM     //*MPY*/NOP/1/1 $

109  PARAM     //*MPY*/NOH/0/1 $

110  PARAM     //*MPY*/FLOOP/V,Y,NODJE=-1/0 $

111  LABEL     LOOPTOP $

112  FA1       KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/S,N,FLOOP/
               S,N,TSTART/S,N,NOCEAD $
```

```
RIGID FORMAT DMAP LISTING
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


113  EQUIV    KXHH,PHIH/NOCEAD/BXHH,CLAMA/NOCEAD/
              KXHH,PHIHL/NOCEAD/BXHH,CLAMAL/NOCEAD/
              CASECC,CASEYY/NOCEAD $

114  COND     VDR,NOCEAD $

115  CEAD     KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $

116  COND     LBLZAP,EIGVS $

117  LABEL    VDR $

118  VDR      CASECC,EQDYN,USETD,PHIH,CLAMA,,/OPHIH,/*CEIGEN*/*MODAL*/
              123/S,N,NOH/S,N,NOP/FMODE $

119  COND     LBL16,NOH $

120  OFP      OPHIH,,,,,//S,N,CARDNO $

121  LABEL    LBL16 $

122  FA2      PHIH,CLAMA,FSAVE/PHIHL,CLAMAL,CASEYY,OVG/S,N,TSTART/C,Y,VREF=
              1.0/C,Y,PRINT=YESB $

123  COND     CONTINUE,TSTART $

124  LABEL    LBLZAP $

125  COND     CONTINUE,FLOOP $

126  REPT     LOOPTOP,100  $

127  JUMP     ERROR3 $

128  LABEL    CONTINUE $

129  PARAML   XYCDB//*PRES*////NOXYCDB $

130  COND     NOXYOUT,NOXYCDB $

131  XYTRAN   XYCDB,OVG,,,,/XYPLTCE/*VG*/*PSET*/S,N,PFILE/S,N,CARDNO $

132  XYPLOT   XYPLTCE//$

133  LABEL    NOXYOUT $

134  PARAM    //*AND*/PJUMP/NOP=-1/JUMPPLOT $

135  COND     FINIS,PJUMP $

136  MODACC   CASEYY,CLAMAL,PHIHL,CASECC,,/CLAMAL1,CPHIH1,CASEZZ,,/
              *CEIGN* $
```

```
RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 9

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


137  DDR1      CPHIH1,PHIDH/CPHID $

138  EQUIV     CPHID,CPHIP/NOA $

139  COND      LBL14,NOA $

140  SDR1      USETD,,CPHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $

141  LABEL     LBL14 $

142  EQUIV     CPHID,CPHIA/NOUE $

143  COND      LBLNOE,NOUE $

144  VEC       USETD/RP/*D*/*A*/*E* $

145  PARTN     CPHID,,RP/CPHIA,,,/1/3 $

146  LABEL     LBLNOE $

147  SDR2      CASEZZ,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDT,CLAMAL1,QPC,CPHIP,EST,,/
               ,OQPC1,OCPHIP,OESC1,OEFC1,PCPHIP/*CEIGN* $

148  OFP       OCPHIP,OQPC1,OESC1,OEFC1,,//S,N,CARDNO $

149  COND      P3,JUMPPLOT $

150  PLOT      PLTPAR,GPSETS,ELSETS,CASEZZ,BGPDT,EQDYN,SILD,,PCPHIP,,/PLOTX3/
               NSIL1/LUSET/JUMPPLOT/PLTFLG/PFILE $

151  PRTMSG    PLOTX3//$

152  LABEL     P3 $

153  JUMP      FINIS $

154  LABEL     ERROR1 $

155  PRTPARM   //-1/*BLADEMDS* $

156  LABEL     ERROR2 $

157  PRTPARM   //-2/*BLADEMDS* $

158  LABEL     ERROR3 $

159  PRTPARM   //-3/*BLADEMDS* $

160  LABEL     ERROR4 $

161  PRTPARM   //-4/*BLADEMDS* $
```

```
RIGID FORMAT DMAP LISTING
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


162  LABEL    ERROR5 $
163  PRTPARM  //-5/*BLADEMDS* $
164  LABEL    ERROR6 $
165  PRTPARM  //-6/*BLADEMDS* $
166  LABEL    ERROR7 $
167  PRTPARM  //-7/*BLADEMDS* $
168  LABEL    FINIS $
169  PURGE    DUMMY/MINUS1 $
170  END      $
```

4.1.2 Description of Important DMAP Operations for Blade Cyclic Modal Flutter Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. Go to DMAP No. 162 and print Error Message No. 5 if no grid points are defined.

7. GP2 generates Element Connection Table with internal indices.

8. GP3 generates Static Loads Table and Grid Point Temperature Table.

9. TA1 generates element tables for use in matrix assembly and stress recovery.

10. Go to DMAP No. 162 and print Error Message No. 5 if no structural elements have been defined.

15. Go to DMAP No. 19 if no stiffness matrix is supplied by the user on an external file.

16. Set parameter NØKGGX = -1 so that the stiffness matrix will not be generated in DMAP No. 20.

17. INPUTT1 reads the user-supplied stiffness matrix [KTØTAL] from an external file (GINØ file INPT).

18. Equivalence $[K^{X}_{gg}]$ to [KTØTAL].

20. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

21. Go to DMAP No. 23 if no stiffness matrix is to be assembled.

22. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

24. Go to DMAP No. 154 and print Error Message No. 1 if no mass matrix is to be assembled.

25. EMA assembles mass matrix $[M_{gg}]$.

26. Go to DMAP No. 29 if no weight and balance information is requested.

27. GPWG generates weight and balance information.

28. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

30. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

31. Go to DMAP No. 33 if there are no general elements.

32. SMA3 adds general elements to $[K^{X}_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

34. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

36. Go to DMAP No. 164 and print Error Message No. 6 if free-body supports are present.

38. GPCYC prepares segment boundary table.

39. Go to DMAP No. 166 and print Error Message No. 7 if the CYJØIN data is inconsistent.

40. Go to DMAP No. 45 if general elements are present.

42. Go to DMAP No. 45 if no potential grid point singularities exist.

43. GPSP generates a table of potential grid point singularities.

44. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

46. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

47. Go to DMAP No. 50 if no multipoint constraints exist.

48. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

49. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \text{ and } \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \ .$$

51. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

52. Go to DMAP No. 54 if no single-point constraints exist.

53. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \text{ and } \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

55. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

56. Go to DMAP No. 59 if no omitted coordinates exist.

57. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

58. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] \ .$$

60. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

61. Go to DMAP No. 156 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

62. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

63. CYCT2 transforms matrices from symmetric components to solution set.

64. Go to DMAP No. 166 and print Error Message No. 7 if a CYCT2 error was found.

65. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{kk} - \lambda M_{kk}]\{\phi_k\} = 0 \ ,$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

66. ØFP formats the summary of eigenvalue extraction information (ØEIGS) and the eigenvalues (LAMK) prepared by READ and places them on the system output file for printing.

67. Go to DMAP No. 160 and print Error Message No. 4 if no eigenvalues were found.

68. CYCT2 finds symmetric components of engenvectors from solution set eigenvectors.

69. Go to DMAP No. 166 and print Error Message No. 7 if a CYCT2 error was found.

70. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \ , \qquad \left\{\begin{array}{c}\phi_a \\ \hline \phi_o\end{array}\right\} = \{\phi_f\} \ ,$$

$$\left\{\begin{array}{c}\phi_f \\ \hline \phi_s\end{array}\right\} = \{\phi_n\} \ , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \ ,$$

$$\left\{\begin{array}{c}\phi_n \\ \hline \phi_m\end{array}\right\} = \{\phi_g\} \ .$$

71. SDR2 prepares eigenvectors (ØPHIG) for output and PPHIG for deformed plotting.

72. ØFP formats the table prepared by SDR2 and places it on the system output file for printing.

75. Go to DMAP No. 81 if there are no structure plot requests.

76. PLTSET transforms user input into a form used to drive the structure plotter.

77. PRTMSG prints error messages associated with the structure plotter.

78. Go to DMAP No. 81 if no deformed (modal) structure plots are requested.

79. PLØT generates all requested deformed (modal) structure plots.

80. PRTMSG prints plotter data and engineering data for each deformed (modal) structure plot generated.

82. APDB processes the aerodynamic data cards from EDT. AERØ and ACPT reflect the aerodynamic parameters. PVECT is a partitioning vector and GTKA is a transformation matrix between aerodynamic (K) and structural (a) degrees of freedom.

83. PARTN partitions the eigenvector into all sine or all cosine components.

84. SMPYAD calculates the modal mass matrix

$$[M] = [\phi_a^x]^T [M_{aa}] [\phi_a^x] .$$

85. MXTRIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

87. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied.

88. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$ and forms $[G_{md}]$ and $[G_{od}]$.

89. GKAM selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] ,$$

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}] ,$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] ,$$

where

KDAMP = -1 (default)	KDAMP = 1
m_i = modal masses	m_i = modal masses
$b_i = m_i\ 2\pi\ f_i\ g(f_i)$	$b_i = 0$
$k_i = m_i\ 4\pi^2\ f_i$	$k_i = (1+ig(f_i))\ 4\pi^2\ f_i^2 m_i$

91. Go to DMAP No. 99 if no plot output is requested.

92. PLTSET transforms user input into a form used to drive the structure plotter.

93. PRTMSG prints error messages associated with the structure plotter.

96. Go to DMAP No. 99 if no undeformed aerodynamic or structural element plots are requested.

97. PLØT generates all requested undeformed aerodynamic and structural element plots.

98. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.

101. AMG forms the aerodynamic matrix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D^1_{jk}]$ and $[D^2_{jk}]$.

103. Go to DMAP No. 105 if there are no user-supplied downwash coefficients.

104. INPUTT2 provides the user-supplied downwash factors due to extra points ($[D^1_{je}]$, $[D^2_{je}]$). PARAM NØDJE must be set to enter these matrices. The downwash w_j on box j due to the motion of an extra point, u_e, is given by

$$\{w_j\} = [D^1_{je} + ikD^2_{je}]\{u_e\} \quad .$$

107. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] \quad , \qquad [G_{ki}] = [G^T_{ka}]^T[\phi_{ai}] \quad ,$$

$$[D^1_{jh}] \Leftarrow [D^1_{ji} \mid D^1_{je}] \quad , \qquad [D^1_{ji}] = [D^1_{jk}]^T[G_{ki}] \quad ,$$

$$[D^2_{jh}] \Leftarrow [D^2_{ji} \mid D^2_{je}] \quad \text{and} \qquad [D^2_{ji}] = [D^2_{jk}]^T[G_{ki}].$$

For each (m,k) pair:

$$[D_{jh}] = [D^1_{jh}] + ik[D^2_{jh}] \quad .$$

For each group:

$$[Q_{jh}] = [A^T_{jj}]^{-1}_{group}\,[D_{jh}]_{group} \quad ,$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}] \quad ,$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

and $$[Q_{hh}] \Leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right] .$$

110. PARAM initializes the flutter loop counter (FLØØP) to zero.

111. Beginning of loop for flutter.

112. FA1 computes the total aerodynamic mass matrix $[M^x_{hh}]$, the total aerodynamic stiffness matrix $[K^x_{hh}]$ and the total aerodynamic damping matrix $[B^x_{hh}]$ as well as a looping table FSAVE. For the K-method

$$M^x_{hh} = (k^2/b^2)M_{hh} + (\rho/2)\, Q_{hh} \ ,$$

$$K^x_{hh} = K_{hh}$$

and $$B^x_{hh} = 0 \ .$$

113. Set up equivalences for the KE- and PK-methods.

114. Go to DMAP No. 117 for the KE- and PK-methods.

115. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M^x_{hh}p^2 + B^x_{hh}p + K^x_{hh}]\{\phi_h\} = 0$$

and normalizes eigenvectors to unit magnitude of the largest component.

116. Go to DMAP No. 124 if no complex eigenvalues were found.

118. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.

119. Go to DMAP No. 121 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.

120. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.

122. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to ØVG.

123. Go to DMAP No. 128 if there is insufficient time for another flutter loop.

125. Go to DMAP No. 128 if the flutter loop is complete.

126. Go to DMAP No. 111 for additional aerodynamic configuration triplet values.

127. Go to DMAP No. 158 and print Error Message No. 3 if the number of flutter loops exceeds 100.

130. Go to DMAP No. 133 if there are no X-Y plot requests.

131. XYTRAN prepares the input for requested X-Y plots.

132. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint versus time.

135. Go to DMAP No. 168 and make normal exit if there are no output requests involving dependent degrees of freedom or forces and stresses.

136. MØDACC selects a list of eigenvalues and eigenvectors whose imaginary parts (velocity in input units) are close to a user input list.

137. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$\{\phi_d^c\} = \{\phi_{dh}\}\{\phi_h\} .$$

138. Equivalence $\{\phi_d^c\}$ to $\{\phi_p^c\}$ if no constraints are applied.

139. Go to DMAP No. 141 if no constraints are applied.

140. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o^c\} = [G_o^d]\{\phi_d^c\} , \qquad \left\{\begin{matrix}\phi_d \\ \hline \phi_o\end{matrix}\right\} = \{\phi_f^c + \phi_e^c\} ,$$

$$\left\{\begin{matrix}\phi_f^c + \phi_e^c \\ \hline \phi_s^c\end{matrix}\right\} = \{\phi_n^c + \phi_e^c\} , \qquad \{\phi_m^c\} = [G_m^d]\{\phi_n^c + \phi_e^c\} ,$$

$$\left\{\begin{matrix}\phi_f^c + \phi_e^c \\ \hline \phi_m^c\end{matrix}\right\} = \{Q_p^c\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$, $\begin{matrix}0 \\ \hline q_s\end{matrix} = \{Q_p^c\}$.

142. Equivalence $\{\phi_d^c\}$ to $\{\phi_a^c\}$ if there are no extra points introduced for dynamic analysis.

143. Go to DMAP No. 146 if there are no extra points.

144. VEC generates a d-size partitioning vector (RP) for the a- and e-sets

$$\{u_d\} \rightarrow \{u_a\} + \{u_e\} .$$

145. PARTN performs partition of $\{\phi_d^c\}$ using RP

$$\{\phi_d^c\} \quad \left\{\begin{matrix}\phi_a^c \\ \hline \phi_e^c\end{matrix}\right\} .$$

147. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output and PCPHIP for deformed plotting.

148. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

149. Go to DMAP No. 152 if no deformed aerodynamic or structural element plots are requested.

150. PLØT prepares all deformed aerodynamic and structural element plots.

151. PRTMSG prints plotter data and engineering data for each deformed plot generated.

153. Go to DMAP No. 168 and make normal exit.

155. Print Error Message No. 1 and terminate execution.

157. Print Error Message No. 2 and terminate execution.

159. Print Error Message No. 3 and terminate execution.

161. Print Error Message No. 4 and terminate execution.

163. Print Error Message No. 5 and terminate execution.

165. Print Error Message No. 6 and terminate execution.

167. Print Error Message No. 7 and terminate execution.

4.1.3 Output for Blade Cyclic Modal Flutter Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The complex eigenvalues are included in the Flutter Summary and are printed for each aerodynamic loop.

The grid point singularities from the structural model are also output.

A Flutter Summary for each value of the configuration parameters is printed out unless PRINT=NØ. This shows Mach number, density, reduced frequency, velocity, damping, and frequency for each complex eigenvalue.

V-g and V-f plots may be requested by the XYØUT control cards by specifying the curve type as VG. The "points" are loop numbers and the "components" are G or F.

Printed output of the following types, sorted by complex eigenvalue root number (SØRT1) and (m, k, ρ), may be requested for all complex eigenvalues kept, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead). (Eigenvectors are not available for the KE-method.)

1. The eigenvector for a list of PHYSICAL and AERØDYNAMIC points (grid points, extra points, and aerodynamic points) or SØLUTIØN points (modal coordinates and extra points).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Complex stresses and forces in selected elements.

The ØFREQUENCY Case Control card can select a subset of the complex eigenvectors for data recovery. In addition, undeformed and deformed shapes may be requested. Undeformed shapes may include only structural or structural and aerodynamic elements.

4.1.4 Case Control Deck for Blade Cyclic Modal Flutter Analysis

The following items relate to subcase definition and data selection for Blade Cyclic Modal Flutter Analysis:

1. Only one subcase is allowed.
2. Desired direct input matrices for stiffness $[K^2_{pp}]$, mass $[M^2_{pp}]$, and damping $[B^2_{pp}]$ must be selected via the keywords K2PP, M2PP, or B2PP.
3. CMETHØD must be used to select an EIGC card from the Bulk Data Deck. (K method only.)
4. FMETHØD must be used to select a FLUTTER card from the Bulk Data Deck.

5. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
6. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.
7. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection Cards or with General Elements.
8. Each NASTRAN run calculates modes for only one symmetry index, K.

4.1.5 Parameters for Blade Cyclic Modal Flutter Analysis

The following parameters are used in Blade Cyclic Modal Flutter Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
   (1) RØT - rotational symmetry
   (2) DRL - dihedral symmetry, using right and left halves
   (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
5. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.
6. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
7. IREF - optional. A positive integer value of this parameter defines the reference streamline number. IREF must be equal to an SLN on a STREAML2 bulk data card. The default value of -1 represents the streamsurface at the blade tip. If IREF does not correspond to an SLN, then the default will be taken.

8. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
9. KGGIN - optional. A positive integer of this parameter indicates that the user-supplied stiffness matrix is to be read from an external file (GINØ file INPT) via the INPUTT1 module in the rigid format. The default value is -1 when not needed.
10. KINDEX - required. The integer value of this parameter specifies a single value of the harmonic index.
11. LFREQ and HFREQ - required unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
12. LMØDES - used unless set to 0. The integer value of this parameter is the number of lowest modes to be used in the modal formulation. The default value of 999999 will result in all modes being used.
13. LØCATIØN and INPTUNIT - required when using the KGGIN parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT1 module. The default values for LØCATIØN and INPTUNIT are -1 and 0, respectively.
14. MAXMACH - optional. The real value of this parameter is the maximum Mach number below which the subsonic unsteady cascade theory is valid. The default value is 0.80.
15. MINMACH - optional. The real value of this parameter is the minimum Mach number above which the supersonic unsteady cascade theory is valid. The default value is 1.01.
16. MTYPE - optional. The BCD value of this parameter controls which components of the cyclic modes are to be used in the modal formulation. MTYPE = SINE uses only sine components and MTYPE = CØSINE uses only cosine components. The default value is CØSINE.
17. NØDJE - optional. A positive integer of this parameter indicates that user-supplied downwash matrices due to extra points are to be read in from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
18. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.
19. PØSITIØN, UNITNUM and USRLABEL - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The defaults for PØSITIØN, UNITNUM and USRLABEL are -1, 11 and TAPEID, respectively.

20. PRINT - optional. The BCD value, NØ, of this parameter suppresses the automatic printing of the flutter summary for the K method. The default value is YESB.
21. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
22. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
23. VREF - optional. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.
24. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

4.1.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

4.1.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Blade Cyclic Modal Flutter Analysis. See Section 2.3.7 for details.

4.1.8 Rigid Format Error Messages from Blade Cyclic Modal Flutter Analysis

The following fatal errors are detected by the DMAP statements in the Blade Cyclic Modal Flutter Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

BLADE FLUTTER ANALYSIS ERRØR NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

BLADE FLUTTER ANALYSIS ERRØR NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

BLADE FLUTTER ANALYSIS ERRØR NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 flutter loops. This number can be increased by ALTERing the REPT instruction following the FA2 module.

BLADE FLUTTER ANALYSIS ERRØR NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

BLADE FLUTTER ANALYSIS ERRØR NØ. 5 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

BLADE FLUTTER ANALYSIS ERRØR NØ. 6 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Blade Cyclic Modal Flutter Analysis. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

BLADE FLUTTER ANALYSIS ERRØR NØ. 7 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

4.2 MODAL FLUTTER ANALYSIS

4.2.1 DMAP Sequence for Modal Flutter Analysis

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
----------------

    1  BEGIN    AERO 10 - MODAL FLUTTER ANALYSIS - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     PHIHL=APPEND/AJJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/
                CLAMAL=APPEND/OVG=APPEND/QHHL=APPEND/SKJ=APPEND/QHJL=APPEND/
                QKHL=APPEND/ $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/MINUS1=-1 $

    6  COND     ERROR5,NOGPDT $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*////JUMPPLOT $

    9  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   10  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   11  COND     ERROR1,NOSIMP $

   12  PARAM    //*ADD*/NOKGGX/1/0 $

   13  PARAM    //*ADD*/NOMGG /1/0 $

   14  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
                S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/
                C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/
                C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
                V,Y,VOLUME/V,Y,SURFACE $

   15  PURGE    KGGX,GPST/NOKGGX $

   16  COND     JMPKGGX,NOKGGX $

   17  EMA      GPECT,KDICT,KELM/KGGX,GPST $

   18  LABEL    JMPKGGX $

   19  COND     ERROR1,NOMGG $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 20  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 21  COND      LGPWG,GRDPNT $
 22  GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 23  OFP       OGPWG,,,,,//S,N,CARDNO $
 24  LABEL     LGPWG $
 25  EQUIV     KGGX,KGG/NOGENL $
 26  COND      LBL11,NOGENL $
 27  SMA3      GEI,/KGGY/LUSET/NOGENL/-1 $
 28  ADD       KGGX,KGGY/KGG $
 29  LABEL     LBL11 $
 30  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
               S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/O/
               REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
 31  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $
 32  COND      LBL4,GPSPFLG $
 33  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 34  OFP       OGPST,,,,,//S,N,CARDNO $
 35  LABEL     LBL4 $
 36  EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 37  PURGE     GM/MPCF1/DM,MR/REACT $
 38  COND      LBL2,MPCF1 $
 39  MCE1      USET,RG/GM $
 40  MCE2      USET,GM,KGG,MGG,,/KNN,MNN,, $
 41  LABEL     LBL2 $
 42  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 43  COND      LBL3,SINGLE $
 44  SCE1      USET,KNN,MNN,,/KFF,KFS,,MFF,, $
```

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 45  LABEL    LBL3 $
 46  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
 47  PURGE    GO/OMIT $
 48  COND     LBL5,OMIT $
 49  PARAM    //*PREC*/PREC $
 50  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 51  SMP2     USET,GO,MFF/MAA $
 52  LABEL    LBL5 $
 53  COND     LBL6,REACT $
 54  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 55  RBMG2    KLL/LLL/ $
 56  RBMG3    LLL,KLR,KRR/DM $
 57  RBMG4    DM,MLL,MLR,MRR/MR $
 58  LABEL    LBL6 $
 59  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/
              LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
              NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $
 60  COND     ERROR2,NOEED $
 61  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 62  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
              NEIGV $
 63  OFP      OEIGS,,,,,//S,N,CARDNO $
 64  COND     ERROR4,NEIGV $
 65  OFP      LAMA,,,,,//S,N,CARDNO $
 66  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
 67  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
```

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 68  GKAD      USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/
               *CMPLEV*/*DISP*/*MODAL*/0.0/0.0/0.0/NOK2PP/
               NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/
               -1/-1/   -1/-1 $

 69  GKAM      USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,
               PHIDH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/
               NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $

 70  APD       EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,
               USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/
               S,N,LUSETA/S,N,BOV $

 71  PARAM     //*MPY*/PFILE/0/1 $

 72  PURGE     PLTSETA,PLTPARA,GPSETSA,ELSETSA/JUMPPLOT $

 73  COND      SKPPLT,JUMPPLOT $

 74  PARAM     //*MPY*/PLTFLG/0/1 $

 75  PLTSET    PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETSA,ELSETSA/S,N,NSIL1/S,
               N,JUMPPLOT $

 76  PRTMSG    PLTSETA // $

 77  COND      SKPPLT,JUMPPLOT $

 78  PLOT      PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO,     ,,,,/PLOTX2/
               NSIL1/LUSETA/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

 79  PRTMSG    PLOTX2 // $

 80  LABEL     SKPPLT $

 81  COND      ERROR2,NOEED $

 82  GI        SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/LUSET $

 83  PARAM     //*ADD*/DESTRY/0/1/ $

 84  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $

 85  COND      NODJE,    NODJE $

 86  INPUTT2   /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $

 87  LABEL     NODJE $

 88  PARAM     //*ADD*/XQHHL/1/0 $
```

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 89  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,
               QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $

 90  PARAM     //*MPY*/FLOOP/V,Y,NODJE=-1/0 $

 91  LABEL     LOOPTOP $

 92  FA1       KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/
               S,N,FLOOP/S,N,TSTART/S,N,NOCEAD $

 93  EQUIV     KXHH,PHIH/NOCEAD/BXHH,CLAMA/NOCEAD/KXHH,PHIHL/NOCEAD/BXHH,
               CLAMAL/NOCEAD/CASECC,CASEYY/NOCEAD $

 94  COND      VDR,NOCEAD $

 95  CEAD      KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $

 96  COND      LBLZAP,EIGVS $

 97  LABEL     VDR $

 98  VDR       CASECC,EQDYN ,USETD,PHIH,CLAMA,,/OPHIH,/*CEIGEN*/*MODAL*/
               123/S,N,NOH/S,N,NOP/FMODE $

 99  COND      LBL16,NOH $

100  OFP       OPHIH,,,,,//S,N,CARDNO $

101  LABEL     LBL16 $

102  FA2       PHIH,CLAMA,FSAVE/    PHIHL,CLAMAL,CASEYY,OVG/S,N,TSTART/
               C,Y,VREF=1.0/C,Y,PRINT=YES $

103  COND      CONTINUE,TSTART $

104  LABEL     LBLZAP $

105  COND      CONTINUE,FLOOP $

106  REPT      LOOPTOP,100 $

107  JUMP      ERROR3 $

108  LABEL     CONTINUE $

109  PARAML    XYCDB//*PRES*////NOXYCDB $

110  COND      NOXYOUT,NOXYCDB $

111  XYTRAN    XYCDB,OVG,,,,/XYPLTCE/*VG*/*PSET*/S,N,PFILE/S,N,CARDNO/
               S,N,NOXYPL $
```

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112  COND      NOXYOUT,NOXYPL $

113  XYPLOT    XYPLTCE// $

114  LABEL     NOXYOUT $

115  PARAM     //*AND*/PJUMP/NOP=-1/JUMPPLOT $

116  COND      FINIS,PJUMP $

117  MODACC    CASEYY,CLAMAL,PHIHL,,,/CLAMAL1,CPHIH1,CASEZZ,,/*CEIGN* $

118  ADR       CPHIH1,CASEZZ,QKHL,CLAMAL1,SPLINE,SILA,USETA/PKF/BOV/
               C,Y,MACH = 0.0/*FLUTTER* $

119  DDR1      CPHIH1,PHIDH/CPHID $

120  EQUIV     CPHID ,CPHIP/NOA $

121  PURGE     QPC/NOA $

122  COND      LBL14,NOA $

123  SDR1      USETD,,CPHID ,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1 /*DYNAMICS* $

124  LABEL     LBL14 $

125  EQUIV     CPHID ,CPHIA/NOUE $

126  COND      LBLNOE,NOUE $

127  VEC       USETA/RP/*D*/*A*/*E* $

128  PARTN     CPHID ,,RP/CPHIA,,,/1/3 $

129  LABEL     LBLNOE $

130  MPYAD     GTKA,CPHIA,/CPHIK/1/1/0/PREC $

131  UMERGE    USETA,CPHIP,/CPHIPS/*PS*/*P*/*SA* $

132  UMERGE    USETA,CPHIPS,CPHIK/CPHIPA/*PA*/*PS*/*K* $

133  UMERGE    USETA,QPC,/QPAC/*PA*/*P*/*K* $

134  SDR2      CASEZZ,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,CLAMAL1,QPAC,CPHIPA,
               EST,,/,OQPAC1,OCPHIPA,OESC1,OEFC1,PCPHIPA/*CEIGN* $

135  OFP       OCPHIPA,OQPAC1,OESC1,OEFC1,,//S,N,CARDNO $

136  COND      FINIS,JUMPPLOT $
```

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137  PLOT     PLTPARA,GPSETSA,ELSETSA,CASEZZ,BGPA,EQAERO,SILGA,,PCPHIPA,,
              /PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/S,N,
              PFILE $

138  PRTMSG   PLOTX3// $

139  JUMP     FINIS $

140  LABEL    ERROR3 $

141  PRTPARM  //-3/*FLUTTER* $

142  LABEL    ERROR2 $

143  PRTPARM  //-2/*FLUTTER* $

144  LABEL    ERROR1 $

145  PRTPARM  //-1/*FLUTTER* $

146  LABEL    ERROR4 $

147  PRTPARM  //-4/*FLUTTER* $

148  LABEL    ERROR5 $

149  PRTPARM  //-5/*FLUTTER* $

150  LABEL    FINIS $

151  PURGE    DUMMY/MINUS1 $

152  END      $
```

4.2.2 Description of Important DMAP Operations for Modal Flutter Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. Go to DMAP No. 148 and print Error Message No. 5 if no grid points are defined.

7. GP2 generates Element Connection Table with internal indices.

9. GP3 generates Static Loads Table and Grid Point Temperature Table.

10. TA1 generates element tables for use in matrix assembly and stress recovery.

11. Go to DMAP No. 148 and print Error Message No. 5 if no structural elements have been defined.

14. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

16. Go to DMAP No. 18 if no stiffness matrix is to be assembled.

17. EMA assembles stiffness matrix $[K^{X}_{gg}]$ and Grid Point Singularity Table.

19. Go to DMAP No. 144 and print Error Message No. 1 if no mass matrix is to be assembled.

20. EMA assembles mass matrix $[M_{gg}]$.

21. Go to DMAP No. 24 if no weight and balance information is requested.

22. GPWG generates weight and balance information.

23. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

25. Equivalence $[K^{X}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

26. Go to DMAP No. 29 if there are no general elements.

27. SMA3 forms the general element stiffness matrix $[K^{Y}_{gg}]$.

28. ADD combines the structural stiffness matrix $[K^{X}_{gg}]$ with the general element stiffness matrix $[K^{Y}_{gg}]$ to obtain the stiffness matrix $[K_{gg}]$.

30. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

32. Go to DMAP No. 35 if no potential grid point singularities exist.

33. GPSP generates a table of potential grid point singularities.

34. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

36. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

38. Go to DMAP No. 41 if no multipoint constraints exist.

39. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

40. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \ .$$

42. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

43. Go to DMAP No. 45 if no single-point constraints exist.

44. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] \ .$$

46. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

48. Go to DMAP No. 52 if no omitted coordinates exist.

50. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

51. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] \ .$$

53. Go to DMAP No. 58 if there are no free-body supports.

54. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right]$$

55. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

56. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

57. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

59. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

60. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

61. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

62. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0 ,$$

calculates rigid body modes by finding a matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

63. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

64. Go to DMAP No. 146 and print Error Message No. 4 if no eigenvalues were found.

65. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

66. MXTRIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

67. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied.

68. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$ and forms $[G_{md}]$ and $[G_{od}]$.

69. GKAM selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] ,$$

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}] ,$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] ,$$

where

KDAMP = -1 (default)

m_i = modal masses

$b_i = m_i\ 2\pi\ f_i\ g(f_i)$

$k_i = m_i\ 4\pi^2\ f_i$.

KDAMP = 1

m_i = modal masses

$b_i = 0$

$k_i = (1+ig(f_i))\ 4\pi^2\ f_i^2 m_i$

70. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.

73. Go to DMAP No. 80 if no plot output is requested.

75. PLTSET transforms user input into a form used to drive the structure plotter.

76. PRTMSG prints error messages associated with the structure plotter.

77. Go to DMAP No. 80 if no undeformed aerodynamic or structural element plots are requested.

78. PLØT generates all requested undeformed aerodynamic and structural element plots.

79. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.

81. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

82. GI forms a transformation matrix $[G_{ka}^T]$ which interpolates between aerodynamic (k) and structural (a) degrees of freedom.

84. AMG forms the aerodynamic matrix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D_{jk}^1]$ and $[D_{jk}^2]$.

85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.

86. INPUTT2 provides the user-supplied downwash factors due to extra points ($[D_{je}^1]$, $[D_{je}^2]$). PARAM NØDJE must be set to enter these matrices. The downwash w_j on box j due to the motion of an extra point, u_e, is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} \ .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] \ , \qquad [G_{ki}] = [G_{ka}^T]^T[\phi_{ai}] \ ,$$

$$[D_{jh}^1] \Leftarrow [D_{ji}^1 \mid D_{je}^1] \ , \qquad [D_{ji}^1] = [D_{jk}^1]^T[G_{ki}] \ ,$$

$$[D_{jh}^2] \Leftarrow [D_{ji}^2 \mid D_{je}^2] \text{ and} \qquad [D_{ji}^2] = [D_{jk}^2]^T[G_{ki}].$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] \ .$$

For each group:

$$[Q_{jh}] = [A_{jj}^T]_{group}^{-1} [D_{jh}]_{group} \ ,$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}] \ ,$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

and

$$[Q_{hh}] \Leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right] .$$

90. PARAM initializes the flutter loop counter (FLØØP) to zero.

91. Beginning of loop for flutter.

92. FA1 computes the total aerodynamic mass matrix $[M_{hh}^x]$, the total aerodynamic stiffness matrix $[K_{hh}^x]$ and the total aerodynamic damping matrix $[B_{hh}^x]$ as well as a looping table

FSAVE. For the K-method

$$M^x_{hh} = (k^2/b^2)M_{hh} + (p/2)\,Q_{hh} \quad ,$$

$$K^x_{hh} = K_{hh}$$

and $$B^x_{hh} = 0 \quad .$$

93. Set up equivalences for the KE- and PK-methods.

94. Go to DMAP No. 97 for the KE- and PK-methods.

95. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M^x_{hh}p^2 + B^x_{hh}p + K^x_{hh}]\{\phi_h\} = 0$$

and normalizes eigenvectors to unit magnitude of the largest component.

96. Go to DMAP No. 104 if no complex eigenvalues were found.

98. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.

99. Go to DMAP No. 101 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.

100. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.

102. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to ØVG.

103. Go to DMAP No. 108 if there is insufficient time for another flutter loop.

105. Go to DMAP No. 108 if the flutter loop is complete.

106. Go to DMAP No. 91 for additional aerodynamic configuration triplet values.

107. Go to DMAP No. 140 and print Error Message No. 3 if the number of flutter loops exceeds 100.

110. Go to DMAP No. 114 if there are no X-Y plot requests.

111. XYTRAN prepares the input for requested V-g plotting.

112. Go to DMAP No. 114 if no plots are possible as requested.

113. XYPLØT prepares the requested V-g plots.

116. Go to DMAP No. 150 and make normal exit if there are no output requests involving dependent degrees of freedom or forces and stresses.

117. MØDACC selects a list of eigenvalues and eigenvectors whose imaginary parts (velocity in input units) are close to a user input list.

118. ADR builds a matrix of aerodynamic forces for each aerodynamic point and prints requested aerodynamic forces for selected elements.

119. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$\{\phi_d^c\} = \{\phi_{dh}\}\{\phi_h\} .$$

120. Equivalence $\{\phi_d^c\}$ to $\{\phi_p^c\}$ if no constraints are applied.

122. Go to DMAP No. 124 if no constraints are applied.

123. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o^c\} = [G_o^d]\{\phi_d^c\} \quad , \qquad \left\{\begin{array}{c}\phi_d \\ \hline \phi_o\end{array}\right\} = \{\phi_f^c + \phi_e^c\} \ ,$$

$$\left\{\begin{array}{c}\phi_f^c + \phi_e^c \\ \hline \phi_s^c\end{array}\right\} = \{\phi_n^c + \phi_e^c\} \ , \qquad \{\phi_m^c\} = [G_m^d]\{\phi_n^c + \phi_e^c\} \ ,$$

$$\left\{\begin{array}{c}\phi_f^c + \phi_e^c \\ \hline \phi_m^c\end{array}\right\} = \{\phi_p^c\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$, $\left\{\begin{array}{c}0 \\ \hline q_s\end{array}\right\} = \{Q_p^c\}$.

125. Equivalence $\{\phi_d^c\}$ to $\{\phi_a^c\}$ if there are no extra points introduced for dynamic analysis.

126. Go to DMAP No. 129 if there are no extra points.

127. VEC generates a d-size partitioning vector (RP) for the a- and e-sets

$$\{u_d\} \rightarrow \{u_a\} + \{u_e\} .$$

128. PARTN performs partition of $\{\phi_d^c\}$ using RP

$$\{\phi_d^c\} \Rightarrow \left\{\begin{array}{c}\phi_a^c \\ \hline \phi_e^c\end{array}\right\} .$$

130. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k^c\} = [G_{ka}^T]^T\{\phi_a^c\} .$$

131. UMERGE is used to expand $\{\phi_p^c\}$ to the ps-set.

132. UMERGE places $\{\phi_k^c\}$ in its proper place in the displacement vector

$$\{\phi_{pa}^c\} \Leftarrow \left\{ \begin{array}{c} \phi_{ps}^c \\ \hline \phi_k^c \end{array} \right\} .$$

133. UMERGE is used to expand $\{Q_p^c\}$ to the pa-set.

134. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIPA) and single-point forces of constraint (ØQPAC1) for output and PCPHIPA for deformed plotting.

135. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

136. Go to DMAP No. 150 and make normal exit if no deformed aerodynamic or structural element plots are requested.

137. PLØT prepares all deformed aerodynamic and structural element plots.

138. PRTMSG prints plotter data and engineering data for each deformed plot generated.

139. Go to DMAP No. 150 and make normal exit.

141. Print Error Message No. 3 and terminate execution.

143. Print Error Message No. 2 and terminate execution.

145. Print Error Message No. 1 and terminate execution.

147. Print Error Message No. 4 and terminate execution.

149. Print Error Message No. 5 and terminate execution.

4.2.3 Output for Modal Flutter Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The complex eigenvalues are included in the Flutter Summary and are printed for each aerodynamic loop.

The grid point singularities from the structural model are also output.

A Flutter Summary for each value of the configuration parameters is printed out unless PRINT=NØ. This shows Mach number, density, reduced frequency, velocity, damping, and frequency for each complex eigenvalue.

V-g and V-f plots may be requested by the XYØUT control cards by specifying the curve type as VG. The "points" are loop numbers and the "components" are G or F.

Printed output of the following types, sorted by complex eigenvalue root number (SØRT1) and (m, k, ρ), may be requested for all complex eigenvalues kept, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead). (Eigenvectors are not available for the KE-method.)

1. The eigenvector for a list of PHYSICAL and AERØDYNAMIC points (grid points, extra points, and aerodynamic points) or SØLUTIØN points (modal coordinates and extra points).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Complex stresses and forces in selected elements.

The ØFREQUENCY Case Control card can select a subset of the complex eigenvectors for data recovery. In addition, undeformed and deformed shapes may be requested. Undeformed shapes may include only structural or structural and aerodynamic elements.

The eigenvectors used in the modal formulation may be obtained for the analysis points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis Rigid Format or by making a modified restart using the Normal Modes Analysis Rigid Format.

4.2.4 Case Control Deck for Modal Flutter Analysis

The following items relate to subcase definition and data selection for Modal Flutter Analysis:

1. Only one subcase is allowed.
2. Desired direct input matrices for stiffness $[K^2_{pp}]$, mass $[M^2_{pp}]$, and damping $[B^2_{pp}]$ must be selected via the keywords K2PP, M2PP, or B2PP.
3. CMETHØD must be used to select an EIGC card from the Bulk Data Deck. (K method only.)
4. FMETHØD must be used to select a FLUTTER card from the Bulk Data Deck.
5. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
6. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

4.2.5 Parameters for Modal Flutter Analysis

The following parameters are used in Modal Flutter Analysis:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. GUSTAERØ - optional. An integer value of +1 causes gust loads to be computed. The default value is -1 for no gust loads.
6. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
7. LFREQ and HFREQ - required, unless LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.

8. LMØDES - required, unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
9. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default value is 0.0.
10. NØDJE - optional. A positive integer of this parameter indicates that user-supplied downwash matrices due to extra points are to be read from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
11. P1, P2 and P3 - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The default values for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.
12. PRINT - optional. The BCD value, NØ, of this parameter suppresses the automatic printing of the flutter summary for the K method. The default value is YES.
13. VREF - optional. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.
14. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

4.2.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

4.2.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Flutter Analysis. See Section 2.3.7 for details.

4.2.8 Rigid Format Error Messages from Modal Flutter Analysis

The following fatal errors are detected by the DMAP statements in the Modal Flutter Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 flutter loops. This number can be increased by ALTERing the REPT instruction following the FA2 module.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 5 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

4.3 MODAL AEROELASTIC RESPONSE

4.3.1 DMAP Sequence for Modal Aeroelastic Response

```
RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

    1  BEGIN    AERO 11 - MODAL AEROELASTIC RESPONSE - APR. 1986 $

    2  PRECHK   ALL $

    3  FILE     AJJL=APPEND/QHHL=APPEND/QKHL=APPEND/QHJL=APPEND/SKJ=APPEND $

    4  PARAM    //*MPY*/CARDNO/0/0 $

    5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/
                S,N,NOGPDT/MINUS1=-1 $

    6  COND     ERROR1,NOGPDT $

    7  GP2      GEOM2,EQEXIN/ECT $

    8  PARAML   PCDB//*PRES*/V,Y,NODJE=-1///JUMPPLOT $

    9  PARAML   XYCDB//*PRES*////NOXYCDB $

   10  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $

   11  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/
                LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $

   12  COND     ERROR3,NOSIMP $

   13  PARAM    //*ADD*/NOKGGX/1/0 $

   14  PARAM    //*ADD*/NOMGG /1/0 $

   15  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/
                S,N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/
                C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/
                C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/
                V,Y,VOLUME/V,Y,SURFACE $

   16  PURGE    KGGX,GPST/NOKGGX $

   17  COND     JMPKGGX,NOKGGX $

   18  EMA      GPECT,KDICT,KELM/KGGX,GPST $

   19  LABEL    JMPKGGX $

   20  COND     ERROR1,NOMGG $
```

```
RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 21  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 22  COND      LGPWG,GRDPNT $
 23  GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 24  OFP       OGPWG,,,,,//S,N,CARDNO $
 25  LABEL     LGPWG $
 26  EQUIV     KGGX,KGG/NOGENL $
 27  COND      LBL11,NOGENL $
 28  SMA3      GEI,/KGGY/LUSET/NOGENL/-1 $
 29  ADD       KGGX,KGGY/KGG $
 30  LABEL     LBL11 $
 31  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
               S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/O/S,N,
               REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
 32  PARAM     //*EQ*/GPSPFLG/AUTOSPC/O $
 33  PURGE     GM/MPCF1/DM,MR/REACT $
 34  COND      LBL4,GPSPFLG $
 35  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 36  OFP       OGPST,,,,,//S,N,CARDNO $
 37  LABEL     LBL4 $
 38  EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
 39  COND      LBL2,MPCF1 $
 40  MCE1      USET,RG/GM $
 41  MCE2      USET,GM,KGG,MGG,,/KNN,MNN,, $
 42  LABEL     LBL2 $
 43  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE $
 44  COND      LBL3,SINGLE $
 45  SCE1      USET,KNN,MNN,,/KFF,KFS,,MFF,, $
```

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RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 46  LABEL    LBL3 $
 47  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
 48  PURGE    GO/OMIT $
 49  COND     LBL5,OMIT $
 50  PARAM    //*PREC*/PREC $
 51  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 52  SMP2     USET,GO,MFF/MAA $
 53  LABEL    LBL5 $
 54  COND     LBL6,REACT $
 55  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 56  RBMG2    KLL/LLL/ $
 57  RBMG3    LLL,KLR,KRR/DM $
 58  RBMG4    DM,MLL,MLR,MRR/MR $
 59  LABEL    LBL6 $
 60  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,TRL,
              EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/NODLT/S,N,NOPSDL/
              NOFRL/NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $
 61  COND     ERROR2,NOEED $
 62  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 63  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
              NEIGV $
 64  OFP      OEIGS,,,,,//S,N,CARDNO $
 65  COND     ERROR4,NEIGV $
 66  OFP      LAMA,,,,,//S,N,CARDNO $
 67  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
 68  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
```

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RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 69  GKAD      USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/
               *CMPLEV*/*DISP*/*MODAL*/0.0/0.0/0.0/NOK2PP/
               NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/
               -1/-1/-1/-1 $

 70  GKAM      USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,
               PHIDH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/
               NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $

 71  APD       EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,
               USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/
               S,N,LUSETA/S,N,BOV $

 72  PARAM     //*MPY*/PFILE/0/1 $

 73  PURGE     PLTSETA,PLTPARA,GPSETSA,ELSETSA/JUMPPLOT $

 74  COND      SKPPLT,JUMPPLOT $

 75  PARAM     //*MPY*/PLTFLG/0/1 $

 76  PLTSET    PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETSA,ELSETSA/S,N,NSIL1/S,N,
               JUMPPLOT $

 77  PRTMSG    PLTSETA // $

 78  COND      SKPPLT,JUMPPLOT $

 79  PLOT      PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO, ,,,,/PLOTX2/
               NSIL1/LUSETA/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $

 80  PRTMSG    PLOTX2 // $

 81  LABEL     SKPPLT $

 82  GI        SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/
               LUSET $

 83  PARAM     //*ADD*/DESTRY/0/1/ $

 84  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $

 85  COND      NODJE,NODJE $

 86  INPUTT2   /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $

 87  LABEL     NODJE $

 88  PARAM     //*ADD*/XQHHL/1/0 $

 89  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,
               QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $
```

```
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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


 90  FRLG     CASECC,USETD,DLT,FRL,GMD,GOD,DIT,PHIDH/PPF,PSF,PDF,FOL,PHF1/
              *MODAL*/S,N,FREQY/S,N,APP $

 91  PARAM    //*NOT*/NOFRY/FREQY $

 92  PURGE    PPF/NOFRY $

 93  GUST     CASECC,DLT,FRL,DIT,QHJL,,,ACPT,CSTMA,PHF1/PHF/
              S,N,NOGUST/BOV/C,Y,MACH/C,Y,Q $

 94  EQUIV    PHF1,PHF/NOGUST $

 95  FRRD2    KHH,BHH,MHH,QHHL,PHF,FOL/UHVF/BOV/C,Y,Q/C,Y,MACH $

 96  EQUIV    UHVF,UHVT/FREQY/FOL,TOL/FREQY $

 97  COND     IFTSKP,FREQY $

 98  IFT      UHVF,CASECC,TRL,FOL/UHVT,TOL/C,Y,IFTM=0 $

 99  LABEL    IFTSKP $

100  MODACC   CASECC,TOL,UHVT,,,/TOL1,UHVT1,,,/APP $

101  ADR      UHVT1,CASECC,QKHL,TOL1,SPLINE,SILA,USETA/PKF/BOV/
              C,Y,MACH/APP $

102  VDR      CASECC,EQDYN,USETD,UHVT1,TOL1,XYCDB,/OUHV1,/APP/*MODAL*/
              0/S,N,NOH/S,N,NOP/FMODE $

103  COND     NOH,  NOH $

104  SDR3     OUHV1,,,,,/OUHV2,,,,, $

105  OFP      OUHV2,,,,,//S,N,CARDNO $

106  COND     NOH,NOXYCDB $

107  XYTRAN   XYCDB,OUHV2,,,,/XYPTTA/APP/*HSET*/S,N,PFILE/S,N,CARDNO/
              S,N,NOXYPL $

108  COND     NOH,NOXYPL $

109  XYPLOT   XYPTTA  $

110  LABEL    NOH $

111  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $

112  COND     FINIS,PJUMP $

113  SDR1     USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIP,,QP/1/*DYNAMICS* $
```

```
RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


114  EQUIV    PHIDH,PHIAH/NOUE $

115  COND     NOUE1,NOUE $

116  VEC      USETD/EVEC/*D*/*A*/*E* $

117  PARTN    PHIDH,,EVEC/PHIAH,,,/1 $

118  LABEL    NOUE1 $

119  MPYAD    GTKA,PHIAH,/PHIK/1/1/0/PREC $

120  UMERGE   USETA,PHIP,/PHIPS/*PS*/*P*/*SA* $

121  UMERGE   USETA,PHIPS,PHIK/PHIPA/*PA*/*PS*/*K* $

122  UMERGE   USETA,QP,/QPA/*PA*/*P*/*PS* $

123  SDR2     CASECC,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,LAMA,QPA,PHIPA,
              EST,XYCDB,/,MQP1,MPHIPA1,MES1,MEF1,/*MMREIG* $

124  COND     NOPF,NOFRY $

125  SDR2     CASECC,,,,EQDYN,,,,,PPF,,,,XYCDB,/OPP1,,,,,/*FREQ* $

126  SDR3     OPP1,,,,,/QPP2,,,,,/ $

127  LABEL    NOPF $

128  SDR3     MPHIPA1,MES1,MEF1,MQP1,,/MPHIPA2,MES2,MEF2,MQP2,, $

129  DDRMM    CASECC,UHVT1,TOL1,MPHIPA2,MQP2,MES2,MEF2,XYCDB,EST,MPT,DIT/
              OUPV2,OQP2,OES2,OEF2, $

130  OFP      OUPV2,,OES2,OEF2,OQP2,//S,N,CARDNO $

131  SCAN     CASECC,OES2,OEF2/OESF2/C,N,*RF* $

132  OFP      OESF2,,,,,//S,N,CARDNO $

133  COND     P2,JUMPPLOT $

134  MPYAD    PHIPA,UHVT1,/UVT1/0 $

135  SDR2     CASECC,CSTMA,,,EQAERO,,,,BGPA,TOL,,UVT1,,,/,,,,,PUVPAT/APP $

136  PLOT     PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO,SILGA,,PUVPAT,,/
              PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/PFILE $

137  PRTMSG   PLOTX3// $
```

```
RIGID FORMAT DMAP LISTING
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 11

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


138  LABEL    P2 $
139  COND     FINIS,NOXYCDB $
140  XYTRAN   XYCDB,,OQP2,OUPV2,OES2,OEF2/XYPLTT/APP/*PSET*/
              S,N,PFILE/S,N,CARDNO/S,N,NOXYPL $
141  COND     NOXYPLTT,NOXYPL $
142  XYPLOT   XYPLTT $
143  LABEL    NOXYPLTT $
144  COND     FINIS,NOFRY $
145  COND     FINIS,NOPSDL $
146  RANDOM   XYCDB,DIT,PSDL,OUPV2,,OQP2,OES2,OEF2,CASECC/PSDF,AUTO/
              S,N,NORN $
147  COND     FINIS,NORN $
148  XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/
              S,N,CARDNO/S,N,NOXYPL $
149  COND     FINIS,NOXYPL $
150  XYPLOT   XYPLTR $
151  JUMP     FINIS $
152  LABEL    ERROR2 $
153  PRTPARM  //-2/*AERORESP* $
154  LABEL    ERROR1 $
155  PRTPARM  //-1/*AERORESP* $
156  LABEL    ERROR4 $
157  PRTPARM  //-4/*AERORESP* $
158  LABEL    ERROR3 $
159  PRTPARM  //-3/*AERORESP* $
160  LABEL    FINIS $
161  PURGE    DUMMY/MINUS1 $
162  END      $
```

4.3.2 Description of Important DMAP Operations for Modal Aeroelastic Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. Go to DMAP No. 158 and print Error Message No. 3 if no grid points are defined.

7. GP2 generates Element Connection Table with internal indices.

10. GP3 generates Grid Point Temperature Table (element temperature).

11. TA1 generates element tables for use in matrix assembly and stress recovery.

12. Go to DMAP No. 158 and print Error Message No. 3 if no structural elements have been defined.

15. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

17. Go to DMAP No. 19 if no stiffness matrix is to be assembled.

18. EMA assembles stiffness matrix $[K^{x}_{gg}]$ and Grid Point Singularity Table.

20. Go to DMAP No. 154 and print Error Message No. 1 if no mass matrix is to be assembled.

21. EMA assembles mass matrix $[M_{gg}]$.

22. Go to DMAP No. 25 if no weight and balance information is requested.

23. GPWG generates weight and balance information.

24. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

26. Equivalence $[K^{x}_{gg}]$ to $[K_{gg}]$ if there are no general elements.

27. Go to DMAP No. 30 if there are no general elements.

28. SMA3 forms the general element stiffness matrix $[K^{y}_{gg}]$.

29. ADD combines the structural stiffness matrix $[K^{x}_{gg}]$ with the general element stiffness matrix $[K^{y}_{gg}]$ to obtain the stiffness matrix $[K_{gg}]$.

31. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

34. Go to DMAP No. 37 if no potential grid point singularities exist.

35. GPSP generates a table of potential grid point singularities.

36. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

38. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

39. Go to DMAP No. 42 if no multipoint constraints exist.

40. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

41. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \ .$$

43. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

44. Go to DMAP No. 46 if no single-point constraints exist.

45. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] \ .$$

47. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

49. Go to DMAP No. 53 if no omitted coordinates exist.

51. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

52. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] \ .$$

54. Go to DMAP No. 59 if no free-body supports exist.

55. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

56. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

57. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

58. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

60. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

61. Go to DMAP No. 152 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

62. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

63. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0 ,$$

calculates rigid body modes by finding a matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

64. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

65. Go to DMAP No. 156 and print Error Message No. 4 if no eigenvalues were found.

66. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

67. MXTRIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

68. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^{2d}_{dd}]$ if no constraints are applied.

69. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$ and forms $[G_{md}]$ and $[G_{od}]$.

70. GKAM selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] \ ,$$

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}] \ ,$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] \ ,$$

where

KDAMP = -1 (default)	KDAMP = 1
m_i = modal masses	m_i = modal masses
$b_i = m_i \, 2\pi \, f_i \, g(f_i)$	$b_i = 0$
$k_i = m_i \, 4\pi^2 \, f_i^2$	$k_i = (1+ig(f_i)) \, 4\pi^2 \, f_i^2 m_i$

71. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.

74. Go to DMAP No. 81 if no plot output is requested.

76. PLTSET transforms user input into a form used to drive the structure plotter.

77. PRTMSG prints error messages associated with the structure plotter.

78. Go to DMAP No. 81 if no undeformed aerodynamic or structural element plots are requested.

79. PLØT generates all requested undeformed aerodynamic and structural element plots.

80. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.

82. GI forms a transformation matrix $[G_{ka}^T]$ which interpolates between aerodynamic (k) and structural (a) degrees of freedom.

84. AMG forms the aerodynamic matrix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D_{jk}^1]$ and $[D_{jk}^2]$.

85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.

86. INPUTT2 provides the user-supplied downwash factors due to extra points ($[D_{je}^1]$, $[D_{je}^2]$). PARAM NØDJE must be set to enter these matrices. The downwash w_j on box j due to the motion of an extra point, u_e, is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} \quad .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] \quad , \qquad [G_{ki}] = [G_{ka}^T]^T[\phi_{ai}] \quad ,$$

$$[D_{jh}^1] \Leftarrow [D_{ji}^1 \mid D_{je}^1] \quad , \qquad [D_{ji}^1] = [D_{jk}^1]^T[G_{ki}] \quad ,$$

$$[D_{jh}^2] \Leftarrow [D_{ji}^2 \mid D_{je}^2] \quad \text{and} \qquad [D_{ji}^2] = [D_{jk}^2]^T[G_{ki}].$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] \quad .$$

For each group:

$$[Q_{jh}] = [A_{jj}^T]_{group}^{-1} [D_{jh}]_{group} \quad ,$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}] \quad ,$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

and

$$[Q_{hh}] \Leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right] \quad .$$

90. FRLG forms the dynamic load vector $\{P_h\}$ from the frequency response data or transient data using a Fourier Transform.

93. GUST forms the loading due to gusts and adds to the direct loads.

94. Equivalence {PHF1} to {PHF} if there are no gust loads.

95. FRRD2 solves for the modal displacements using

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K + qQ_{hh}(k)]U_h = P_h(\omega) \quad .$$

96. Equivalence {UHVF} to {UHVT} and FØL to TØL if it is a frequency response formulation.

97. Go to DMAP No. 99 if it is a frequency response formulation.

98. IFT performs Inverse Fourier Transform of the displacements for transient formulation.

100. MØDACC uses data from ØFREQ or ØTIME data cards to select solutions for data recovery.

101. ADR produces aerodynamic load output (PKF) for selected points in frequency response only.

102. VDR prepares solution set displacements (ØUHV1), sorted by frequency or time, for output. The solution set includes mode amplitudes and extra points.

103. Go to DMAP No. 110 if the request is for output sorted by frequency or time step.

104. SDR3 prepares requested output sorted by solution set points.

105. ØFP formats the table prepared by SDR3 for output sorted by solution set point and places it on the system output file for printing.

106. Go to DMAP No. 110 if no X-Y plots are requested.

107. XYTRAN prepares the input for X-Y plotting of solution set points versus time or frequency.

108. Go to DMAP No. 110 if no plots are possible as requested.

109. XYPLØT prepares the requested X-Y plots of solution set points versus time or frequency.

112. Go to DMAP No. 160 if no output for physical points is requested.

113. SDR1 recovers physical displacements (PHIP) and forces of constraint (QP) for the real eigenvectors associated with the modes.

114. Equivalence $\{\phi_{dh}\}$ to $\{\phi_{ah}\}$ if there are no extra points introduced for dynamic analysis.

115. Go to DMAP No. 118 if no extra points are present.

116. VEC generates a d-size partitioning vector (EVEC) for the a- and e-sets

$$\{u_d\} \rightarrow \{u_a\} + \{u_e\} \quad .$$

117. PARTN performs partition of $\{\phi_{dh}\}$ using EVEC

$$\{\phi_{dh}\} \Rightarrow \left\{\begin{array}{c}\phi_{ah} \\ \hline 0\end{array}\right\} \quad .$$

119. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k\} = [G_{ka}^T]^T\{\phi_{ah}\} \quad .$$

120. UMERGE is used to expand $\{Q_p\}$ to the ps-set.

121. UMERGE places $\{\phi_k\}$ in its proper place in the displacement vector

$$\{\phi_{pa}\} \Leftarrow \left\{ \begin{array}{c} \phi_{ps} \\ \hline \phi_k \end{array} \right\} .$$

122. UMERGE is used to expand $\{Q_p\}$ to the pa-set.

123. SDR2 calculates element forces (MEF1) and stresses (MES1) and prepares eigenvectors (MPHIPA1) and single-point forces of constraint (MQP1) for output sorted by frequency or time.

124. Go to DMAP No. 127 if it is not a frequency response formulation.

125. SDR2 prepares load vectors for output (ØPP1) sorted by frequency.

126. SDR3 prepares requested load output sorted by point number.

128. SDR3 prepares requested modal quantities output sorted by point number.

129. DDRMM prepares a subset of the element forces (ØEF2) and stresses (ØES2), displacement vectors (ØUPV2), and single-point forces of constraint (ØQP2) for output sorted by point number or element number.

130. ØFP formats the requested physical output prepared by DDRMM and places it on the system output file for printing.

131. SCAN examines the element stresses and forces calculated by DDRMM and generates scanned output that meets the specifications set by the user.

132. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.

133. Go to DMAP No. 138 if no deformed aerodynamic or structural element plots are requested.

134. MPYAD generates vectors for use by the SDR2 module.

135. SDR2 prepares vectors for deformed plotting.

136. PLØT prepares all requested deformed aerodynamic and structural element plots.

137. PRTMSG prints plotter data and engineering data for each deformed plot generated.

139. Go to DMAP No. 160 and make normal exit if no X-Y plots are requested.

140. XYTRAN prepares the input for physical point X-Y plots.

141. Go to DMAP No. 143 if no plots are possible as requested.

142. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of the constraint versus frequency or time.

144. Go to DMAP No. 160 and make normal exit if it is a transient response formulation.

145. Go to DMAP No. 160 and make normal exit if no power spectral density functions or autocorrelation functions are requested.

146. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

147. Go to DMAP No. 160 and make normal exit if no X-Y plots of RANDØM calculations are requested.

148. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

149. Go to DMAP No. 160 and make normal exit if no plots are possible as requested.

150. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

151. Go to DMAP No. 160 and make normal exit.

153. Print Error Message No. 2 and terminate execution.

155. Print Error Message No. 1 and terminate execution.

157. Print Error Message No. 4 and terminate execution.

159. Print Error Message No. 3 and terminate execution.

4.3.3 Output for Modal Aeroelastic Response

The real Eigenvalue Summary Table and real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

The following printed output, sorted by point number or element number (SØRT2), is available, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead), for the list of frequencies or times specified by ØFREQUENCY or ØTIME (in transient formulations, these are real):

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation). Velocities and accelerations are not available for transient analysis.
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points. Aerodynamic forces on selected aerodynamic elements.
3. Stresses and forces in selected elements (ALL available only for SØRT1).

The following printed output is available for Random Response calculations:

1. Power spectral density function and mean deviation for the response of selected components for points or elements. The expected frequency of zero crossings.
2. Autocorrelation function for the response of selected components for points or elements.

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the aerodynamic and structural model for selected intervals.
3. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or a SØLUTIØN point.
4. X-Y plot of any component of the applied load vector or single-point force of constraint.
5. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing the X-Y plots may be punched or printed in tabuar form (see Volume I, Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

4.3.4 Case Control Deck for Modal Aeroelastic Response

The following items relate to subcase definition and data selection for Modal Aeroelastic Response:

1. METHØD must appear above the subcase level to select an eigenvalue extraction method.
2. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
3. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading condition - one subcase for each dynamic loading condition.
4. Constraints must be defined above the subcase level.
5. DLØAD must be used to define a frequency-dependent loading condition for each subcase. If transient loads are selected, a Fourier Transform is used to compute frequency-dependent loads. All loads in one run must be of the same type.
6. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card form the Bulk Data Deck. If TLØADs are selected, a TSTEP must be selected.
7. ØFREQUENCY (ØTIME) may be used above the subcase level or within each subcase to select a subset of the solution frequencies (times) for output requests. The default is to use all solution frequencies (times).
8. If Random Response calculations are desired, RANDØM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one ØFREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

4.3.5 Parameters for Modal Aeroelastic Response

The following parameters are used in Modal Aeroelastic Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. GUSTAERØ - optional. An integer value of +1 causes gust loads to be computed. The default value is -1 for no gust loads.
6. IFTM - optional. The integer value of this parameter selects the method for the integration of the Inverse Fourier Transform. An integer value of 0 specifies a rectangular fit; 1 specifies a trapezoidal fit; and 2 specifies a cubic spline fit to obtain solutions versus time for which aerodynamic forces are functions of frequency. The default value is 0.
7. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
8. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
9. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
10. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default value is 0.0.
11. NØDJE - optional. A positive integer for this parameter indicates that user-supplied downwash matrices due to extra points are to be read from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
12. P1, P2, and P3 - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The default values for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.
13. Q - required. The real value of this parameter defines the dynamic pressure.

14. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
16. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

4.3.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

4.3.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Aeroelastic Response. See Section 2.3.7 for details.

4.3.8 Rigid Format Error Messages from Modal Aeroelastic Response

The following fatal errors are detected by the DMAP statements in the Modal Aeroelastic Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FORMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

U.S. GOVERNMENT PRINTING OFFICE: 1990 727-064/06007