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BLADED-SHROUDED-DISC AEROELASTIC ANALYSES: COMPUTER PROGRAM UPDATES IN NASTRAN LEVEL 17.7

by

A. MICHAEL GALLO

V. ELCHURI

S. C. SKALSKI

BELL AEROSPACE TEXTRON

POST OFFICE BOX ONE

BUFFALO, NEW YORK 14240

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16. Abstract

In October 1979, a computer program based on the state-of-the-art compressor and structural technologies applied to bladed-shrouded-disc was developed and delivered to NASA Lewis Research Center under Contract NAS3-20382. The program was made operational in NASTRAN Level 16.

As part of the effort under the present contract NAS3-22533, the bladed disc computer program has been updated for operation in NASTRAN Level 17.7. This report documents the program in the form of Updates to NASTRAN Level 17.7 Theoretical, User's, Programmer's and Demonstration Manuals.

The supersonic cascade unsteady aerodynamics routine UCAS, delivered as part of the NASTRAN Level 16 program has been recoded to improve its execution time. These improvements are presented in the Appendix.

The work was conducted under Contract NAS3-22533 from NASA Lewis Research Center, Cleveland, Ohio, with Mr. Richard E. Morris as the Technical Monitor.

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INTRODUCTION

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CONTENTS

THEORETICAL MANUAL UPDATES (LEVEL 17.7)

This section contains new and replacement pages for Level 17.7 of the NASTRAN Theoretical Manual, NASA SP-221(05).

The updates pertain to aeroelastic theory for turbomachines. The pages to be replaced or inserted are:

Section	Pages
Table of Contents	xiii
18.1	18.1-1 to 18.1-2
18.2	18.2-1 to 18.2-9
18.3	18.3-1 to 18.3-9

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18. AEROELASTIC, MODAL AND FLUTTER ANALYSES OF UNSTALLED AXIAL FLOW TURBOMACHINES

18.1 INTRODUCTION

The rotors and stators of axial flow compressors and turbines are subjected to centrifugal, thermal and airloads that depend on the geometry and the operating parameters. Steady aeroelastic and unsteady response of these "cyclically symmetric" structures, in turn, influence the applied thermal and airloads. These inter-active loads and responses arise fundamentally from the elasticity of the structure and determine the performance and stability characteristics of the "flexible" turbomachine.

Theoretical developments of Ref rences 1-3, have been applied to determine the thermal and airloads on the rotor/stator blade of an axial flow turbomachine. The computer code of Reference 1 has been adapted for NASTRAN in the functional module ALG to generate the steady state aerodynamic pressure and temperature loads. Computer codes of linearized, two-dimensional, harmonic cascade theories for subsonic and supersonic flows (References 2 and 3, respectively) have been utilized in the functional module AMG to estimate the harmonic airloads on the blade in a strip-theory manner. No transonic flow theory has been included presently, and the airloads on and near the transonic cylinder (or cone) are estimated by linear interpolation from subsonic and supersonic adjacent strip results.

These steady and harmonic aerodynamic theories, in conjunction with the existing structural analyses capabilities in NASTRAN have been implemented in the form of two new rigid formats to perform:

(1) Static aerothermoelastic "design/analysis", including differential stiffness effects, of an axial flow compressor rotor/stator (DISP Approach RF 16), and

(2) Cyclic modal, unstalled flutter and subcritical roots analyses of an axial flow compressor and turbine rotor/stator (AERØ Approach RF 9).

AEROELASTIC AND DYNAMIC ANALYSES OF TURBOMACHINES

The rigid formats are designed such that the rotor (or stator) of a single-stage, or of each stage of a multi-stage compressor or turbine is analyzed as an isolated structure.

Rigid formats have been designed in a modular fashion so that additional or improved aerodynamic computer codes could replace those currently incorporated.

18.2 STATIC AEROTHERMOELASTIC "DESIGN/ANALYSIS" OF AXIAL FLOW COMPRESSORS WITH DIFFERENTIAL STIFFNESS

At an operating point under steady-state conditions, the bladed-disc of the compressor is subjected to centrifugal, thermal and aerodynamic loads that result in deformation of the elastic structure. For a fixed flow rate and rotational speed, the deformation implies a change in the operating point pressure ratio.

The process of arriving at an "as manufactured" blade shape to produce a desired, design operating point pressure ratio at a given flow rate and speed is herein termed the "design" problem. The subsequent process of analyzing the performance of the "as manufactured" geometry at off-design conditions including the effects of flexibility is herein termed the "analysis" problem.

The current NASTRAN Static Analysis with Differential Stiffness rigid format has been modified to include the effects of non-aerodynamic (centrifugal, etc.) and aerodynamic (pressure and temperature) loads. The following remarks apply to the simplified problem flow and the algorithm shown in Figures 1 and 2, respectively.

1. The geometry of the compressor bladed-disc sector, its material properties and the applied constraints are used to generate and partition the elastic stiffness matrix. Non-aerodyanmic load vectors are formed and an operating point flow rate, speed, loss parameters, etc. are selected.

2. Based on the undeformed blade geometry and the operating point aerodynamic parameters, the functional module ALG generates the aerodynamic load vector.

3. Total loads are defined as a combination of aerodynamic and non-aerodynamic loads.

4. A linear solution for independent displacements is obtained based on the elastic stiffness and the total loads.

5. Omitted and constrained displacements are recovered, and stresses, reactions, etc., are obtained.

6. A differential stiffness matrix is derived as a function of the grid point displacements.

7. A total stiffness matrix is now defined as a sum (or difference) of the elastic and geometric (differential) stiffness matrices for the "analysis" (or "design") problem.

8. The linear displacements obtained earlier are used to revise the blade geometry and a revised aerodynamic load vector is obtained.

9. Again, the aerodynamic and non-aerodynamic load vectors are combined to define the total load vector.

10. A non-linear solution for independent displacements is obtained based on the total stiffness and the total loads.

11. Dependent displacements are obtained and data such as stresses, reactions, etc., are recovered.

12. Convergence of the solution is based on the parameter ε defined by

$$\varepsilon = \left| \frac{\lfloor u_g^b \rfloor \ \{P_{g12} - P_{g2}\}}{\lfloor u_g^b \rfloor \ \{P_{g2}\}} \right| \leq \varepsilon_0$$

Upon convergence, the final displacements, loads, the deformed blade geometry, etc., are output. Otherwise, further iterations are performed.

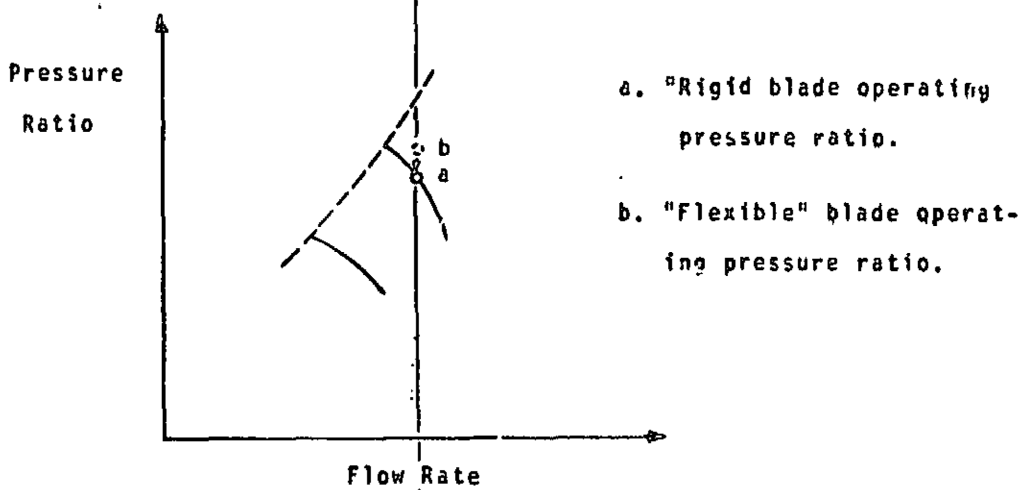
A decision to update the differential stiffness matrix requires a shift to the outer loop. Only the load vector is revised in the inner loop iterations.

12.1 The final pass, upon convergence, through the functional module ALG yields the "flexible" operating point pressure ratio (among other aerodynamic data), which can be relocated on the compressor map.

AEROELASTIC ANALYSIS OF TURBOMACHINES

The "design" mode of the rigid format is exercised only at the design operating point of the compressor. It is a two-step procedure in that having "designed" the blade shape, i.e., the "as manufactured" shape, it should be "analyzed" at the same operating point to confirm the design point pressure ratio. The "analysis" mode of the rigid format is a one-step procedure. The "designed" blade is "analyzed" at selected operating points over the compressor map, one at a time, to generate the "flexible" performance characteristics of the compressor. The differential stiffness matrix generated during the analysis can be saved for use in subsequent modal analysis.

1. Compressor bladed-disc sector geometry, constraints, stiffness matrix, non-aerodynamic loads + operating point (flow rate, speed, loss parameters, etc.).



2. Aerodynamic pressure and temperature loads, $\{P_g^A\}$ on undeformed blade, ALG

3. Total loads $\{P_g\}$ (Aerodynamic and non-aerodynamic)

4. Independent displacements $\{u_\ell\}$ (linear solution)

5. Dependent displacements, stresses, etc. (linear solution) → (A)

Figure 1. Simplified Problem Flow for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial Flow Compressors including Differential Stiffness Effects. (continued)

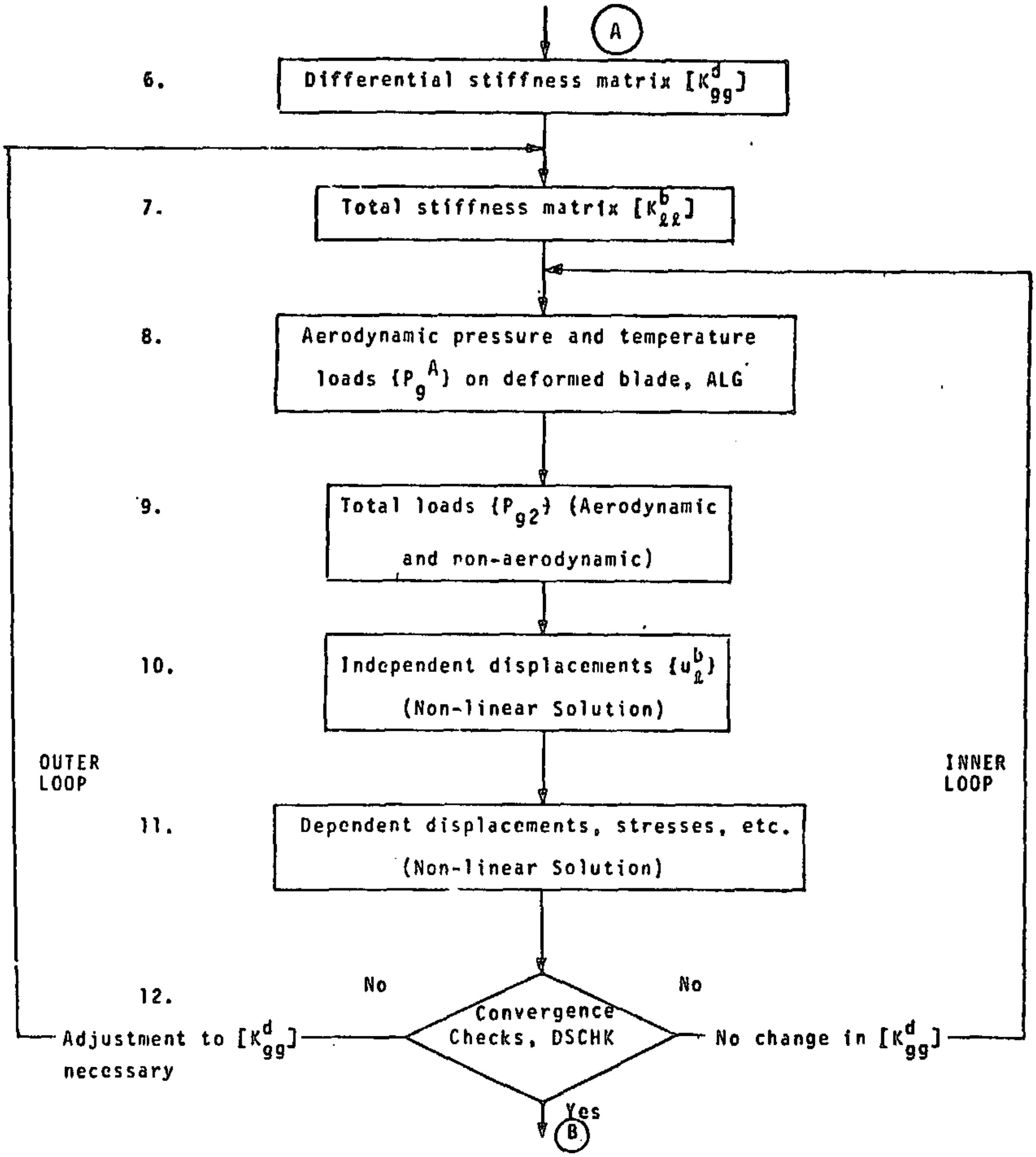


Figure 1. Simplified Problem Flow for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial FlowCompressors including Differential Stiffness Effects. (continued)

B

12.1 Final displacements $\{u_g^b\}$, deformed blade geometry, stress, etc. + operating point pressure ratio and other flow parameters. → Point b on the map

Exit

Figure 1. Simplified Problem Flow for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial Flow Compressors including Differential Stiffness Effects. (concluded)

1. Enter, after the application of constraints and partitioning to the stiffness matrix and the generation and transformation of the non-aerodynamic load vectors (centrifugal, etc.), with K_{aa}, P_g^{NA}, G_m, G_o, etc.

2. $\{P_g^A\} \leftarrow$ ALG $\leftarrow$ Undeformed blade geometry + operating point (flow rate, speed, loss parameters, etc.)

   Aerodynamic Load Generator (pressure and temperature)

3. $\{P_g\} = \{P_g^{NA}\} + \{P_g^A\}$

   $\{P_\ell\} \xleftarrow[\text{partition}]{\text{constrain}} \{P_g\}$

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

5. $\{u_g\} \xleftarrow[{[G_m],\ [G_o],\ \text{etc.}}]{\text{recover}} \{u_\ell\}$

6. $[K_{gg}^d] \xleftarrow{\text{generate}} [K_{gg}^d\ (\{u_g\})]$

   $\{P_g\} = \{P_g^{NA}\}$

   $\{P_{g1}\} = \{P_g\}$ ——— A OUTER LOOP begins

   $[K_{aa}^d] \xleftarrow[\text{partition}]{\text{constrain}} [K_{gg}^d]$

7. $[K_{\ell\ell}^b] = [K_{aa}] \pm [K_{aa}^d]$, (+) for "analysis" mode of the rigid format
   (-) for "design" mode of the rigid format

   $\{P_{go}\} = \{P_{g1}\} + \{o\}$

   $\{u_g^A\} = \{u_g\}$

Figure 2. Simplified Solution Algorithm for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial Flow Compressors including Differential Stiffness Effects. (continued)

--------- (B) Inner Loop begins

8. $\{P_g^{\,A}\} \leftarrow$ ALG $\leftarrow$ Deformed blade geometry, revised with $\{u_g^{\,A}\}$, + operating point.

9. $\{P_{g2}\} = \{P_{g1}\} + \{P_g^{\,A}\}$

$\{P_\ell^b\} \xleftarrow[\text{partition}]{\text{constrain}} \{P_{g2}\}$

10. $\{u_\ell^b\} = [K_{\ell\ell}^b]^{-1} \ \{P_\ell^b\}$

11. $\{u_g^b\} \xleftarrow[{[G_m],\ [G_o],\ \text{etc.}}]{\text{recover}} \{u_\ell^b\}$

$\{u_g^{\,A}\} = \{u_g^b\}$

$\{u_g^d\} = \{u_g\} - \{u_g^b\}$

$[\delta K_{gg}^d] \xleftarrow{\text{generate}} [\delta K_{gg}^d \ (\{u_g^d\})]$

$\{P_{gI1}\} = [\delta K_{gg}^d] \ \{u_g^b\} + \{P_{go}\}$

$\{P_{gI2}\} = \{P_{gI1}\} + \{P_g^{\,A}\}$

12. Convergence checks $\leftarrow$ DSCHK $\leftarrow$ $\{P_{g2}\}$, $\{P_{gI2}\}$, $\{u_g^b\}$

<u>D</u>ifferential <u>S</u>tiffness <u>C</u>hecks

1. $\epsilon \leq \epsilon_o$.

<u>Exit</u> with

a. $\{u_g^b\}$, stresses, etc.

Figure 2. Simplified Solution Algorithm for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial Flow Compressors including Differential Stiffness Effects. (continued)

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b. Final deformed blade geometry → ALG → $\{P_g^A\}$ + operating pressure ratio and other flow parameters.
+ operating point (flow rate, speed, loss parameters, etc.).

<u>OR</u> 2. $\varepsilon > \varepsilon_o$ <u>and</u> adjustment to K_{gg}^d <u>not</u> necessary.

Shift to the beginning of Inner Loop with

a. $\{P_{g1}\} = \{P_{gI1}\}$ ---------------- To B

<u>OR</u> 3. $\varepsilon > \varepsilon_o$ <u>and</u> adjustment to K_{gg}^d necessary.

Shift to the beginning of Outer Loop with

a. $\{u_g\} = \{u_g^b\}$

b. $[K_{gg}^d] = [K_{gg}^d] - [\delta K_{gg}^d]$ ---------------- To A

Figure 2. Simplified Solution Algorithm for Static Aerothermoelastic "Design/Analysis" Rigid Format for Axial Flow Compressors including Differential Stiffness Effects. (concluded)

18.3 CYCLIC MODAL AND FLUTTER ANALYSES OF AXIAL FLOW TURBOMACHINES

The problem of determining the complete, unstalled flutter boundaries of a cyclically symmetric compressor or turbine bladed disc involves each member set of the series of harmonic families of its modes, and the effects of permissible interblade phase angle, over an adequate set of operating points (flow rates, speeds, pressure ratios, implied Mach numbers, etc.) of the performance map. In view of the large number of variables influencing the definition of the flutter boundaries, a thorough parametric study requires systematic effective solution procedure.

A capability, therefore, has been introduced in NASTRAN which, with repeated exercises over the range of variables involved, will enable determination of the flutter boundaries. The existing features of NASTRAN for Normal Modes Analysis using Cyclic Symmetry (Section 3.16, User's Manual) and Modal Flutter Analysis (Section 3.20, User's Manual) have been suitably combined for the cyclic modal, flutter and subcritical roots analyses in a new Rigid Format 9, Approach AERØ. Provision is also made to include the differential stiffness effects by using the total stiffness matrix saved from the Static Aerothermoelastic Analysis (see Section 18.2).

In a compressor or turbine, an operating point implies an equilibrium of flow properties such as density, velocity, Mach number, flow angle, etc., that vary across the blade span. Blade properties such as the blade angle, stagger angle, chord, etc., also, in general, change from the blade root to the tip. The resulting spanwise variation in the local reduced frequency and the relative Mach number must be accounted for in estimating the chordwise generalized aerodynamic forces per unit span at each streamline. Integration of these forces over the blade span yields the blade generalized aerodynamic force matrix. Since the relative Mach number varies along the blade span, two two-dimensional, linearized, harmonic cascade theories (Refs. 2 and 3) one each for subsonic and supersonic flow have been implemented in a strip theory manner along the blade span. The chordwise aerodynamic matrices for streamlines with transonic inflow are derived by linear interpolation between those on adjacent (subsonic and supersonic) streamlines.

The generation of the generalized air force matrices is an expensive operation and should be judiciously controlled. In the present development, the aerodynamic matrices are computed at a few reduced frequencies and interblade phase angles, and interpolated for others. Additionally, the chordwise generalized air force matrices are first computed for "aerodynamic modes" (heave, pitch, etc.). The matrices for chordwise structural modes are then determined from bilinear transformations along each streamline prior to the spanwise integration to obtain the complete blade generalized aerodynamic matrix. This permits a change in the structural mode shapes of the same or a different harmonic number to be included in the flutter analysis without having to recompute the modal aerodynamic matrices for aerodynamic modes.

The following remarks apply to the simplified problem flow shown in Figure 1. In this figure, a compressor bladed disc performance map is shown, although the analysis is equally applicable to both compressors and turbines.

1. The geometry and the material properties of the bladed disc sector are defined along with the applicable constraints. An operating point is selected near the expected location of the flutter boundary. The solution procedure examines if this operating point is a flutter point.

2. Flutter parameters such as densities, interblade phase angles and reduced frequencies are selected.

3. The chosen operating point implies a certain spanwise variation of blade and flow properties.

4. A harmonic number is selected for the cyclic modal analysis. Grid point mass and stiffness matrices are generated. The stiffness matrix saved from a previous Static Aerothermoelastic Analysis can be used instead, and would include the differential stiffness effects at the steady state operating point under consideration.

5. Constraints and partitioning yield the analysis set mass and stiffness matrices.

6. Forward cyclic transformation results in the solution set mass and stiffness matrices for the cyclic eigenvalue problem.

7. Eigenvalues and eigenvectors in the solution set are obtained.

8. Symmetric components eigenvectors are derived by a backward cyclic transformation.

9. Symmetric components eigenvectors are augmented by recovering the dependent components, and are prepared for output if desired.

10. For a non-zero harmonic number, the symmetric component eigenvectors are partitioned to separate the cosine and sine components.

11. Based on the number of modes selected for flutter analysis the modal mass matrix is computed.

12,13. Direct input mass, stiffness and damping matrices, if necessary, and the constraints thereon define these matrices for further analysis.

14. The augmented eigenvectors, including any extra (or scalar) points introduced for dynamic analysis, are formed and used to define the new generalized mass, stiffness and

damping matrices.

15. The streamline generalized aerodynamic matrices for chordwise <u>aerodynamic</u> modes are generated. The variation of the relative Mach number from streamline to streamline dictates the use of either of the subsonic and supersonic harmonic cascade theories. Such matrices for the streamlines with transonic inflow are interpolated. No transonic flow theory has been currently included.

16. The <u>structural</u> modes are introduced via bilinear transformations along each streamline to define the chordwise generalized air force matrices.

17. The blade generalized aerodynamic matrix is derived by a spanwise integration of the chordwise aerodynamic matrices for <u>structural</u> modes.

18 - 20. The analysis loops through the user-selected combinations of density, interblade phase angle and reduced frequency.

21. Based on the (σ,k) combination, the appropriate blade aerodynamic matrix is chosen for the flutter equation. Linear or surface interpolation, at user's option, is used if necessary.

22. The generalized mass, stiffness and damping matrices of Step 14 and the generalized air force matrix of Step 21 are used to define the modal flutter equations.

23. The solution to the flutter equations is sought in the form of complex eigenvalues and eigenvectors.

24. The velocity-damping and velocity-frequency curves output for each (ρ,σ,k) group are interpreted to identify flutter points.

25. Based on the relative stiffnesses of the blade and the hub of the bladed disc sector, a series of harmonic numbers are investigated before arriving at the flutter boundaries. Presently, the solution rigid format is designed to accept one harmonic number at a time.

The cyclic modal flutter analysis discussed herein is illustrated by the example 9-5-1 of the Demonstration Problems Manual.

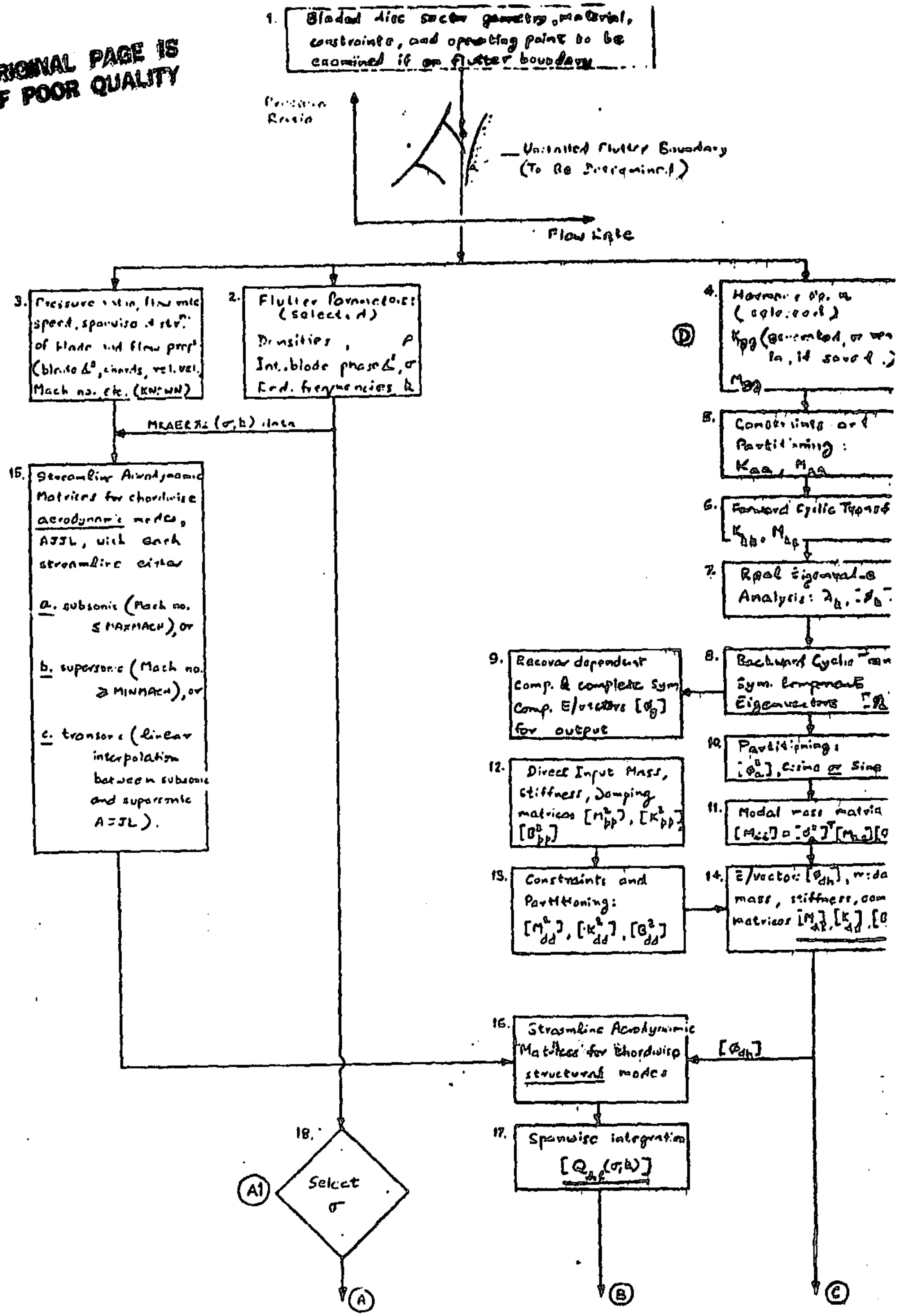

Figure 1. Simplified Problem Flow: Cyclic Modal Flutter Analysis of Bladed Discs (continued).

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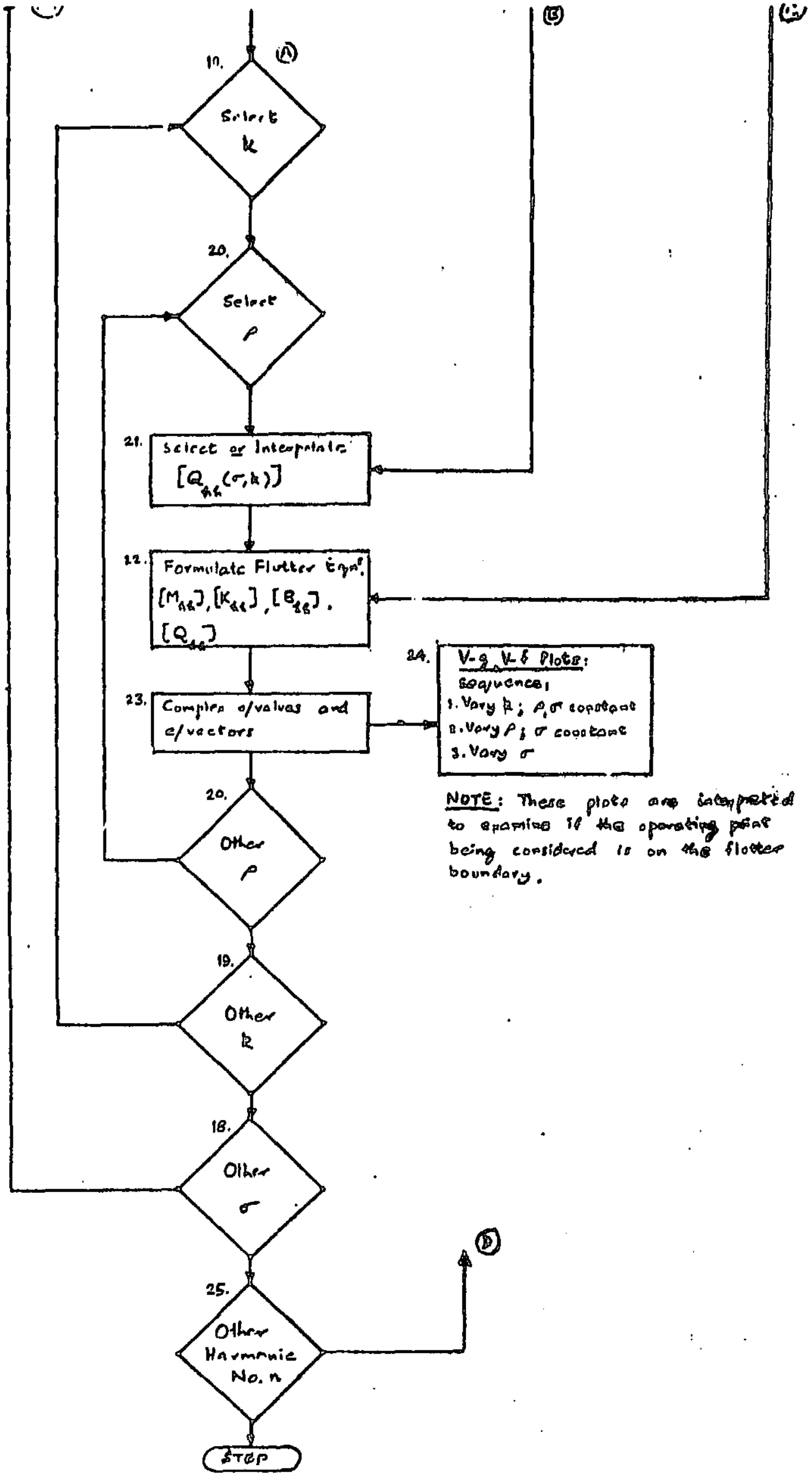

Figure 1. Simplified Problem Flow: Cyclic Modal Flutter Analysis of Bladed Discs (concluded).

REFERENCES

1. Hearsey, Richard M., " A Revised Computer Program for Axial Compressor Design," ARL-75-0001, Vol. I and II, Wright-Patterson AFB, Jan. 1975.

2. Rao, B. M., and Jones, W. P., "Unsteady Airloads for a Cascade of Staggered Blades in Subsonic Flow," 46th Propulsion Energetics Review Meeting, Monterey, California, Sept. 1975.

3. Gold tein, M. E., Braun Willis, and Adamczyk, J. J., "Unsteady Flow in a Supersonic Cascade with Strong In-Passage Shocks," Journal of Fluid Mechanics, Vol. 83, part 3, Dec. 1977, pp. 569-604.

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USER'S MANUAL UPDATES

STRUCTURAL MODELING

1.14 STATIC AEROELASTIC AND FLUTTER MODELING OF AXIAL FLOW TURBOMACHINES

1.14.1 Introduction

The NASTRAN aeroelastic and flutter capability has been extended to solve a class of problems associated with axial flow turbomachines. The capabilities included are:

1. Steady state aerothermoelastic analysis of compressors to determine:

(a) The change in geometry between the design point operating shape and the "as manufactured" shape of the flexible blade to ensure the required performance (pressure ratio, flow rate, rpm) at the design point. (This is termed the "design" problem.)

(b) The performance at off-design operating conditions for a given "as manufactured" blade shape. (This is termed the "analysis" problem.)

(c) Displacements, stresses, reactions, plots, etc., at selected operating points over the compressor map.

(d) A differential stiffness matrix due to centrifugal and aerodynamic pressure and thermal loads for use in subsequent modal analysis.

2. Modal, unstalled flutter and subcritical roots analysis of compressors and turbines.

The rotor/stator of a single-stage, or each stage of a multi-stage compressor or turbine is analyzed as an isolated structure. Two new Rigid Formats (Displacement RF 16 and Aero RF 9) have been developed, one each for the aeroelastic steady state and the oscillatory state problems (see Sections 3.22, 3.23, 3.24). The rotational cyclic symmetry (see Section 1.12) inherent in these structures about the axis of rotation has been taken into account in designing the capability, so that only a representative one-blade sector need be idealized.

The steady aerothermoelastic analysis is based on the theory described in Volume I of Reference 1. The computer code of the same reference (Volume II), with minor changes, has been adapted for NASTRAN in the functional module ALG. The current NASTRAN Static Analysis with Differential Stiffness Rigid Format has been accordingly modified to include the effect of centrifugal, aerodynamic pressure and temperature loads.

The existing features of NASTRAN for Normal Modes Analysis using Cyclic Symmetry (Section 3.16) and Modal Flutter Analysis (Section 3.20) have been suitably combined for the modal flutter and subcritical roots analysis of the axial flow turbomachinery rotor/stator.

These developments are compatible with the general structural capability in NASTRAN. The structural part of the problem is modeled as described in Section 1 of the User's Manual. This section deals with the aerodynamic data pertaining to the bladed disc sector. The associated aerodynamic modeling is discussed in Section 1.14.2.

Section 1.14.3 describes the steady aerothermoelastic "design/analysis" formulations.

Section 1.14.5 presents the modal, flutter and subcritical roots analyses.

Sample problems and their solutions are presented in Sections 1.14.4 and 1.14.6.

1.14.2 Aerodynamic Modeling

The aerodynamic model is based on a grid generated by the intersection of a series of streamlines and "computing stations" (similar to potential lines) as shown in Figure 1. This arrangement also facilitates the subsequent use of two-dimensional, unsteady, subsonic and supersonic infinite cascade theories (see Section 18 of the Theoretical Manual) in the flutter problem. They are used in a strip-theory manner on the various streamlines spanning the blade.

The aerodynamic loads are assumed significant only on the bladed portion of a bladed disc and no other part of the structure need be modeled aerodynamically. The data required to generate the aerodynamic model for the steady state aeroelastic analyses are specified on DTI bulk data cards, and are described in Section 1.14.3.1 of the User's Manual. Blade streamline data for flutter and subcritical roots analyses are specified on STREAMLi bulk data cards.

The streamlines are defined by the intersection of the blade mean surface and a set of coaxial cylindrical (or conical) surfaces. The axis of the cylinders (cones) coincides with the axis of rotation of the turbomachine. The "computing stations" lie on the blade mean surface and divide it from the leading edge to the trailing edge. The choice of the number and location of the streamlines and the "computing stations" is dictated by the expected variation of the relative flow properties across the blade span, and the complexity of the mode shapes exhibited by this part of the structure. However, a minimum of three streamlines (including the blade root and

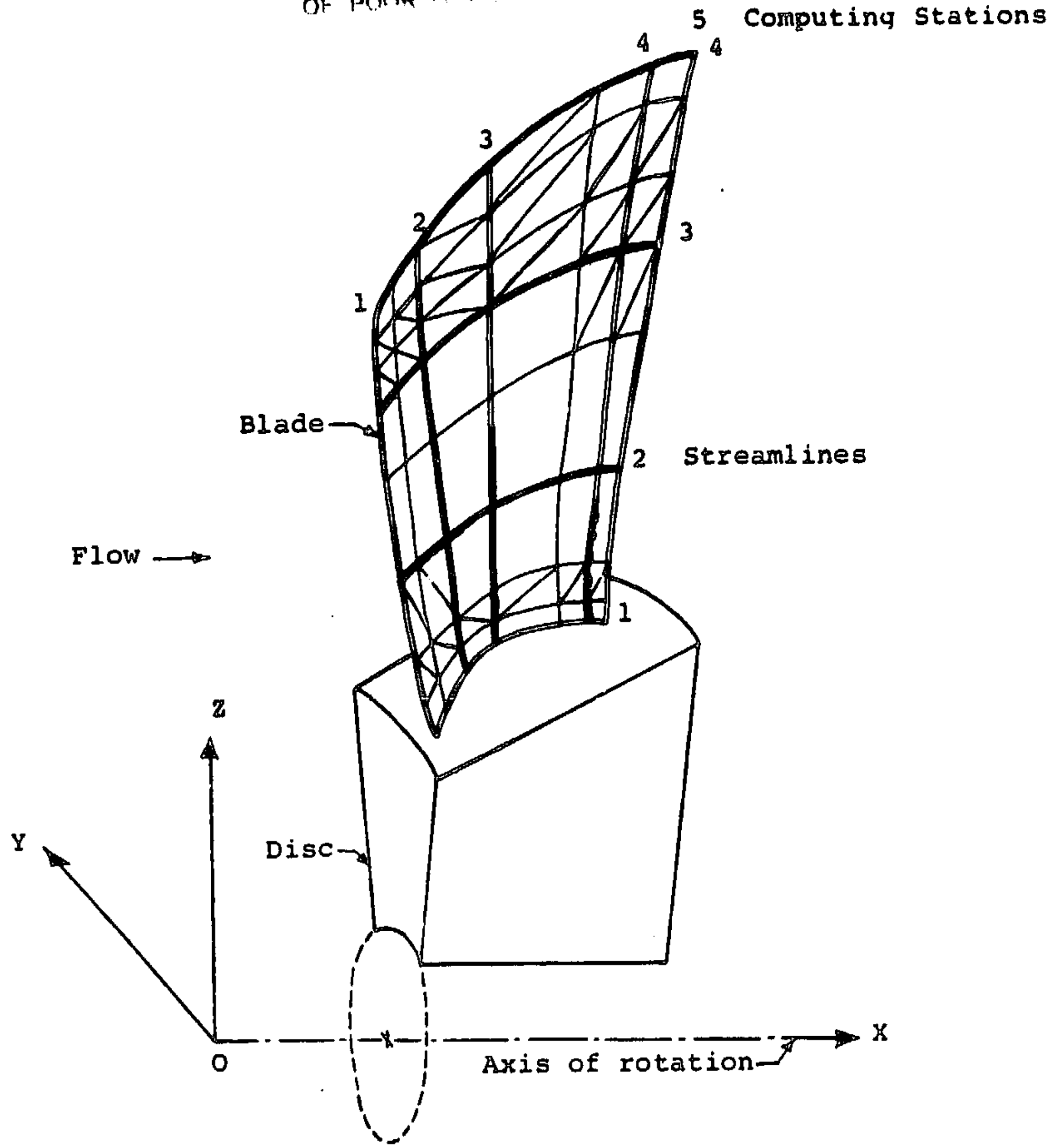

Figure 1 Bladed-disc Aerodynamic Grid And The Basic Coordinate System

the tip) and three "computing stations" (including the blade leading edge and the trailing edge) must be specified.

The distribution of the aerodynamic parameters over the blade is, in general, different from that of the structural parameters such as stress, strain, etc. Accordingly, the aerodynamic model and the structural model of the blade, in general, may differ. The difference currently permitted in the two models is as seen in Figure 1 wherein the aerodynamic grid is shown to be a part of the structural grid.

The x-axis of the BASIC coordinate system (Figure 1) is chosen to coincide with the axis of rotation and is oriented in the direction of the flow. The location of the origin is arbitrary. The z-plane (BASIC) lies normal to the "mean" meridional plane passing through the blade, with the z-axis (BASIC) directed towards the blade. The aerodynamic grid can be specified in any coordinate system (CP). The aerodynamic model data mainly related to the bladed disc problems are specified on the DTI, STREAML1 and STREAML2 bulk data cards.

1.14.3 Steady Aerothermoelastic "Design/Analysis"

An operating point on a compressor map defines a distribution of centrifugal force and aerodynamic pressure and temperature loads on the bladed-disc of the axial flow turbomachine. The equilibrium, deformed shape of the elastic structure is reached at the end of a series of quasi-equilibrium states during which the loads on the bladed-disc and its geometric stiffness change as a function of the deformation. The operating point pressure ratio (given the flow rate and the rpm), in effect, also changes during this process.

Two different problems can thus be stated:

1. Given the desired <u>design</u> operating point and the "rigid" geometry, to determine the "as manufactured" geometry ("design" problem) that would produce the design conditions and

2. Given the "as manufactured" geometry, to determine the performance of the flexible blade at off-design operating points ("analysis" problem).

Rigid format Displacement 16 has been developed to solve these "design/analysis" problems. The value of the PARAMeter SIGN (= ± 1) selects the analysis or the design mode of the rigid format. Deformation of the structure as a result of the applied centrifugal and aerodynamic loads is used to revise the blade geometry each time through the differential stiffness loop of the rigid format. Because of the non-linear relationship between the blade geometry and the resulting operating point pressure ratio, provision is made to control the fraction of the displacements used to redefine the blade geometry. This is especially helpful in the solution of the "design" problem. The fractions of the displacements used to redefine the blade geometry are specified via the FXCOOR, FYCOOR and FZCOOR parameters. The application of the aerodynamic pressure and thermal loads is controlled respectively by the parameters APRESS and ATEMP. These parameters also enable the inclusion of the centrifugal loads alone.

The functional module ALG is used in the rigid format before, within and after the differential stiffness loops (see Section 4.1.6.2) to generate the aerodynamic loads. Printed output from this module during these three stages can respectively be controlled through the use of the parameters IPRTCI, IPRTCL and IPRTCF. This enables observation of the variation in the aerodynamic loads as a function of the blade geometry.

GRID, CTRIA2 and PTRIA2 bulk data cards for the final blade shape can be punched out using the parameter PGEØM. At the end of a "design" run, these define the "as manufactured" blade shape which can subsequently be "analyzed" at selected operating points over the compressor map. In an "analysis" run at any operating point, the total stiffness (elastic and geometric) of the bladed-disc structure can be saved via the parameter KTØUT for use in subsequent modal, modal flutter and subcritical roots analyses.

The subsections 1.14.3.1 and 1.14.3.2 describe the aerodynamic Direct Table Input and the output data for the steady state analyses.

1.14.3.1 Aerodynamic DTI Data

The input data consist of an initial indication of the number of entries that are to be made to each of the two program sections (analytic meanline blade section and aerodynamic section), and then a data-set for each entry to each section. The data that are required for the interfacing of the output from the analytic meanline blade section to the aerodynamic section are included in the data-set for the analytic meanline section. Because partial input to the aerodynamic section is generated by execution of the analytic meanline section, the input for the aerodynamic section to be supplied directly by the user varies. This is indicated in the charts below by giving the variable name LOG5 for the file from which any data are taken that are not always supplied directly.

LOG5 is the file from which input is taken that is generated by the analytic meanline section. When the analytic meanline section has been directed to produce data for the aerodynamic section for a particular computing station, LOG5 becomes an internally generated scratchfile. Otherwise, LOG5 is attached to the standard input unit and the user supplies the data.

The following input data items must be input using NASTRAN Direct Table Input (DTI) bulk data cards. A description of the DTI card is in the NASTRAN User's Manual.
The table data block name must be ALGDB. The trailer value for T1 is the number of logical records in the DTI table, not

counting the header record. This is the same as the maximum value of IREC used in the table. The trailer values for T2 through T6 are all zero. Each of the following input cards corresponds to one logical record of the DTI table. Trailing zeroes need not be input. Data types, i.e., alphanumeric (BCD), real and integer, must correspond to those specified for each data item. Data item names that begin with the letters I,J,K,L,M, and N are to be input as integers while all others are input as real numbers. Titles are input as alphanumeric (BCD) with the restriction that only alphabetic letters occupy the first character in each field of the DTI card. Titles may use up to nine DTI fields.

NRAD NDPTS NDATR NSWITC NLE NTE

XKSHPE SPEED

NOUT1 NOUT2 NOUT3 - Refers to leading edge station

NR NTERP NMACH NLOSS NL1

(cont.) NL2 NEVAL NCURVE NLITER NDEL

(cont.) NOUT1 NOUT2 NOUT3 NBLAD

R XLOSS }- Occurs NR times

Occurs for each station within blade or at trailing edge

RTE

DM DVFRAC] -Occurs NDPTS times

Occurs NRAD times

* RDTE DELTAD AC}Occurs NDATR times

This group is used to generate LOG5 data for the aerodynamic section

The following data-set is input to the aerodynamic section and the last record in this set is indicated with a double asterisk.

TITLE3

CP GASR G EJ

NSTNS NSTRMS NMAX NFORCE NBL NCASE

(cont.) NSPLIT NSET1 NSET2 NREAD NPUNCH NPLOT

(cont.) NPAGE NTRANS NMIX NMANY NSTPLT NEQN NLE NTE NSIGN

NWHICH - Occurs NMANY times on the same card

G EJ SCLFAC TOLNCE VISK SHAPE

XSCALE PSCALE RLOW PLOW XMMAX RCONST

CONTR CONMX

FLOW SPDFAC

NSPEC

XSTN RSTN - Occurs NSPEC times

Occurs NSTNS Times

NDATA NTERP NDIMEN NMACH

DATAC DATA1 DATA2 DATA3 - Occurs NDATA times

Inlet condition specification

(LOG5) NDATA NTERP NDIMEN NMACH NWORK

(cont.) NLOSS NL1 NL2 NEVAL NCURVE NLITER

(cont.) NDEL NOUT1 NOUT2 NOUT3 NBLADE

(LOG5) SPEED-If NDATA >0

(LOG5) DATAC DATA1 DATA2 DATA3 DATA4

(cont.) DATA5

(LOG5) DATA6 DATA7 DATA8 DATA9

Occurs NDATA times

DELC DELTA - Occurs NDEL times

For stations 2 thru NSTNS

WBLOCK BBLOCK BDIST -Occurs NSTNS times

NDIF

DIFF FDHUB FDMID FDTIP -Occurs NDIFF times

Occurs NSET1 times

NM NRAD

TERAD

DM WFRAC -Occurs NM times

Occurs NRAD times

Occurs NSET2 Times

DELF(1) DELF(2)....DELF (NSTRMS) - if NSPLIT = 1 (6/CARD)
or NREAD = 1

** R X XL II JJ - Occurs NSTRMS times for NSTNS stations if NREAD = 1

Data Item Defintions:

The aerodynamic section may be used with any self-consistent unit system and, additionally, a "linear dimension scaling factor" (SCLFAC) is incorporated into the input so that some commonly used but inconsistent unit sytems may be used. This is principally intended to allow the use of inches for physical dimensions and yet retain feet for velocities. The basic dimensions used in the data are length (L), time (T), and force (F). Angles are expressed in degrees (A), and temperatures on an absolute temperature scale (D). Heat capacities (H) are also required. Some possible unit systems are given below, togehter with the corresponding value of SCLFAC.

L	T	F	D	H	SCLFAC
Feet	Seconds	Pounds	Deg. Rankine	BTU	1.0
Inches	Seconds	Pounds	Deg. Rankine	BTU	12.0
Meters	Seconds	Kilograms	Deg. Kelvin	CHU	1.0

Note that some data names are used in more than one section; care should be taken to consult the correct sub-division below for defintions.

a. Initial Directives

TITLE1 This is a title card for the run.

NANAL Set NANAL = 1

NAERO Set NAERO = 1

b. Analytic Meanline Blade Section

For a more detailed discussion of the input to this section through item XB, see Reference and . For this section, the dimensioned input is either in degree (A) or in length (L).

TITLE2	A title card for the analytic meanline section of the program.
NLINES	The number of stream surfaces which are defined, and on which blade sections will be designed. Must satisfy $2 \le NLINES \le 21$.
NSTNS	The number of computing stations at which the stream surface radii are specified. Must satisfy $3 \le NSTNS \le 10$.
NZ	The number of constant-z planes on which manufacturing (Cartesian) coordinates for the blade are required. Must satisfy $3 \le NZ \le 15$.
NSPEC	The number of radially disposed points at which the parameters of the blade sections are specified. Must satisfy $1 \le NSPEC \le 21$.
NPOINT	The number of points that will be generated to specify the pressure and suction surfaces of each blade section. Must satisfy $2 \le NPOINT \le 80$. Generally, no less than 30 should be used.
NBLADE	The number of blades in the blade row.
ISTAK	If ISTAK = 0, the blade will be stacked at the leading edge. If ISTAK = 1, the blade will be stacked at the trailing edge.

	If ISTAK = 2, the blade will be stacked at, or offset from, the section centroid.
IPUNCH	Set IPUNCH = 0
ISECN	If ISECN = 0, the blade will be constructed using the polynomial camber line and the standard (i.e., double-cubic) thickness distribution. If ISECN = 1, the exponential camber line and the standard thickness distribution will be used. If ISECN = 2, the circular arc camber line and the double-circular-arc thickness distribution will be used. If ISECN = 3, the multiple-circular-arc meanline and the standard thickness distribution will be used.
IFCORD	If IFCORD = 0, the meridional projection of the stream surface blade section chords are specified. If IFCORD = 1, the stream surface blade section chords are specified.
IFPLOT	Set IFPLOT = 0
IPRINT	The input data is always listed by the program. Details of the stream surface and manufacturing sections are printed as prescribed by IPRINT.

If IPRINT = 0, details of the stream surface and manufacturing sections are printed.

If IPRINT = 1, details of stream surface sections are printed.

If IPRINT = 2, details of manufacturing sections are printed.

If IPRINT = 3, details of neither stream surface nor manufacturing sections are printed. (The interface data for use with the aerodynamic section of the program is is still displayed.)

ISPLIT	Set ISPLIT = 0
INAST	Set INAST = 0. See the Output Data description (Section) for further details.
IRLE	The computing station number at the blade leading edge.
IRTE	The computing station number at the blade trailing edge.
NSIGN	Indicator used to sign blade pressure forces according to program sign conventions. For compressor rotors, if the machine rotates clockwise when viewed from the front, set NSIGN to 1; otherwise, set NSIGN to -1. For compressor stators, the two values given for NSIGN are reversed.

ZINNER, ZOUTER	The NZ manufacturing sections are equi-spaced between z equals ZINNER and ZOUTER.
SCALE	Set scale = 0.0.
STACKX	This is the axial coordinate of the stacking axis for the blade, relative to the same origin as used for the station locations, XSTA.
PLTSZE	Set PLTSZE = 0.0.
KPTS	The number of points provided to specify the shape of a computing station. If KPTS = 1, the computing station is upright and linear. If KPTS = 2, the computing station is linear and either upright or inclined. If KPTS >2, a spline curve is fit through the points provided to specify the shape of the station.
IFANGS	If IFANGS = 0, the calculations of the quantities required for aerodynamic analysis will be omitted at a particular computing station. If IFANGS = 1, these calculations will be performed at that station.
XSTA	An array of KPTS axial coordinates (relative to an arbitrary origin) which, toghter with RSTA, specify the shape of a particular computing station.

RSTA	An array of KPTS radii which, together with XSTA, specify the shape of a particular computing station.
R	The stream surface radii at NLINES locations at each of the NSTNS stations.
BLAFOR	Set BLAFOR = 0.0.
ZR	The variation of properties of the stream surface blade section is specified as a function of stream surface number. The various quantitites are then interpolated (or extrapolated) at each stream surface. The stream surfaces are numbered consecutively from the inner-most outward, starting with 1.0. ZR must increase monotonically, there being NSPEC values in all.
B1	The blade inlet angle.
B2	The blade outlet angle.
PP	If ISECN = 0, PP is the ratio of the second derivative of the camber line at the leading edge to its maximum value. Must satisfy $-2.0 < PP < 1.0$. If ISECN = 1, PP is the ratio of the second derivative of the camber line at the leading edge to its maximum value forward of the inflection point. Must satisfy $0.0 < PP \leq 1.0$.

If ISECN = 2 or 3, PP is superfluous.

QQ — If ISECN = 0, QQ is the ratio of the second derivative of the camber line at the trailing edge to its maximum value. Must satisfy $0.0 \leq QQ \leq 1.0$.

If ISECN = 1, QQ is the ratio of the second derivative of the camber line at the trailing edge to its maximum value rearward of the inflection point. Must satisfy $0.0 < QQ \leq 1.0$.

If ISECN = 2 or 3, QQ is superfluous.

RLE — The ratio of blade leading edge radius to chord.

TC — The ratio of blade maximum thickness to chord.

TE — The ratio of blade trailing edge half-thickness to chord.

If ISECN = 2, TE is superfluous.

Z — The location of the blade maximum thickness, as a fraction of camber line length from the leading edge.

If ISECN = 2, Z is superfluous.

CORD — If IFCORD = 0, CORD is the meridional projection of the blade chord.

If IFCORD = 1, CORD is the blade chord.

DELX, DELY — The stacking axis passes through the stream surface blade sections, offset from the centroids, leading, or trailing edge by DELX

	and DELY in the x and y directions respectively.
S, BS	If ISECN = 1 or 3, S and BS are used to specify the locations of the inflection point (as a fraction of the meridionally-projected chord length) and the change in camber angle from the leading edge to the inflection point. If the absolute value of the angle at the inflection point is larger than the absolute value of B1, BS should have the same sign as B1, otherwise, B1 and BS should be of opposite signs.
NRAD	The number of radii at which a distribution of the fraction of trailing edge deviation is input. Must satisfy $1 \leq NRAD \leq 5$.
NDPTS	The number of points used to define each deviation curve. Must satisfy $1 \leq NDPTS \leq 11$.
NDATR	The number of radii at which an additional deviation angle increment and the point of maximum camber are specified. Must satisfy $1 \leq NDATR \leq 21$.
NSWITC	If NSWITC = 1, the deviation correlation parameter "m" for the NACA (A_{10}) meanline is used.
	If NSWITC = 2, the deviation correlation parameter "m" for double-circular-arc blades is used.
NLE	Station number at leading edge.
NTE	Station number at trailing edge.
XKSHPE	The blade shape correction factor in the deviation rule.

SPEED	See definition for Aerodynamic Section.
NR	The number of radii where a "loss" is input.
NTERP NMACH NLOSS NL1 NL2 NEVAL NCURVE NLITER NDEL NOUT1 NOUT2 NOUT3 NBLAD	See definition for Aerodynamic Section.
R	Radius at which loss is specified.
XLOSS	Loss description. The form is prescribed by NLOSS; see aerodynamic section.
RTE	Radius at blade trailing edge where the following deviation fraction/chord curve applies. If NRAD = 1, it has no significance. Must increase monotonically.
DM	The location on the meridional chord where the deviation fraction is given. Expressed as a fraction of the meridional chord from the leading edge. Must increase monotonically.
DVFRAC	Fraction of trailing-edge deviation that occurs at location DM.
RDTE	Radius at trailing edge where additional deviation and point of maximum camber are specified.

DELTAD	Additional deviation angle added to that determined by deviation rule. Input positive for conventionally positive deviation for both rotors and stators.
AC	Fraction of blade chord from leading edge where maximum camber occurs.

c. Aerodynamic Section

TITLE3	A title card for the aerodynamic section of the program.
CP	Specific heat at constant pressure. An input value of zero will be reset to 0.24. Units: H/F/D.
GASR	Gas constant. An input value of zero will be reset to 53.32. Units: L/SCLFAC/D.
G	Acceleration due to gravity. An input value of zero will be reset to 32.174. Units: L/SCLFAC/T/T.
EJ	Joules equivalent. An input value of zero will be reset to 778.16. Units: LF/SCLFAC/H.
NSTNS	Number of computing stations. Must satisfy 3 ≤ NSTNS ≤ 30.
NSTRMS	Number of streamlines. Must satisfy 3 ≤ NSTRMS ≤ 21. An input value of zero will be reset to 11.
NMAX	Maximum number of passes through the iterative streamline determination procedure. An input value of zero will be reset to 40.
NFORCE	The first NFORCE passes are performed with arbitrary numbers inserted should any calculation produce impossible values. Thereafter, execution will cease, the calculation having "failed". An input value of zero will be reset to 10.
NBL	If NBL = 0, the annulus wall boundary layer blockage allowance will be held at the values prescribed by WBLOCK. If NBL = 1, blockage due to annulus wall boundary layers will be recalculated except at station 1. VISK and SHAPE are used in the calculation.

NCASE	Set NCASE = 1.
NSPLIT	If NSPLIT = 0, the flow distribution between the streamlines will be determined by the program so that roughly uniform increments of computing station will occur between the streamlines at station 1. If NSPLIT = 1, the flow distribution between the streamlines is read in (see DELF).
NSET1	The blade loss coefficient re-evaluation option (specified by NEVAL) requires loss parameter/diffusion factor data. NSET1 sets of data are input, the set numbers being allocated according to the order in which they are input. Up to 4 sets may be input (see NDIFF).
NSET2	When NLOSS = 4, the loss coefficients at the station are determined as a fraction of the value at the trailing edge. Then, NSET2 sets of curves are input to define this fraction at a function of radius and meridional chord. Up to 2 sets may be input (see NM).
NREAD	If NREAD = 0, the initial streamline pattern estimate is generated by the program. If NREAD = 1, the initial streamline pattern estimate and also the DELF values are read in. (See DELF, R, X, XL.)
NPUNCH	Set NPUNCH = 0
NPLOT	Set NPLOT = 0
NPAGE	The maximum number of lines printed per page. An input value of zero will be reset to 60.
NTRANS	IF NTRANS = 0, no action is taken. If NTRANS = 1, relative total pressure loss coefficients will be modified to account for radial transfer of wakes. See Section V.11, Ref. .

NMIX — If NMIX = 0, no action is taken. If NMIX = 1, entropy, angular momentum, and total enthalpy distributions will be modified to account for turbulent mixing. See Section V.12, Ref. .

NMANY — The number of computing stations for which blade descriptive data is being generated by the analytic meanline section.

NSTPLT — If NSTPLT = 0, no action is taken. If NSTPLT = 1, a line-printer plot of the changes made to the midstreamline 'ℓ' coordinate is made for each computing station. If more than 59 passes through the iterative procedure have been made, then the plots will show the changes for the last 59 passes. The graph should decay approximately exponentially towards zero, indicating that the streamline locations are stabilizing. Decaying oscillations are equally acceptable, but, growing oscillations show the need for heavier damping in the streamline relocation calculations, that is, a decrease in RCONST.

NEQN — This item controls the selection of the form of momentum equation that will be used to compute the meridional velocity distributions at each computing station. There are two basic forms, and for each case, one may select not to compute the terms relating to blade forces. (See also Section V. 1, Ref. .

If NEQN = 0, the momentum equation involves the differential form of the continuity equations and hence ($1-M_m^2$) terms in the denominator. Streamwise gradients of entropy and angular momentum (blade forces) are computed within blades and at the blade edges (provided data that describe the blades are given). Elsewhere, streamwise entropy gradients only are included in a simpler form of the momentum equation, except that at the first and last computing station, all streamwise gradients are taken to be zero. This is generally the preferred option when computing stations are located within the blade rows.

If NEQN = 1, the momentum equation form is similar to that used when NEQN = 0, but angular momentum gradients (blade force terms) are nowhere computed. This generally is the preferred option when computing stations are located at the blade edges only.

If NEQN = 2, the momentum equation includes an explicit dVm/dm term instead of the ($1-M_m^2$)

denominator terms. All streamwise gradients (including blade force terms) are computed as for the case NEQN = 0. When computing stations are located within the blade rows, the results will generally be similar to those obtained with NEQN = 0, and solutions may be found that cannot be computed with NEQN = 0 due to high meridional Mach numbers.

If NEQN = 3, the momentum equation is similar to that used when NEQN = 1, but (as for the case NEQN = 1) no angular momentum gradients are computed. This may be used when computing stations are located only at the blade edges and high meridional Mach numbers preclude the use of NEQN = 1.

NLE NTE NSIGN	See the Analytic Section.
NWHICH	The numbers of each of the computing stations for which blade descriptive data is being generated by the analytic meanline section.
SCLFAC	Linear dimension scale factor , see page . An input value of zero will be reset to 12.0.
TOLNCE	Basic tolerance in iterative calculation scheme. An input value of zero will be reset to 0.001. (See discussion of tolerance scheme in Section VI, Ref. .)

VISK — Kinematic viscosity of gas (for annulus wall boundary layer calculations). An input value of zero will be reset to 0.00018. Units: LL/SCLFAC/SCLFAC/T.

SHAPE — Shape factor for annulus wall boundary layer calculations. An input value of zero will be reset to 0.7.

XSCALE, PSCALE, RLOW, PLOW — Set each equal to 0.0.

XMMAX — The square of the Mach number that appears in the equation for the streamline relocation relaxation factor is limited to be not greater than XMMAX. Thus, at computing stations where the appropriate Mach number is high enough for the limit to be imposed, a decrease in XMMAX corresponds to an increase in damping. If a value of zero is input, it is reset to 0.6.

RCONST — The constant in the equation for the streamline relocation relaxation factor. The value of 8.0 that the analysis yields is often too high for stability. If zero is input, it is reset to 6.0.

CONTR — The constant in the blade wake radial transfer calculations.

CONMX — The eddy viscosity for the turbulent mixing calculations. Units: $L^2/SCLFAC^2/T$.

FLOW	Compressor flow rate. Units: F/T.
SPDFAC	The speed of rotation of each computing station is SPDFAC times SPEED (I). The units for the product are revolutions/(60xT).
NSPEC	The number of points used to define a computing station. Must satisfy $2 \le$ NSPEC ≤ 21, and also the sum of NSPEC for all stations ≤ 150. If 2 points are used, the station is a straight line. Otherwise, a spline-curve is fitted through the given points.
XSTN, RSTN	The axial and radial coordinates, respectively, of a point defining a computing station. The first point must be on the hub and the last point must be on the casing. Units: L.
NDATA	Number of points defining conditions or blade geometry at a computing station. Must satisfy $0 \le$ NDATA ≤ 21, and also the sum of NDATA for all stations ≤ 100.
NTERP	If NTERP = 0, and NDATA ≥ 3, interpolation of the data at the station is by spline-fit. If NTERP = 1 (or NDATA ≤ 2), interpolation is linear point-to-point.
NDIMEN	If NDIMEN = 0, the data are input as a function of radius. If NDIMEN = 1, the data are input as a function of radius normalized with respect to tip radius. If NDIMEN = 2, the data are input as a function of distance along the computing station from the hub. If NDIMEN = 3, the data are input as a function of distance along the computing station normalized with respect to the total computing station length.
NMACH	If NMACH = 0, the subsonic solution to the continuity equation is sought. If NMACH = 1, the supersonic solution to the continuity equation is sought. This should only be used at stations where the relative flow angle is specified, that is, NWORK = 5, 6, or 7.
DATAC	The coordinate on the computing station, defined according to NDIMEN, where the following data items apply. Must increase monotonically. For dimensional cases, units are L.

DATA1	At Station 1 and if NWORK = 1, DATA1 is total pressure. Units: F/L/L. If NWORK = 0 and the station is at a blade leading edge, by setting NDATA ≠ 0, the blade leading edge may be described. Then DATA1 is the blade angle measured in the cylindrical plane. Generally negative for a rotor, positive for a stator. (Define the blade lean angle (DATA3) also). Units: A. If NWORK = 2, DATA1 is total enthalpy. Units: H/F.

If NWORK = 3, DATA1 is angular momentum (radius times absolute whirl velocity). Units: LL/SCLFAC/T.

If NWORK = 4, DATA1 is absolute whirl velocity. Units: L/SCLFAC/T.

If NWORK = 5, DATA1 is blade angle measured in the streamsurface plane. Generally negative for a rotor, positive for a stator. If zero deviation is input, it becomes the relative flow angle. Units: A.

If NWORK = 6, DATA1 is the blade angle measured in the cylindrical plane. Generally negative for a rotor, positive for a stator. If zero deviation is input, it becomes, after correction for streamsurface orientation and station lean angle, the relative flow angle. Units: A.

If NWORK = 7, DATA1 is the reference relative outlet flow angle measured in the streamsurface plane. Generally negative for a rotor, positive for a stator. Units: A.

DATA2 — At Station 1, DATA2 is total temperature. Units: D.

If NLOSS = 1, DATA2 is the relative total pressure loss coefficient. The relative total pressure loss is measured from the station that is NL1 stations removed from the current station, NL1 being negative to indicate an upstream station. The relative dynamic head is determined NL2 stations removed from the current station, positive for a downstream station, negative for an upstream station.

If NLOSS = 2, DATA2 is the isentropic efficiency of compression relative to conditions NL1 stations removed, NL1 being negative to indicate an upstream station.

If NLOSS = 3, DATA2 is the entropy rise relative to the value NL1 stations removed, NL1 being negative to indicate an upstream station. Units: H/F/D.

If NLOSS = 4, DATA2 is not used, but a relative total pressure loss coefficient is determined from the trailing edge value and curve set number NCURVE of the NSET2 families of curves. NL1 and NL2 apply as for NLOSS = 1.

If NWORK = 7, DATA 2 is the reference (minimum) relative total pressure loss coefficient. NL1 and NL2 apply as for NLOSS = 1.

DATA3	The blade lean angle measured from the projection of a radial line in the plane of the computing station, positive when the innermost portion of the blade precedes the outermost in the direction of rotor rotation. Units: A.
DATA4	The fraction of the periphery that is blocked by the presence of the blades.
DATA5	Cascade solidity. When a number of stations are used to describe the flow through a blade, values are only required at the trailing edge. (They are used in the loss coefficient re-estimation procedure, and to evaluate diffusion factors for the output.)
DATA6	If NWORK = 5 or 6, DATA6 is the deviation angle measured in the streamsurface plane. Generally negative for a rotor, positive for a stator. Units: A.
	If NWORK = 7, DATA6 is reference relative inlet angle, to which the minimum loss coefficient (DATA2) and the reference relative outlet angle (DATA7) correspond. Measured in the streamsurface plane and generally negative for a rotor, positive for a stator. Units: A.
DATA7	If NWORK = 7, DATA7 is the rate of change of relative outlet angle with relative inlet angle.
DATA8	If NWORK = 7, DATA8 is the relative inlet angle larger than the reference value at which the loss coefficient attains twice its reference value. Measured in the streamsurface plane. Units: A.

DATA9 — If NWORK = 7, DATA9 is the relative inlet angle smaller than the reference value at which the loss coefficient attains twice its reference value. Measured in the streamsurface plane. Units: A.

NWORK — If NWORK = 0, constant entropy, angular momentum, and total enthalpy exist along streamlines from the previous station. (If NMIX = 1, the distributions will be modified.)

If NWORK = 1, the total pressure distribution at the computing station is specified. Use for rotors only.

If NWORK = 2, the total enthalpy distribution at the computing station is specified. Use for rotors only.

If NWORK = 3, the absolute angular momentum distribution at the computing station is specified.

If NWORK = 4, the absolute whirl velocity distribution at the computing station is specified.

If NWORK = 5, the relative flow angle distribution at the station is specified by giving blade angles and deviation angles, both measured in the streamsurface plane.

If NWORK = 6, the relative flow angle distribution at the station is specified by giving the blade angles measured in the cylindrical plane, and the deviation angles measured in the streamsurface plane.

If NWORK = 7, the relative flow angle and relative total pressure loss coefficient distributions are specified by means of an off-design analysis procedure. "Reference", "stalling", and "choking" relative inlet angles are specified. The minimum loss coefficient varies parabolically with the relative inlet angle so that it is twice the minimum value at the "stalling" or "choking" values. A maximum value of 0.5 is imposed. "Reference" relative outlet angles and the rate of change of outlet angle with inlet angle are specified, and the relative outlet angle varies linearly from the reference value with the relative inlet angle. NLOSS should be set to zero.

NLOSS — If NLOSS = 1, the relative total pressure loss coefficient distribution is specified.

If NLOSS = 2, the isentropic efficiency (for compression) distribution is specified.

If NLOSS = 3, the entropy rise distribution is specified.

If NLOSS = 4, the total pressure loss coefficient distribution is specified by use of curve-set NCURVE of the NSET2 families of curves giving the fraction of final (trailing edge) loss coefficient.

NL1 — The station from which the loss(in whatever form NLOSS specifies) is measured, is NL1 stations removed from the station being evaluated. NL1 is negative to indicate an upstream station.

NL2 — When a relative total pressure loss coefficient is used to specify losses, the relative dynamic head is taken NL2 stations removed from the station being evaluated. NL2 may be positive, zero, or negative; a positive value indicates a downstream station, a negative value indicates an upstream station.

NEVAL — If NEVAL = 0, no action is taken.

If NEVAL > 0, curve-set number NEVAL of the NSET1 families of curve giving diffusion loss parameter as a function of diffusion factor will be used to re-estimate the relative total pressure loss coefficient. NLOSS must be 1, and NL1 and NL2 must specify the leading edge of the blade. See also NDEL.

If NEVAL 0, curve-set number NEVAL is used as NAVAL 0, except that the re-estimation is only made after the overall computation is completed (with the input losses). The resulting loss coefficients are displayed but not incorporated into the overall calculation. See also NDEL.

NCURVE — When NLOSS = 4, curve-set NCURVE of the NSET2 families of curves, specifying the fraction of trailing-edge ;pss coefficient as a function of meridional chord is used.

NLITER	When NEVAL > 0, up to NLITER re-estimations of the loss coefficient will be made at a given station during any one pass through the overall iterative procedure. Less than NLITER re-estimations will be made if the velocity profile is unchanged by re-estimating the loss coefficients. (See discussion of tolerance scheme in Section VI, Ref .)
NDEL	When NEVAL = 0, set NDEL to 0. When NEVAL $\neq 0$, and NDEL > 0, a component of the re-estimated loss coefficient is a shock loss. The relative inlet Mach number is expanded (or compressed) through a Prandtl-Meyer expansion on the suction surface, and NDEL is the number of points at which the Prandtl-Meyer angle is given. If NDEL = 0, the shock loss is set at zero. Must satisfy $0 \leq$ NDEL ≤ 21, and also the sum of NDEL for all stations ≤ 100.
NOUT1	Set NOUT1 = 0
NOUT2	Set NOUT2 = 0
NOUT3	This data item controls the generation of NASTRAN - compatible temperature and pressure difference output for use in subsequent blade stress analyses. For details of the triangular mesh that is used, see the Output Description in Section .

NOUT3 = XY, where

If X = 1, the station is at a blade leading edge.

If X = 2, the station is at a blade trailing edge.

If Y = 0, then both temperature and pressure data will be generated.

If Y = 1, then only pressure data will be generated.

If Y = 2, then only temperature data will be generated.

If NOUT3 = 0, the station may be between blade rows, or within a blade row for which output is required, depending upon the use of NOUT3 ≠ 0 elsewhere. See also description of NBLADE below.

NBLADE

This item is used in determining the pressure difference across the blade. The number of blades is | NBLADE |. If NBLADE is positive, "three-point averaging" is used to determine the pressure difference across each blade element. If NBLADE is negative, "four point averaging" is used. (See the Output Description in Section 1.14.3.2.) If NBLADE is input as zero, a value of +10 is used. At a leading edge, the value for the following station is used: elsewhere the value at a station applies to the interval upstream of the station. Thus by varying the sign of NBLADE, the averaging method used for the pressure forces may be varied for different axial segments of a blade row.

SPEED — This card is omitted if NDATA = 0. The speed of rotation of the blade. At a blade leading edge, it should be set to zero. The product SPDFAC times SPEED has units of revolutions/(T x 60).

DELC — The coordinate at which Prandtl-Meyer expansion angles are given. It defines the angle as a function of the dimensions of the leading edge station, in the manner specified by NDIMEN for the current, that is trailing edge station. Must increase monotonically. For dimensional cases, units are L.

DELTA — The Prandtl-Meyer expansion angles. A positive value implies expansion. If blade angles are given at the leading edge, the incidence angles are added to the value specified by DELTA. Units: A. (Blade angles are measured in the cylindrical plane.)

WBLOCK — A blockage factor that is incorporated into the continuity equation to account for annulus wall boundary layers. It is expressed as the fraction of total area at the computing station that is blocked. If NBL = 1, values (except at Station 1) are revised during computation, involving data items VISK and SHAPE.

BBLOCK, BDIST	A blockage factor is incorporated into the continuity equation that may be used to account for blade wakes or other effects. It varies linearly with distance along the computing station. BBLOCK is the value at mid-station (expressed as the fraction of the periphery blocked), and BDIST is the ratio of the value on the hub to the mid-value.
NDIFF	When NSET1 > 0, there are NDIFF points defining loss diffusion parameter as a function of diffusion factor. Must satisfy 1 ≤ NDIFF ≤ 15.
DIFF	The diffusion factor at which loss parameters are specified. Must increase monotonically.
FDHUB	Diffusion loss parameter at 10 per cent of the radial blade height.
FDMID	Diffusion loss parameter at 50 per cent of the radial blade height.
FDTIP	Diffusion loss parameter at 90 per cent of the radial blade height.
NM	When NSET2 > 0, there are NM points defining the fraction of trailing edge loss coefficient as a function of meridional chord. Must satisfy 1 ≤ NM ≤ 11.
NRAD	The number of radial locations where NM loss fraction/chord points are given. Must satisfy 1 ≤ NRAD ≤ 5.
TERAD	The fraction of radial blade height at the trailing edge where the following loss fraction/chord curve applies. If NRAD = 1, it has no significance.
DM	The location on the meridional chord where the loss fraction is given. Expressed as a fraction of meridional chord from the leading edge. Must increase monotonically.
WFRAC	Fraction of trailing edge loss coefficient that occurs at location DM.

DELF The fraction of the total flow that is to occur between the hub and each streamline. The hub and casing are included, so that the first value must be 0.0, and the last (NSTRM) value must be 1.0.

R Estimated streamline radius. (These data are input from hub to tip for the first station, from hub to tip for the second station, and so on.) Units: L.

X Estimated axial coordinate at intersection of streamline with computing station. Units: L.

XL Estimated distance along computing station from hub to intersection of streamline with computing station. Units: L.

II, JJ Station and streamline number. These are merely read in and printed out to give a check on the order of the cards.

1.14.3.2 AERODYNAMIC OUTPUT DATA

1. ANALYTIC MEANLINE SECTION

Printed output may be considered to consist of four sections; a printout of the input data, details of the blade sections on each streamsurface, a listing of quantities required for aerodynamic analysis, and details of the manufacturing sections determined on the constant-z planes. These are briefly described below. In the explanation which follows, parenthetical statements are understood to refer to the particular case of the double-circular-arc blade (ISECN = 2).

The input data printout includes all quantities read in, and is self-explanatory.

Details of the streamsurface blade sections are printed if IPRINT = 0 or 1. Listed first are the parameters defining the blade section. These are interpolated at the streamsurface from the tables read in. Then follow details of the blade section in "normalized" form. The blade section geometry is given for the section specified, except that the meridional projection of the chord is unity. For this section of the output, the coordinate origin is the blade leading edge. The following quantities are given: blade chord; stagger angle; camber angle; section area; location of the centroid of the section; second moments of area of the section about the centroid; orientation of the principal axes; and the principal second moments of area of the section about the centroid. Then are listed the coordinates of the camber line, the camber line angle, the section thickness, and the coordinates of the blade surfaces. NPOINT values are given.

A lineprinter plot of the normalized section follows. The scales for the plot are arranged so that the section just fills the page, so that the scales will generally differ from one plot to another. "Dimensional" details of the blade section are given next. The normalized data given previously is scaled to give a blade section as defined by IFCORD and CORD. For this section of the output, the coordinates are with respect to the blade stacking axis. The following quantities are given: blade chord; radius and location of center of leading (and trailing) edge(s); section area, the second moments of area of the section about the centroid and the principal second moments of area of the section about the centroid. The coordinates of NPOINT points on the blade surfaces are then listed, followed by the coordinates of 31 points distributed at (roughly) six degree intervals around the leading (and trailing) edges. Finally, the coordinates of the blade surfaces and points around the leading (and trailing) edge(s) is (are) shown in Cartesian form.

The quantities required for aerodynamic analysis are printed at all computing stations specified by the IFANGS parameter. The radius, blade section angle, blade lean angle, blade blockage, and relative angular location of the camber line are printed at each streamsurface intersection with the particular computing station. The blade section angle is measured in the cylindrical plane, and the blade lean angle is measured in the constant-axial-coordinate plane.

Details of the manufacturing sections are printed if IPRINT = 0 or 2. At each value of z specified by ZINNER, ZOUTER, and NZ, section properties and coordinates are given. The origin for the coordinates is the blade stacking axis. The following quantities are given: section area; the location of the centroid of the section; the second moments of area of the section about the centroid; the principal second moments of area of the section about the centroid; the orientation of the principal axes; and the section torsional constant. Then the coordinates of NPOINT points on the blade section surfaces are listed, followed by 31 points around the leading (and trailing) edge(s).

If NAERO = 1, the additional input and output required for, and generated by, the interface are also printed. (Apart from the input data printout, this is the only printed output when IPRINT = 3.)

If the NASTRAN parameter PGEOM ≠ -1 then cards are punched that may be used as input for the NASTRAN stress analysis program. For the purpose of stress analysis, the blade is divided into a number of triangular elements, each defined by three grid points. The intersections between computing stations and streamsurfaces are used as the grid points and the grid points and element numbering scheme adopted is illustrated in Figure 1.

TheNASTRAN input data format includes cards identified by the codes GRID, CTRIA2 and PTRIA2. The data are fully described in Reference 7, but briefly, the GRID cards each define a grid point number and give the coordinates at the grid point, the CTRIA2 cards each define an element in terms of the three appropriate grid points (by number, and in a significant order), the PTRIA2 cards each give an average blade thickness for an element.

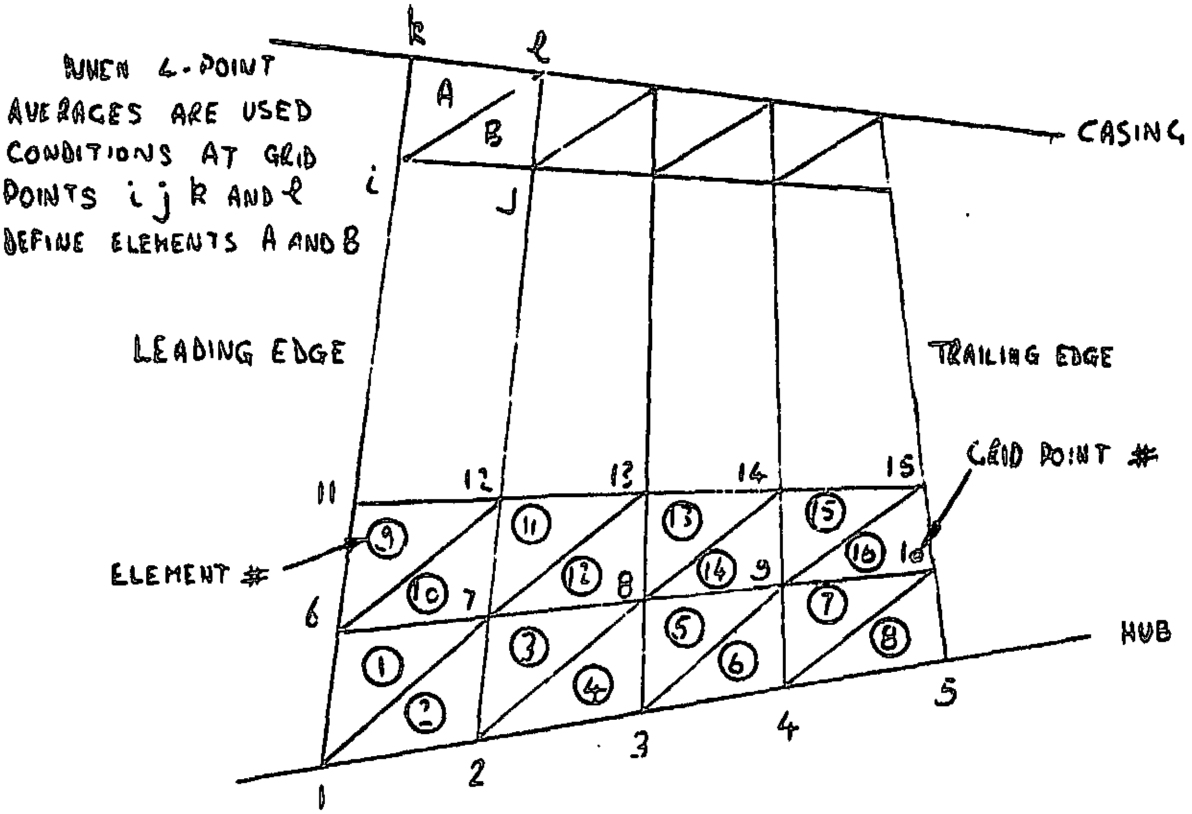

Figure 1. NASTRAN Grid Point and Element Numbering Scheme.

2. AERODYNAMIC SECTION

a. Regular Printed Output

The input data are first printed out in its entirety, and the results for each running point follow. The output is generally self-explanatory and definitions are given here for some derived quantities. Tabular output is generally not started on a page unless it can be completed on the same page, according to the maximum number of lines permitted by the input variable NPAGE.

The results of each running point are given under a heading giving the running point number. Any diagnostics generated during the calculation will appear first under the heading. (Diagnostics are described in the following section.) Then, a station-by-station print out follows for each station through to the last station, or to the station where the calculation failed, if this occurred. One or more diagnostics will indicate the reason for the failure, in this event. Included in the meshpoint coordinate data is the distance along the computing station from the hub to the interception of the streamline with the station (L), and the station lean angle (GAMA). Where the radius of curvature of a streamline is shown as zero, the streamline has no curvature. The whirl angle is defined by

$$\tan \alpha = \frac{V_\theta}{V_m} \tag{1}$$

For stations within a blade, or at a blade trailing edge, a relative total pressure loss coefficient is shown. The loss of relative total pressure is computed from the station defined by the input variable NL1. If a loss coefficient was used in the input for the station (NLOSS = 1 or 4, or NWORK = 7), the input variable NL2 defines the station where the normalizing relative dynamic head is taken; otherwise, it is taken at the station defined by NL1. If the cascade solidity is given as anything but zero, it is used in the determination of diffusion factors. The following definition is used:

$$D = 1 - \frac{V_{2r}}{V_{1r}} + \frac{V_{\theta_{1r}} \quad V_{\theta_{2r}}}{2\sigma V_{1r}} \tag{2}$$

Inlet conditions (subscript 1) are taken from the station defined by the input variable NL1.

The last term in Equation 2 is multiplied by -1 if the blade speed is greater than zero, or the blade speed is zero and the preceding rotating blade row has negative rotation. This is necessary because relative whirl angles are (generally) negative for rotor blades and for stator blades that follow a rotor having "negative" wheel speed. Incidence and deviation angles are treated in the same way, so that positive and negative values have their conventional significance for all blades.

If annulus wall boundary layer computations were made (NBL = 1), details are shown for each station. Then, an overall result is given, including a statement of the number of passes that have been performed and whether the calculation is converged, unconverged, or failed. When the calculation is unconverged, the number of mesh points where the meridional velocity component has not remained constant to within the specified tolerance (TOLNCE) on the last two passes is shown as IVFAIL. Similarily, the number of streamtubes, defined by the hub and each streamline in turn, where the fraction of the flow is not within the same tolerance of the target value is shown as IFFAIL. If these numbers are small, say less than 10% of the maximum possible values, the results may generally be used. Otherwise, the computation should be rerun, either for a greater number of passes, or with modified relaxation factor constants. The default option relaxation constants will generally be satisfactory but may need modification for some cases. If insufficient damping is specified by the constants, the streamlines generated will tend to oscillate and this may be detected by observing a relatively small radius of curvature for the mid-passage streamline that also changes sign from one station to the next. This may be corrected by rerunning the problem (from scratch) with a lower value input for RCONST, say, of 4.0 instead of 6.0. When the damping is excessive, the velocities will tend to remain constant while the streamlines will not adjust rapidly to the correct locations. This will be indicated by a small IVFAIL and a relatively large IFFAIL. For optimum program performance, RCONST should be increased, and the streamline pattern generated thus far could be used as a starting point. The second constant XMMAX (the maximum value of the square of Mach number used in the relaxation factor) is incorporated so that in high subsonic or supersonic cases the damping does not decrease unacceptably. The default value of 0.6 may be too low for rapid program convergence in some such cases.

If the generation of blade pressure load data for the NASTRAN program is specified (by the input variable NOUT3), a self-explanatory printout is also made. The blade element numbering scheme is the same as that incorporated into both blading sections of the program, and illustrated in Figure 1.

If the loss coefficient re-estimation routine has been used for any bladerow(s) (NEVAL $\neq$ 0), a printout summarizing the computations made will follow. A heading indicating whether the re-estimation was incorporated into the overall iterative procedure or whether it was merely made "after the event" is first printed. Then follows a self-explanatory tabulation of various quantities involved in the redetermination of the loss coefficient on each streamline.

b. Diagnostic Printed Output

The various diagnostic messages that may be produced by the aerodynamic section of the program are all shown. Where a computed value will occur, "x" is shown here.

JOB STOPPED - TOO MUCH INPUT DATA

The above message will occur if the sum of NSPEC or NDATA or NDEL for all stations is above the permitted limit. Execution ceases.

STATIC ENTHALPY BELOW LIMIT AT xxx. xxxxxExxx

The output routine (subroutine UD0311) calculates static enthalpy at each meshpoint when computing the various output parameters and this message will occur if a value below the limit (HMIN) occurs. The limiting value will be used, and the results printed become correspondingly arbitrary. HMIN is set in the Program UD03AR and should be maintained at some positive value well below any value that will be validly encountered in calculation.

PASSxxx STATIONxxx STREAMLINExxx PRANDTL-MEYER FUNCTION NOT CONVERGED - USE INLET MACH NO

The loss coefficient re-estimation procedure involves iteratively solving for the Mach number in the Prandtl-Meyer function. If the calculation does not converge in 20 attempts, the above message is printed, and as indicated, the Mach number following the expansion (or compression) is assumed to equal the inlet value. (The routine only prints output following the completion of all computations and printing of the station-by-station output data.)

PASSxxx STATIONxxx ITERATIONxxx STREAMLINExxx
MERIDIONAL VELOCITY UNCONVERGED VM = xx. xxxxxxExx
VM(OLD) = xx. xxxxxxExx

For "analysis" cases, that is at stations where relative flow angle is specified, the calculation of meridional velocity proceeds iteratively at each meshpoint from the mid-streamline to the case and then to the hub. The variable LPMAX (set to 10 in Subroutines UD0308 and UD0326) limits the maximum number of iterations that may be made at a streamline without the velocity being converged before the calculation proceeds to the next streamline. The above message will occur if all iterations are used without achieving convergence, and the pass number is greater than NFORCE. Convergence is here defined as occurring when the velocity repeats to within TOLNCE/5.0, applied nondimensionally. No other program action occurs.

PASSxxx STATIONxxx MOMENTUM AND/OR CONTINUITY UNCONVERGED W/W SPEC = xx.xxxxx VM/VM (OLD) HUB = xx.xxxxxMID=xx.xxxxx TIP = xx.xxxxx

If, following completion of all ITMAX iterations permitted for the flow rate or meridional velocity, the simultaneous solution of the momentum and continuity equations profile is unconverged, and the pass number is greater than NFORCE, the above message occurs. Here converged means that the flow rate equals the specified value, and the meridional velocity repeats, to within TOLNCE/5.0, applied nondimensionally. If loss coefficient re-estimation is specified (NEVAL > 0), an additional iteration is involved, and the tolerance is halved. No further program action occurs.

PASSxxx STATIONxxx VM PROFILE NOT CONVERGED WITH LOSS RECALC VM NEW/VM PREV HUB = xx.xxxxxx MID = xx.xxxxxx CASE = xx.xxxxxx

When loss re-estimation is specified (NEVAL > 0), up to NLITER solutions to the momentum and continuity equations are completed, each with a revised loss coefficient variation. If, when the pass number is greater than NFORCE, the velocity profile is not converged after the NLITER cycles of calculation have been performed, the above message is issued. For convergence, the meridional velocities must repeat to within TOLNCE/5.0, applied nondimensionally. No further program action occurs.

A further check on the convergence of this procedure is to compare the loss coefficients used on the final pass of calculation, and thus shown in the station-by-station results, with those shown in the output from the loss coefficient re-estimation routine, which are computed from the final velocities, etc.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx STATIC ENTHALPY BELOW LIMIT IN MOMENTUM EQUATION AT xxx. xxxxxExxx

The static enthalpy is calculated (to find the static temperature) during computation of the "design" case momentum equation, that is, when whirl velocity is specified. If a value lower than HMIN (see discussion of second diagnostic message) is produced, the limiting value is inserted. If this occurs when IPASS > NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed out through to this station.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx LOOPxxx STATIC H IN MOMENTUM EQUN. BELOW LIMIT AT xxx. xxxxxExxx

This corresponds to the previous message, but for the "analysis" case. For failure, it must occur on the final iteration and loop.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx MERIDIONAL MACH NUMBER ABOVE LIMIT AT xxx. xxxxxExx

When Subroutine UD0308 is selected (NEQN = 0 or 1), the meridional Mach number is calculated during computation of the design momentum equation, and a maximum value of 0.99 is permitted. If a higher value is calculated, the limiting value is inserted. If this occurs when IPASS > NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed through to this station.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx LOOPxxx MERIDIONAL MACH NUMBER ABOVE LIMIT AT xxx. xxxxxExxx

This corresponds to the previous message, but for the "analysis" case. For failure, it must occur at the final iteration and loop.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx MOMENTUM EQUATION EXPONENT ABOVE LIMIT AT xxx. xxxxxExxx

An exponentiation is performed during the computation of the design case momentum equation, and the maximum value of the exponent is limited to 88.0. If this substitution is required when IPASS > NFORCE, the above message is printed. If it occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed through to this station.

PASSxxx STATIONxxx ITERATIONSxxx STREAMLINExxx
(MERIDIONAL VELOCITY) SQUARED BELOW LIMIT AT
xxx.xxxxxExxx.

If a meridional velocity, squared, of less than 1.0 is calculated during computation of the design-case momentum equation, this limit is imposed. If this occurs when IPASS>NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed out through to this station.

PASSxxx STATIONxxx ITERATIONxxx STREAMLINExxx LOOPxxx
(MERIDIONAL VELOCITY) SQUARED BELOW LIMIT AT
xxx.xxxxxExxx.

This corresponds to the previous message, but for the "analysis" case. For failure, it must occur on the last iteration and loop.

PASSxxx STATIONxxx ITERATIONxxx STREAMTUBExxx
STATIC ENTHALPY BELOW LIMIT IN CONTINUITY EQUATION
AT xxx.xxxxxExxx.

The static enthalpy is calculated during computation of the continuity equation. If a value lower than HMIN (see discussion of second diagnostic message) is produced, the limiting value is imposed. If this occurs when IPASS>NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed out through to this station.

PASSxxx STATIONxx ITERATIONxxx STREAMLINExxx
MERIDIONAL VELOCITY BELOW LIMIT IN CONTINUITY AT
xxx.xxxxxExxx.

If a meridional velocity of less than 1.0 is calculated when the velocity profile is incremented by the amount estimated to be required to satisfy continuity, this limit is imposed. If this occurs when IPASS > NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed through to this station.

PASSxxx STATIONxxx ITERATIONxxx OTHER CONTINUITY
EQUATION BRANCH REQUIRED

If when IPASS>NFORCE, a velocity profile is produced that corresponds to a subsonic solution to the continuity equation when a supersonic solution is required, or vice versa, the above message is printed. If this occurs on the final iteration, failure is deemed to have occurred, calculation ceases, and results are printed out through to this station.

PASSxxx STATIONxxx ITERATIONxxx STREAMLINExxx
MERIDIONAL VELOCITY GREATER THAN TWICE MID VALUE

During integration of the "design" momentum equations, no meridional velocity is permitted to be greater than twice the value on the mid-streamline. If this occurs when IPASS>NFORCE, the above message is printed. If this occurs on the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed through to this station. In the event that this limit interferes with a valid velocity profile, the constants that appear on cards 08.272, 08.279, 26.229, and 26.236 may be modified accordingly. Note that as the calculation is at this point working with the square of the meridional velocity, the constant for a limit of 2.0 times the mid-streamline value, for instance, appears as 4.0.

PASSxxx STATIONxxx ITERATIONxxx STREAMLINExxx
LOOPxxx MERIDIONAL VELOCITY ABOVE LIMIT xxxxxExx
LIMIT = xxxxxExx.

During integration of the "analysis" momentum equations, no meridional velocity is permitted to be greater than three times the value on the mid-streamline. If this occurs when IPASS>NFORCE, the above message is printed. If this occurs on the final loop of the final iteration, the calculation is deemed to have failed, calculation ceases, and results are printed through to this station. In the event that the limit interferes with a valid velocity profile, the constants that appear on cards 08.398, 08.409, 26.323, 26.334, and 26.329 may be modified accordingly. In each case except that of the last card noted, the program is working with meridional velocity squared, so that a limit of, for instance, 3.0 times the mid-streamline value appears as 9.0.

PASSxxx STATIONxxx STREAMLINExxx LIMITING MERIDIONAL
VELOCITY SQUARED = xxxxxExx.

In the Subroutine UD0308 (NEQN= 0 or 1), a maximum permissable meridional velocity (equal to the speed of sound) is established for each streamline at the beginning of each pass. The calculation yields the square of the velocity, and if a value of less than 1.0 is obtained, a value of 6250000.0 is superimposed (which corresponds to a meridional velocity of 2500.0). If this occurs when IPASS>NFORCE, the above message is printed, and the calculation is deemed to have failed. Calculation ceases after the station computations are made, and results are printed through to this station.

PASSxxx STATIONxxx ITERATIONxxx STREAMLINExxx
MERIDIONAL VELOCITY ABOVE SOUND SPEED VM =
xxxx.xx A = xxxx.xx.

In Subroutine UD0308 (NEQN = 0 or 1), no meridional velocity is permitted to be larger than the speed of sound. The above message will occur if this limit is violated during integration of the "design" momentum when IPASS > NFORCE. If the limit is violated at any point when IPASS > NFORCE and on the last permitted iteration (last permitted loop also in the case of the "analysis" momentum equation), the calculation is deemed to have failed. Calculation ceases, and the results are printed through to this station.

MIXING CALCULATION FAILURE NO. n

The above message occurs when flow mixing calculations are specified, and the computation fails. The overall calculation is halted, and results are printed through to the station that is the upstream boundary for the mixing interval in which the failure occurred. The integer n takes on different values to indicate the specific problems as follows.

n = 1 In solving for the static pressure distribution at the upstream boundary of each mixing step, the average static enthalpy is determined in each streamtube (defined by an adjacent pair of streamlines). This failure indicates that a value less than HMIN was determined.

n = 2 Calculation of the static pressure distribution at the upstream boundary of the mixing step is iterative. This failure indicates that the procedure was not converged after 10 iterations.

n = 3 The static enthalpy on each streamline at the mixing step upstream boundary is determined from the static pressure and entropy there. This failure indicates that a value less than HMIN was determined.

n = 4 The axial velocity distribution at the mixing step upstream boundary is determined from the total enthalpy, static enthalpy, and tangential velocity distributions. This failure indicates that a value less than VMIN was determined.

n = 5 In solving for the static pressure distribution at the downstream boundary of each mixing step, the average static enthalpy is determined in each streamtube (defined by an adjacent pair of streamlines). This failure indicates that a value less than HMIN was determined.

n = 6 Calculation of the static pressure distribution at the downstream boundary of the mixing step is iterative. This failure indicates that the procedure was not converged after 10 iterations.

n = 7 The static enthalpy distribution at the mixing step downstream boundary is found from the total enthalpy, axial velocity, and tangential velocity distributions. This failure indicates that a value less than HMIN was determined.

n = 8 In order to satisfy continuity, the static pressure level at the mixing step downstream boundary is iteratively determined. This failure indicates that after 15 attempts, the procedure was unconverged.

c. Aerodynamic Load and Temperature Output

Four output options may result in cards being produced by the aerodynamic section of the program. Use of the input item NOUT3 gives "PLOAD2 and Temperature - Cards" punched in a format compatible with the NASTRAN stress program. For the purposes of stress analysis, the blade is taken to be composed of a number of triangular elements. Two such elements are formed by the quadrilateral defined by two adjacent streamlines and two adjacent computing stations. The way that each quadrilateral is divided into two triangles, and the element numbering scheme that is used, are illustrated in Figure 1. The pressure difference for each element is given by an average of either three or four values at surrounding meshpoints. The pressure difference at each meshpoint is computed from the equation

$$\Delta p = \frac{2\pi r \rho}{N}\left\{\sin\beta\cos\beta\, g\, J\, T \frac{dS}{dm} + \frac{V_m}{r}\frac{d}{dm}(rV_\theta)\right\} \quad (3)$$

and as follows. At the blade leading edge a forward difference is used to determine the meridional gradients. At the blade trailing edge the pressure difference is taken to be zero. At stations with the bladerow (following a leading edge), mean central differences are used to determine the meridional gradients. When the input item NBLADE is positive (or zero) for a particular blade axial segment, then three-point averaging is used. For instance, for element number 1 in Figure 1, pressure differences at grid points 1, 6, and 7 would be used. If NBLADE is negative, four-point averaging is used. For instance for element number 1, pressure differences at grid points 1, 2, 6 and 7 would be used. The same average would also apply to element number 2. Relative total temperatures are output at the grid points on the blade. A TEMPD value is also output using the average temperature at the blade root for the grid points on the rest of the structure.

USER'S MANUAL UPDATES

1.14.4 Sample Problem

The Static Aerothermoelastic Design/Analysis procedure for the bladed disc of an axial flow compressor rotor is illustrated by this sample problem. As explained in Section 1.14.3 the Design and Analysis steps are carried out only at the design operating point of the compressor bladed disc - the "as manufactured" structure being only "analyzed" at off-design operating points. The Design or Analysis mode of the Displacement Rigid Format 16 is selected by the PARAMETER SIGN. The present example uses the Design mode (SIGN = -1) of the rigid format.

The finite element model of a sector of the bladed disc is shown in Figure 1. The blade grid is specified in the Basic coordinate system located on the axis of rotation as shown in the figure. The hub is specified in a cylindrical coordinate system with the origin and the z-axis respectively coincident with the origin and the x-axis of the Basic system. A schematic of the aerodynamic model used is shown in Figure 2 wherein the aerodynamic mesh is generated by the intersection of 4 streamlines and 5 computing stations, three of which lie on the blade. Two additional computing stations have been used for the aerodynamic section (see Section 1.14.3.1), one each upstream and downstream of the blade to enable flow description in these regions. The NASTRAN deck for the use of the rigid format is listed in Figure 3.

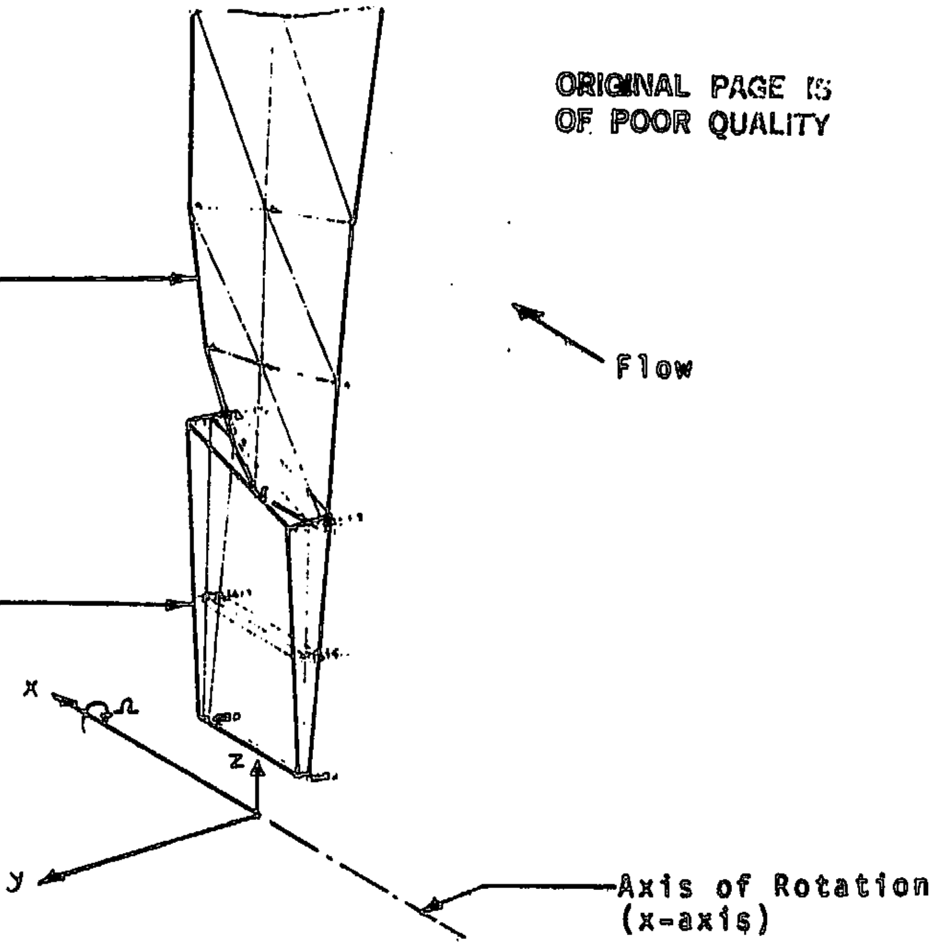

Figure 1. Finite Element Model of an Axial Flow Compressor Bladed Disc Sector, and the Basic Coordinate System

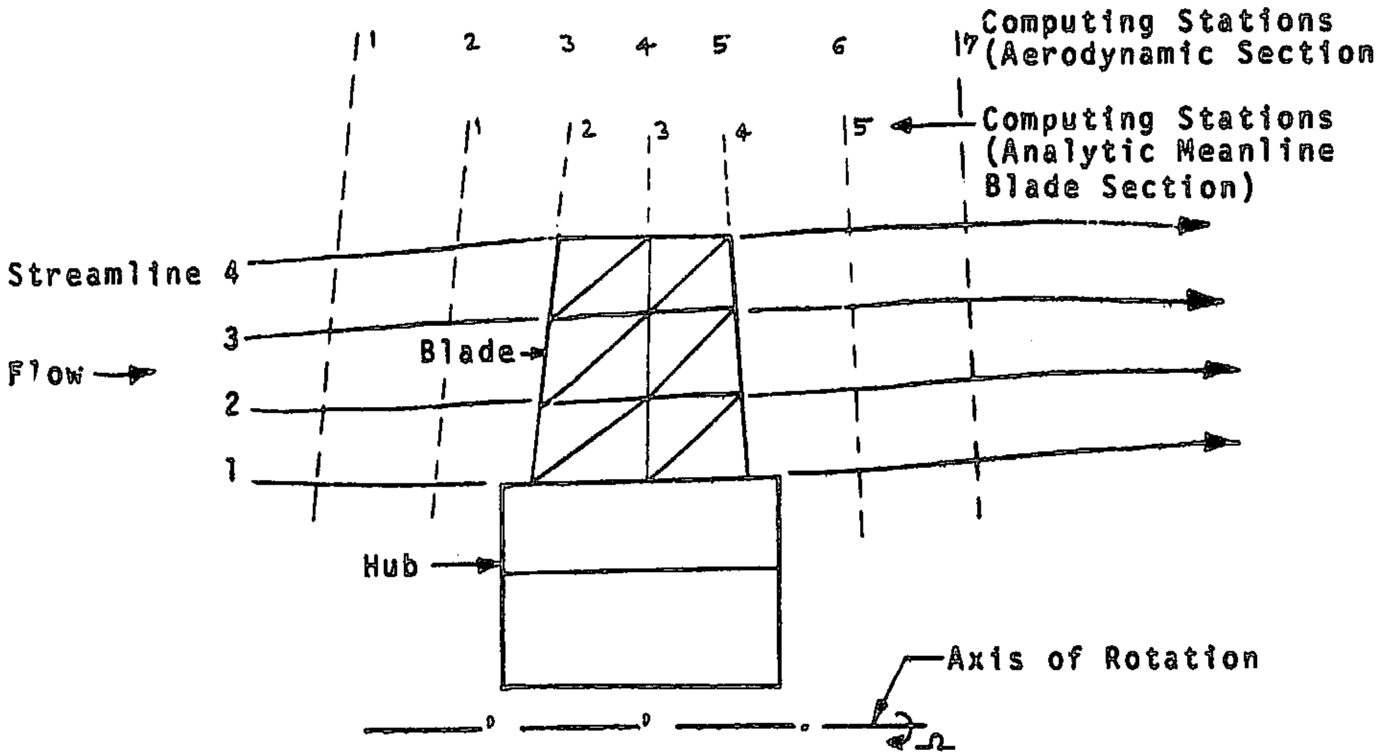

Figure 2. Aerodynamic Grid (See Section 1.15.3, User's Manual)

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID     NASA , L[illegible]
APP    DISPLACEMENT
SOL 16
TIME 10
DIAG 14
CEND
```


Figure 3. NASTRAN deck for Static Aerothermoelastic Design/Analysis

DESIGN OF BLADE

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      TITLE = NASA LEWIS, BLADED SHROUDED DISK ANALYSIS
  2      SUBTITLE = EXAMPLE SINGLE-STAGE DESIGN OF ROTOR BLADE
  3      LABEL = DESIGN OF BLADE
  4      SPC = 500
  5      MPC = 600
  6      LOAD = 1
  7      DISP = ALL
  8      SPCF = ALL
  9      OLOAD = ALL
 10      STRESS = ALL
 11      FORCE  = ALL
 12      SUBCASE 1
 13      LABEL = LINEAR SOLUTION OF ROTOR BLADE
 14      SUBCASE 2
 15      LABEL = NONLINEAR SOLUTION OF ROTOR BLADE
 16      GPFORCE=ALL
 17      OUTPUT(PLOT)
 18      PLOTTER NASTPLT, MODEL D,1
 19      PAPER SIZE 12.0 X 11.5
 20      SET 1 = ALL
 21      ORTHOGRAPHIC PROJECTION
 22      MAXIMUM DEFORMATION 0.5
 23      AXES X,Y,Z
 24      VIEW 0.0,0.0,0.0
 25      FIND SCALE, ORIGIN 1, SET 1
 26      PLOT SET 1, ORIGIN 1, LABEL
 27      AXES Y,Z,X
 28      FIND SCALE, ORIGIN 2, SET 1
 29      PLOT SET 1, ORIGIN 2, LABEL
 30      AXES Z,X,Y
 31      FIND SCALE, ORIGIN 3, SET 1
 32      PLOT SET 1, ORIGIN 3, LABEL
 33      AXES X,Y,Z
 34      VIEW 34.27,23.17,0.0
 35      FIND SCALE, ORIGIN 4, SET 1
 36      PLOT STATIC DEFORMATION 0,   SET 1, ORIGIN 4, LABEL
 37      AXES Z,X,Y
 38      VIEW 0.0,0.0,0.0
 39      FIND SCALE, ORIGIN 5, SET 1
 40      PLOT STATIC DEFORMATION 0,   SET 1, ORIGIN 5, LABEL
 41      BEGIN BULK
```

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DESIGN OF BLADE

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CHEXA1	201	1	101	103	104	108	113	115	&CH1
2-	&CH1	116	120							
3-	CHEXA1	202	1	108	104	105	107	120	116	&CH2
4-	&CH2	117	119							
5-	CHEXA1	203	1	121	123	124	128	101	103	&CH3
6-	&CH3	104	108							
7-	CHEXA1	204	1	128	124	125/	127	108	104	&CH4
8-	&CH4	105	107							
9-	CORD2C	1		0.0	0.0	0.0	1.0	0.0	0.0	&CD1
10-	&CD1	0.	0.	1.						
11-	CTRIA2	1	2000	1	5	4				
12-	CTRIA2	2	2000	1	2	5				
13-	CTRIA2	3	2005	2	6	5				
14-	CTRIA2	4	2005	2	3	6				
15-	CTRIA2	5	2010	4	8	7				
16-	CTRIA2	6	2010	4	5	8				
17-	CTRIA2	7	2015	5	9	8				
18-	CTRIA2	8	2015	5	6	9				
19-	CTRIA2	9	2020	7	11	10				
20-	CTRIA2	10	2020	7	8	11				
21-	CTRIA2	11	2025	8	12	11				
22-	CTRIA2	12	2025	8	9	12				
23-	DTI	ALGDB	0	0	0	0	0	0	0	&ALG01
24-	&ALG01	ENDREC								
25-	DTI	ALGDB	1	NASA LEWIS EXPERIMENTAL FAN				ENDREC		
26-	DTI	ALGDB	2	1	1	0	0	ENDREC		
27-	DTI	ALGDB	3	GRID GENERATION ENDREC						
28-	DTI	ALGDB	4	4	5	3	4	30	43	&ALG41
29-	&ALG41	2	0	2	1	0	3	0	0	&ALG42
30-	&ALG42	2	4	1	ENDREC					
31-	DTI	ALGDB	5	4.384	10.0	1.0	.0	11.0	ENDREC	
32-	DTI	ALGDB	6	2	0	ENDREC				
33-	DTI	ALGDB	7	-2.0	3.60	ENDREC				
34-	DTI	ALGDB	8	-2.0	10.04	ENDREC				
35-	DTI	ALGDB	9	3.6	.0	ENDREC				
36-	DTI	ALGDB	10	5.5	.0	ENDREC				
37-	DTI	ALGDB	11	7.4	.0	ENDREC				
38-	DTI	ALGDB	12	10.04	.0	ENDREC				
39-	DTI	ALGDB	13	4	1	ENDREC				
40-	DTI	ALGDB	14	-.898	3.8	ENDREC				
41-	DTI	ALGDB	15	-.763	5.5	ENDREC				
42-	DTI	ALGDB	16	-.629	7.4	ENDREC				
43-	DTI	ALGDB	17	-.424	10.0	ENDREC				
44-	DTI	ALGDB	18	3.8	.0	ENDREC				
45-	DTI	ALGDB	19	5.5	.0	ENDREC				
46-	DTI	ALGDB	20	7.4	.0	ENDREC				
47-	DTI	ALGDB	21	10.	.0	ENDREC				
48-	DTI	ALGDB	22	4	1	ENDREC				

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
51-	DTI	ALGDB	25	.0	7.4	ENDREC				
52-	DTI	ALGDB	26	.0	10.	ENDREC				
53-	DTI	ALGDB	27	4.0	.0	ENDREC				
54-	DTI	ALGDB	28	5.5	.0	ENDREC				
55-	DTI	ALGDB	29	7.4	.0	ENDREC				
56-	DTI	ALGDB	30	10.	.0	ENDREC				
57-	DTI	ALGDB	31	4	1	ENDREC				
58-	DTI	ALGDB	32	.898	4.2	ENDREC				
59-	DTI	ALGDB	33	.780	5.5	ENDREC				
60-	DTI	ALGDB	34	.629	7.4	ENDREC				
61-	DTI	ALGDB	35	.424	10.	ENDREC				
62-	DTI	ALGDB	36	4.2	.0	ENDREC				
63-	DTI	ALGDB	37	5.5	.0	ENDREC				
64-	DTI	ALGDB	38	7.4	.0	ENDREC				
65-	DTI	ALGDB	39	10.	.0	ENDREC				
66-	DTI	ALGDB	40	2	0	ENDREC				
67-	DTI	ALGDB	41	2.0	4.4	ENDREC				
68-	DTI	ALGDB	42	2.0	10.04	ENDREC				
69-	DTI	ALGDB	43	4.4	.0	ENDREC				
70-	DTI	ALGDB	44	5.5	.0	ENDREC				
71-	DTI	ALGDB	45	7.4	.0	ENDREC				
72-	DTI	ALGDB	46	10.04	.0	ENDREC				
73-	DTI	ALGDB	47	1.0	-38.1	32.0	.0	.0	.01615	&ALG471
74-	&ALG471	ENDREC								
75-	DTI	ALGDB	48	.0980	.01559	.56	1.796	.04722	-.02302	&ALG481
76-	&ALG481	ENDREC								
77-	DTI	ALGDB	49	2.0	-45.0	-4.6	.0	.0	.01243	&ALG491
78-	&ALG491	ENDREC								
79-	DTI	ALGDB	50	.0735	.01391	.54	1.851	.00722	-.02946	&ALG501
80-	&ALG501	ENDREC								
81-	DTI	ALGDB	51	3.0	-53.2	-42.0	.0	.0	.00912	&ALG511
82-	&ALG511	ENDREC								
83-	DTI	ALGDB	52	.036	.00566	.49	1.864	.00077	-.00689	&ALG521
84-	&ALG521	ENDREC								
85-	DTI	ALGDB	53	4.0	-66.5	-59.6	.0	.0	.00482	&ALG531
86-	&ALG531	ENDREC								
87-	DTI	ALGDB	54	.0268	.00429	.48	1.863	-.02667	.01423	&ALG541
88-	&ALG541	ENDREC								
89-	DTI	ALGDB	55	1	5	1	2	2	4	&ALG551
90-	&ALG551	ENDREC								
91-	DTI	ALGDB	56	1.0	16042.8	ENDREC				
92-	DTI	ALGDB	57	0	0	10	ENDREC			
93-	DTI	ALGDB	58	1	0	0	4	-1	-1	&ALG581
94-	&ALG581	0	1	0	0	0	0	0	-43	&ALG582
95-	&ALG582	ENDREC								
96-	DTI	ALGDB	59	.0	.0	ENDREC				
97-	DTI	ALGDB	60	8	0	0	1	-2	-2	&ALG601
98-	&ALG601	-1	0	0	2	0	0	20	-43	&ALG602
99-	&ALG602	ENDREC								
100-	DTI	ALGDB	61	4.20	.05	ENDREC				

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DESIGN OF BLADE

```
                                   S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT         .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
  101-        DTI       ALGDB   62      4.62    .05     ENDREC
  102-        DTI       ALGDB   63      5.50    .05     ENDREC
  103-        DTI       ALGDB   64      6.50    .05     ENDREC
  104-        DTI       ALGDB   65      7.400   .05     ENDREC
  105-        DTI       ALGDB   66      8.400   .05     ENDREC
  106-        DTI       ALGDB   67      9.500   .05     ENDREC
  107-        DTI       ALGDB   68      10.00   .05     ENDREC
  108-        DTI       ALGDB   69      .0      ENDREC
  109-        DTI       ALGDB   70      .00     .00     ENDREC
  110-        DTI       ALGDB   71      .25     .25     ENDREC
  111-        DTI       ALGDB   72      .50     .50     ENDREC
  112-        DTI       ALGDB   73      .75     .75     ENDREC
  113-        DTI       ALGDB   74      1.00    1.00    ENDREC
  114-        DTI       ALGDB   75      .0      .0      .5      ENDREC
  115-        DTI       ALGDB   76      AERODYNAMIC ANALYSIS OF NASA LEWIS BLADEENDREC
  116-        DTI       ALGDB   77      .0      .0      .0      .0      ENDREC
  117-        DTI       ALGDB   78      7       4       0       40      0       0       &ALG781
  118-        &ALG781   0       1       1       0       0       0       0       0       &ALG782
  119-        &ALG782   0       3       0       0       3       5       1       ENDREC
  120-        DTI       ALGDB   79      3       4       5       ENDREC
  121-        DTI       ALGDB   80      .0      .0      .0      .001    ENDREC
  122-        DTI       ALGDB   81      1.0     1.0     4.0     .0      .7      8.0     &ALG811
  123-        &ALG811   ENDREC
  124-        DTI       ALGDB   82      .0      .0      ENDREC
  125-        DTI       ALGDB   83      73.146  1.0     ENDREC
  126-        DTI       ALGDB   84      2       ENDREC
  127-        DTI       ALGDB   85      -4.0    3.25    ENDREC
  128-        DTI       ALGDB   86      -4.0    10.04   ENDREC
  129-        DTI       ALGDB   87      2       ENDREC
  130-        DTI       ALGDB   88      -2.0    3.6     ENDREC
  131-        DTI       ALGDB   89      -2.0    10.04   ENDREC
  132-        DTI       ALGDB   90      4       ENDREC
  133-        DTI       ALGDB   91      -.898   3.8     ENDREC
  134-        DTI       ALGDB   92      -.763   5.5     ENDREC
  135-        DTI       ALGDB   93      -.629   7.4     ENDREC
  136-        DTI       ALGDB   94      -.424   10.0    ENDREC
  137-        DTI       ALGDB   95      4       ENDREC
  138-        DTI       ALGDB   96      .0      4.0     ENDREC
  139-        DTI       ALGDB   97      .0      5.5     ENDREC
  140-        DTI       ALGDB   98      .0      7.4     ENDREC
  141-        DTI       ALGDB   99      .0      10.0    ENDREC
  142-        DTI       ALGDB   100     4       ENDREC
  143-        DTI       ALGDB   101     .898    4.2     ENDREC
  144-        DTI       ALGDB   102     .780    5.5     ENDREC
  145-        DTI       ALGDB   103     .629    7.4     ENDREC
  146-        DTI       ALGDB   104     .424    10.0    ENDREC
  147-        DTI       ALGDB   105     2       ENDREC
              DTI       ALGDB   106     2.0     4.4     ENDREC
```

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SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
151-	DTI	ALGDB	109	4.0	4.75	ENDREC				
152-	DTI	ALGDB	110	4.0	10.04	ENDREC				
153-	DTI	ALGDB	111	1	ENDREC					
154-	DTI	ALGDB	112	3.25	14.7	518.7	.0	ENDREC		
155-	DTI	ALGDB	113	0	ENDREC					
156-	DTI	ALGDB	114	4.0	.0	ENDREC				
157-	DTI	ALGDB	115	10.0	1.0	ENDREC				
158-	DTI	ALGDB	116	0	ENDREC					
159-	DTI	ALGDB	117	0	ENDREC					
160-	DTI	ALGDB	118	.0	ENDREC					
161-	DTI	ALGDB	119	.0	ENDREC					
162-	DTI	ALGDB	120	.0	ENDREC					
163-	DTI	ALGDB	121	.0	ENDREC					
164-	DTI	ALGDB	122	.0	ENDREC					
165-	DTI	ALGDB	123	.0	ENDREC					
166-	DTI	ALGDB	124	.0	ENDREC					
167-	DTI	ALGDB	125	6	ENDREC					
168-	DTI	ALGDB	126	.0	.006	.006	.006	ENDREC		
169-	DTI	ALGDB	127	.2	.007	.007	.007	ENDREC		
170-	DTI	ALGDB	128	.4	.014	.014	.014	ENDREC		
171-	DTI	ALGDB	129	.6	.030	.031	.031	ENDREC		
172-	DTI	ALGDB	130	.8	.060	.060	.060	ENDREC		
173-	DTI	ALGDB	131	1.0	.125	.125	.125	ENDREC		
174-	DTI	ALGDB	132	2	1	ENDREC				
175-	DTI	ALGDB	133	.0	ENDREC					
176-	DTI	ALGDB	134	.0	ENDREC					
177-	DTI	ALGDB	135	1.0	ENDREC					
178-	GRID	1		-0.8980	-0.2732	3.7502				
179-	GRID	2		.0	.0532	3.9996				
180-	GRID	3		.8980	-0.2499	4.1926				
181-	GRID	4		-0.7630	-0.5004	5.4772				
182-	GRID	5		.0	.0205	5.5000				
183-	GRID	6		.7800	.2342	5.4950				
184-	GRID	7		-0.6290	-0.7494	7.3620				
185-	GRID	8		.0	.0131	7.4000				
186-	GRID	9		.6290	.6365	7.3725				
187-	GRID	10		-0.4240	-0.9230	9.9564				
188-	GRID	11		.0	-0.0221	10.0000				
189-	GRID	12		.4240	.7558	9.9711				
190-	GRID	101	1	2.375	4.186	-0.587	1			
191-	GRID	103	1	2.375	4.186	.587	1			
192-	GRID	104	1	2.375	.0	.587	1			
193-	GRID	105	1	2.375	-4.186	.587	1			
194-	GRID	107	1	2.375	-4.186	-0.587	1			
195-	GRID	108	1	2.375	.0	-0.587	1			
196-	GRID	113	1	3.982	4.186	-0.587	1			
197-	GRID	115	1	4.539	4.186	.587	1			
198-	GRID	116	1	4.539	.0	.587				
199-	GRID	117	1	4.539	-4.186	.587	1			
200-	GRID	119	1	3.992	-4.186	-0.587	1			

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DESIGN OF BLADE

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
201-	GRID	120	1	3.982	.0	-0.987				
202-	GRID	121	1	.905	4.186	-0.987	1			
203-	GRID	123	1	.905	4.186	.987	1			
204-	GRID	124	1	.905	.0	.987	1			
205-	GRID	125	1	.905	-4.186	.987	1			
206-	GRID	127	1	.905	-4.186	-0.987	1			
207-	GRID	128	1	.905	.0	-0.987	1			
208-	MAT1	1	31.0E6		.3	7.300E-4				
209-	MPC	600	1	1	1.0	2	1	-1.0		
210-	MPC	600	1	2	1.0	2	2	-1.0		
211-	MPC	600	1	3	1.0	2	3	-1.0		
212-	MPC	600	1	4	1.0	2	4	-1.0		
213-	MPC	600	1	5	1.0	2	5	-1.0		
214-	MPC	600	1	6	1.0	2	6	-1.0		
215-	MPC	600	3	1	1.0	2	1	-1.0		
216-	MPC	600	3	2	1.0	2	2	-1.0		
217-	MPC	600	3	3	1.0	2	3	-1.0		
218-	MPC	600	3	4	1.0	2	4	-1.0		
219-	MPC	600	3	5	1.0	2	5	-1.0		
220-	MPC	600	3	6	1.0	2	6	-1.0		
221-	MPC	600	101	1	1.0	107	1	-1.0		
222-	MPC	600	101	2	1.0	107	2	-1.0		
223-	MPC	600	101	3	1.0	107	3	-1.0		
224-	MPC	600	103	1	1.0	105	1	-1.0		
225-	MPC	600	103	2	1.0	105	2	-1.0		
226-	MPC	600	103	3	1.0	105	3	-1.0		
227-	MPC	600	113	1	1.0	119	1	-1.0		
228-	MPC	600	113	2	1.0	119	2	-1.0		
229-	MPC	600	113	3	1.0	119	3	-1.0		
230-	MPC	600	115	1	1.0	117	1	-1.0		
231-	MPC	600	115	2	1.0	117	2	-1.0		
232-	MPC	600	115	3	1.0	117	3	-1.0		
233-	MPC	600	116	1	1.0	2	1	-1.0		
234-	MPC	600	116	2	1.0	2	2	-1.0		
235-	MPC	600	116	3	1.0	2	3	-1.0		
236-	MPC	600	120	1	1.0	2	1	-1.0		
237-	MPC	600	120	2	1.0	2	2	-1.0		
238-	MPC	600	120	3	1.0	2	3	-1.0		
239-	MPC	600	121	1	1.0	127	1	-1.0		
240-	MPC	600	123	1	1.0	125	1	-1.0		
241-	PARAM	APRESS	1							
242-	PARAM	ATEMP	1							
243-	PARAM	FXCOOR	.3							
244-	PARAM	FYCOOR	.3							
245-	PARAM	FZCOOR	.3							
246-	PARAM	IPRTCF	1							
247-	PARAM	IPRTCI	1							

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                                        S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
 251-        PARAM   STREAML -1
 252-        PARAM   ZORIGN  .0
 253-        PTRIA2  2000    1       .1040   0.0
 254-        PTRIA2  2005    1       .1040   0.0
 255-        PTRIA2  2010    1       .0707   0.0
 256-        PTRIA2  2015    1       .0707   0.0
 257-        PTRIA2  2020    1       .0422   0.0
 258-        PTRIA2  2025    1       .0422   0.0
 259-        FFORCE  1       0       0       267.267 1.0     .0      .0
 260-        SPC1    500     23      121     123     124     125     127     128
 261-        SPC1    500     45      7       10      12
 262-        SPC1    500     456     101     103     104     105     107     108
 263-        SPC1    500     456     113     115     116     117     119     120
 264-        SPC1    500     456     121     123     124     125     127     128
 265-        STREAML11       1       THRU    3
 266-        STREAML12       4       THRU    6
 267-        STREAML13       7       THRU    9
 268-        STREAML14       10      THRU    12
             ENDDATA                         1
```

The Executive Control Deck consists of cards from ID to CEND. SØL 16 and APP Displacement are used for the Steady Aerothermoelastic Design/Analysis problem. CPU time (in minutes) is estimated on the TIME card. DIAG (optional) is used to request diagnostic output.

The Case Control Deck is used to select the boundary conditions imposed on, and the loads applied to the structure. The extent and the form of the output desired is also selected in this deck. In this problem, SPC set 500 is used to restrain the hub-shaft attachment degrees of freedom from moving in the axial and tangential direction. MPC set 600 is used to define the blade-hub attachment and the relative motion of the corresponding grid points on the two sides of the cyclic sector. Two subcases must be defined for this rigid format. Subcase 1 is for the linear solution based on the elastic stiffness while Subcase 2 solution includes the differential stiffness effects. The ØUTPUT (PLØT) packet requests the plots, and is explained in Section 4. of the User's Manual.

The blade is idealized by 12 CTRIA2 plate elements while 4 CHEXA1 solid elements are used to model the hub. The aerodynamic data describing the blade geometry (blade angle, chords, stagger angles etc.) and the operating conditions (flow rate, speed, losses etc.) are specified in the ALGDB data block input via the DTI bulk data cards. The geometry, material and constraint bulk data are as discussed in previous sections of this manual. Parameters APRESS = 1 and ATEMP = 1 enable the inclusion of the aerodynamic pressure and thermal loads. FXCØØR, FYCØØR and FZCØØR parameters each equal to 0.3 indicate that, in this design example, three tenths of the displacements obtained (both linear and non-linear) are used to redefine the blade geometry. Parameters IPRTCF = 1 and IPRTCI = 1 are used for a detailed printout from the ALG module upon final and initial entries. IPRTCL = 0 requests a summary from the ALG module during the differential stiffness loop (see Section 18 of the Theoretical Manual). PGEØM = 3 causes the GRID, CTRIA2, PTRIA2 and DTI bulk data cards to be punched out during the final pass through the ALG module. These cards represent the final blade geometry and the operating conditions. Parameter STREAML = -1 suppresses the output of STREAML1 and STREAML2 bulk data cards, while ZØRIGN = 0 only is currently permitted. STREAML1 cards identify the grid points defining the blade.

Results are presented in the Demonstration Problems Manual.

1.14.5 Modal, Flutter & Subcritical Roots Analyses

Cyclic symmetric flow is assumed while analyzing the turbomachinery rotor/stator. Due to rotational cyclic symmetry, only one-bladed disc sector is modeled. The harmonic number dependent cyclic normal modal analysis of such structures is described in Section 1.12 of the User's Manual. In the present development, the results of the normal modes analysis using cyclic symmetry have been appropriately integrated with unsteady cascade aerodynamic theories and the existing k-method of modal flutter analysis. The Mach number parameter has been conveniently replaced by the interblade phase angle parameter for blade flutter problems. The discussion that follows is to bring out the features pertinent to bladed disc analysis.

In a compressor or turbine, an operating point implies an equilibrium of flow properties such as density, velocity, Mach number, flow angle, etc., that vary across the blade span. Blade properties like the blade angles, stagger angle, chord, etc., also, in general, change from the blade root to the tip. The resulting spanwise variation in the local reduced frequency and the relative Mach number must be accounted for in estimating the chordwise generalized aerodynamic forces per unit span at each streamline. Integration of these forces over the blade span yields the blade generalized aerodynamic force matrix. In order to nondimensionalize this matrix, the flow and blade properties at a referenced streamline are used. The reference streamline number, IREF, is specified on a PARAM bulk data card.

Since the relative Mach number varies along the blade span, necessitating the use of either the subsonic or supersonic cascade theories, parameters MAXMACH and MINMACH are used respectively to specify the upper and lower limits below and above which the subsonic and supersonic unsteady cascade theories are applicable. For streamlines with relative Mach numbers between the limits MAXMACH and MINMACH, linear interpolation is used. No transonic cascade theories have been incorporated.

C-2

It should be noted that for a given interblade phase angle and reference reduced frequency, chordwise generalized aerodynamic matrices corresponding to local spacing, stagger and Mach number at the selected operating point will be generated for each streamline on the blade. This is an expensive operation and should be carefully controlled to reduce the computational work. The aerodynamic matrices are, therefore, computed at a few interblade phase angles and reduced frequencies, and interpolated for others. These parameters are selected on the MKAERO1 and MKAERO2 bulk data cards. Matrix interpolation is an automatic feature of Rigid Format Aero 9. Additional aerodynamic matrices may be generated and appended to the previous group on restart with new MKAERO1 cards, provided the rest of the data used for the matrix calculation remain unaltered.

To save further computational time, the chordwise generalized aerodynamic matrices are first computed for "aerodynamic modes" (see the Theoretical Manual, Section 18). The aerodynamic matrices for chordwise structural modes are then determined from bilinear transformations along each streamline prior to the spanwise integration to obtain the complete blade generalized aerodynamic matrix. This permits a change in the structural mode shapes of the same or a different harmonic number to be included in the flutter analysis without having to recompute the modal aerodynamic matrices for aerodynamic modes. This can be achieved by appropriate ALTERS to the Rigid Format.

For non-zero harmonic numbers, the normal modes analysis using cyclic symmetry results in both "sine" and "cosine" mode shapes (Section 1.12). The BCD value of the parameter MTYPE on a PARAM bulk data card selects the type of mode shapes to be used in flutter calculations. It is immaterial which is selected.

The method of flutter analysis is specified on the FLUTTER bulk data card. The FLUTTER card is selected by an FMETHØD card. At the present time, only the k-method of flutter analysis is available. This allows looping through three sets of parameters: density ratio (ρ/ρ_{ref}; ρ_{ref} is given on AERØ card); interblade phase angle (σ); and reduced frequency, (k.) For example, if the user specifies two values of each, there will be eight loops in the following order.

LØØP	DENS	σ	RFREQ
1	1	1	1
2	2	1	1
3	1	1	2
4	2	1	2
5	1	2	1
6	2	2	1
7	1	2	2
8	2	2	2

Values for the parameters are listed on FLFACT bulk data cards. Usually, one or two of the parameters will have only a single value.

A parameter VREF may be used to scale the output velocity. This can be used to convert from consistent units (e.g., in/sec) to any units the user may desire (e.g., mph), determined from $V_{out} = V/V_{REF}$. Another use of this parameter is to compute flutter index, by choosing $V_{REF} = b\omega_{\theta}\sqrt{\mu}$.

If physical output (grid point deflections or element forces, plots, etc.) is desired rather than modal amplitudes, this data recovery can be made upon a user selected subset of the cases. The selection is based upon the velocity; the method is discussed in Section 3.23.3.

1.14.6 Sample Problem

The problem of determining the complete, unstalled flutter boundaries of a compressor or turbine bladed disc involves each member set of an appropriate whole series of harmonic families of modes of the cyclically symmetric bladed discs, and effects of interblade phase angle, over an adequate set of operating points (flow rates, speeds, pressure ratios, implied Mach numbers, etc.). This sample problem, therefore, is only to illustrate the procedure to obtain typical data leading to the definition of flutter boundaries.

The finite element model of the compressor bladed disc sector is shown in Figure 1. The aerodynamic model (see Section 1.14.2) with 4 streamlines and 3 computing stations is shown in Figure 2. The first four of the zeroth harmonic family of natural modes and frequencies are chosen for flutter investigation via the PARAMeters LMØDES = 4 and KINDEX = 0. Operating point conditions of 73.15 lb m/sec flow rate, 16043 rpm, and 1.84 total pressure ratio are selected so as to demonstrate the use of the total stiffness matrix, for cyclic modal analysis, saved from the Static Aerothermoelastic Analysis at this operating point (see Demonstration Manual examples 9-5-1 and 16-1). For this, the Parameter KGGIN is set equal to 1. The k-method of flutter analysis is used which is the only method currently permitted. The NASTRAN deck used is listed in Figure 3.

The Executive Control Deck, cards ID through CEND, selects the Cyclic Modal Flutter Analysis Rigid Format via the SØL 9 and APP AERØ cards. An estimated CPU TIME of 20 minutes is indicated for this example. The DIAG 14 card is optional and lists the Rigid Format.

The Case Control Deck is used to select constraints, methods and output. In this problem, SPC set 500 is used to constrain the hub-shaft attachment degrees of freedom to move only in the radial direction. MPC set 600 is used to define the blade-hub connection. A METHØD card must select an EIGR bulk data card for real eigenvalue analysis. An FMETHØD card must be used to select a FLUTTER data card for flutter analysis. A CMETHØD card must select an EIGC data card for complex eigenvalue extraction. For a flutter summary printout, the parameter PRINT is set to YESB. The XYPAPERPLØT request shown will plot V-g and V-f split frame "plots" on the printer output. To produce plots, it is necessary to specify a plotter, request a plot tape, and specify XYPAPERPLØT VG. The "curves" refer to the loops of the flutter analysis, and in this example the 9 loops have been arranged with 3 loops to each frame.

The blade and the hub are respectively modeled by 12 CTRIA2 and 4 CHEXA1 elements. The geometry, material and constraint bulk data are as discussed in previous sections of this manual, and there are no special rules for aeroelastic flutter analysis. CYJØIN data card specifies the pairs of corresponding grid points on the two sides of the cyclic sector. INV method of real eigenvalue extraction is selected on an EIGR card wherein five mode shapes and frequencies are requested.

Of these, the first four (Parameter LMØDES = 4) modes are used to form the modal flutter equations. The AERØ bulk data card is used to specify the reference chord and reference density. For bladed disc flutter analysis, the other two parameters on the AERØ card are of no significance. The MKAERØ1 data card causes the aerodynamic matrices to be computed for three interblade phase angle-reduced frequency pairs, i.e. ($\sigma = 180^{\circ}$, $k = 0.3$), (180°, 0.7) and (180°, 1.0).

The FLUTTER bulk data card selects the presently permitted k-method of flutter analysis and refers to the FLFACT cards specifying density ratios, interblade phase angles, and reduced frequencies. The analysis loops through all combinations of densities, interblade phase angles and reduced frequencies, with density on the inner loop and interblade phase angle on the outermost loop. In this example, 3 density ratios, 1 interblade phase angle and 3 reduced frequencies (on FLFACT cards) result in (3 x 1 x 3 =) 9 loops. Both linear and surface splines are available for interpolation of aerodynamic matrices to intermediate values of interblade phase angle and reduced frequency. The EIGC card is required and the HESS method is used. The number of complex eigenvectors to be extracted must be specified, and will usually agree with the number of modes saved for output specified on the FLUTTER data card.

For bladed discs, STREAML1 and STREAML2 data cards are required. The grid points on each streamline on the blade are identified on the STREAML1 card. The flow and blade geometry is specified for each streamline on the STREAML2 cards. It should be noted that at least 3 streamlines per blade (including the root and the tip) and 3 grid points per streamline must be selected for cyclic modal flutter analysis.

Results are presented in the Demonstration Problems Manual.

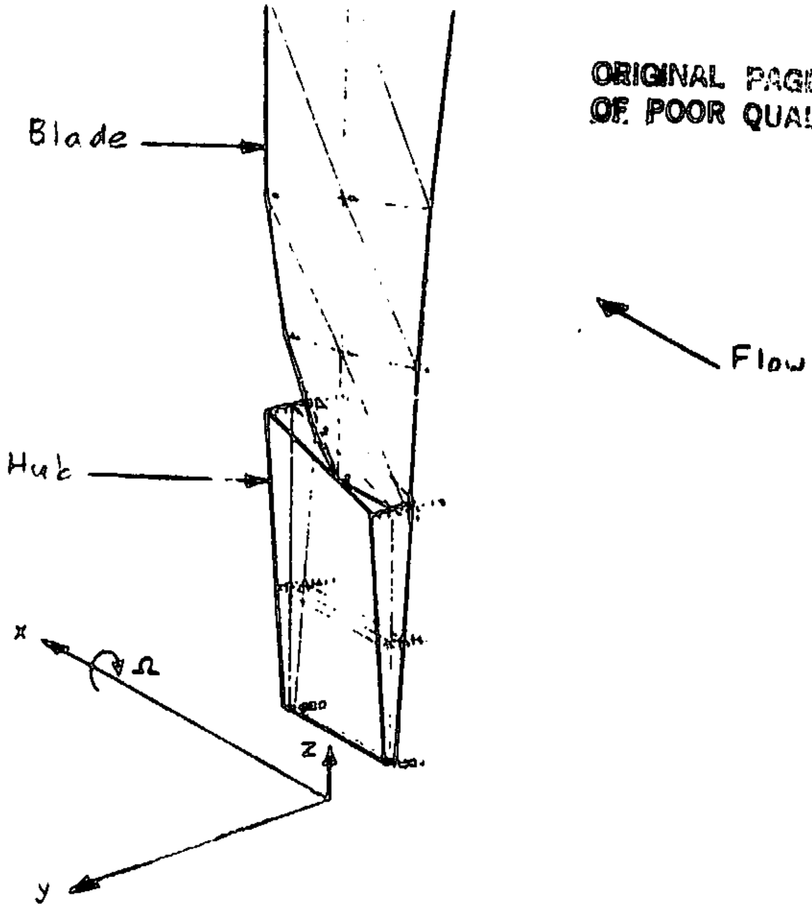

FIGURE 1. FINITE ELEMENT MODEL

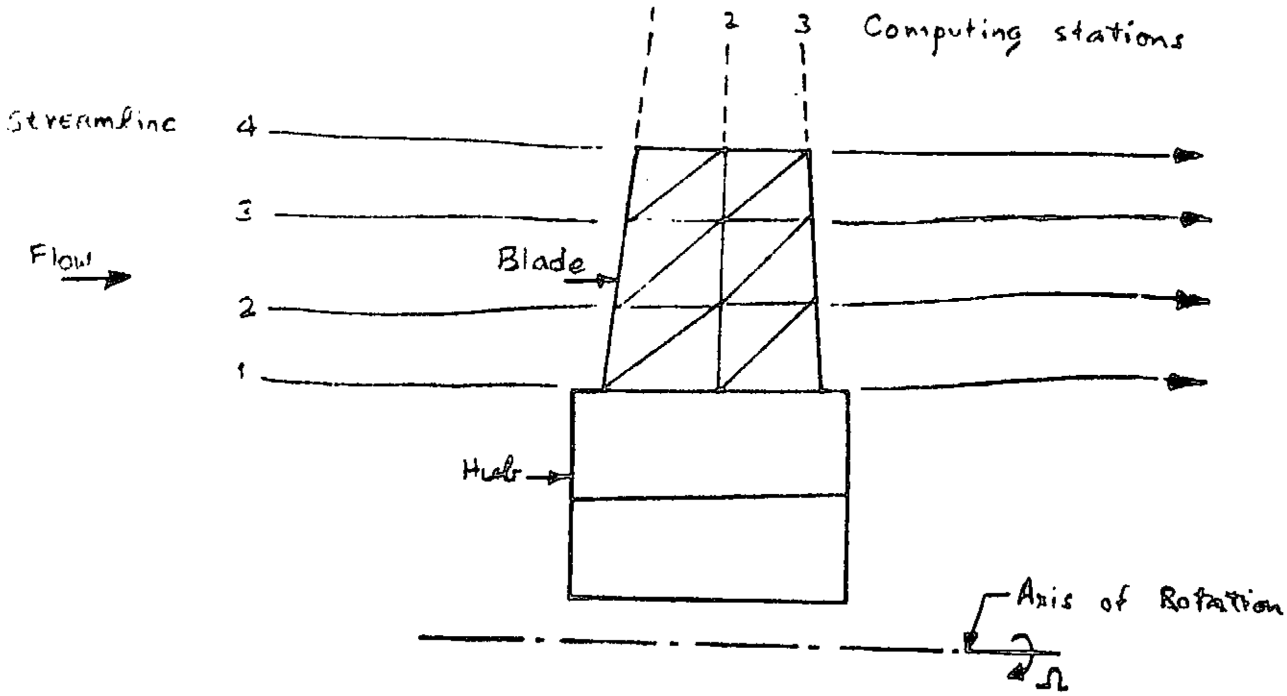

FIGURE 2. AERODYNAMIC MODEL

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K , E C H O

```
ID     NASA , LEWIS
APP    AERO
SOL 9
TIME 20
DIAG 14
CEND
```

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Figure 3. NASTRAN DECK FOR CYCLIC MODAL FLUTTER ANALYSIS OF BLADED DISCS

C
C   CASE CONTROL DECK

```
TITLE = NASA LEWIS, BLADED SHROUDED DISK ANALYSIS
SUBTITLE = EXAMPLE SINGLE-STAGE DESIGN OF ROTOR BLADE
LABEL = AEROELASTIC FLUTTER ANALYSIS
FMETHOD = 30
SPC = 500
MPC = 600
METHOD = 10
CMETHOD = 20
DISP = ALL
OUTPUT(XYOUT)
XTITLE = VELOCITY-V
YTTITLE = DAMPING-G
YBTITLE = FREQUENCY-F
XYPAPERPLOT VG /1(G,F),4(G,F),7(G,F)/2(G,F),5(G,F),8(G,F)/
                3(G,F),6(G,F),9(G,F)
BEGIN BULK
```

AEROELASTIC FLUTTER ANALYSIS

S O R T E D B U L K D A T A E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	AERO	0	1.364	1.86958	1.507-6					
2-	CHEXA1	201	1	101	103	104	108	113	115	&CH1
3-	&CH1	116	120							
4-	CHEXA1	202	1	108	104	105	107	120	116	&CH2
5-	&CH2	117	119							
6-	CHEXA1	203	1	121	123	124	128	101	103	&CH3
7-	&CH3	104	108							
8-	CHEXA1	204	1	128	124	125	127	108	104	&CH4
9-	&CH4	105	107							
10-	CORD2C	1		0.0	0.0	0.0	1.0	0.0	0.0	&CD1
11-	&CD1	0.	0.	1.						
12-	CTRIA2	1	2000	1	5	4				
13-	CTRIA2	2	2000	1	2	5				
14-	CTRIA2	3	2005	2	6	5				
15-	CTRIA2	4	2005	2	3	6				
16-	CTRIA2	5	2010	4	8	7				
17-	CTRIA2	6	2010	4	5	8				
18-	CTRIA2	7	2015	5	9	8				
19-	CTRIA2	8	2015	5	6	9				
20-	CTRIA2	9	2020	7	11	10				
21-	CTRIA2	10	2020	7	8	11				
22-	CTRIA2	11	2025	8	12	11				
23-	CTRIA2	12	2025	8	9	12				
24-	CYJOIN	1		121	101	113	123	103	115	
25-	CYJOIN	2		127	107	119	125	105	117	
26-	EIGC	20	HESS	MAX						&EIGC20
27-	&EIGC20							3		
28-	EIGR	10	INV	200.0	2000.0	8	5			&EIGR10
29-	&EIGR10	MAX								
30-	FLFACT	1	.059164	.118328	.177492					
31-	FLFACT	2	180.0							
32-	FLFACT	3	.3	.7	1.0					
33-	FLUTTER	30	K	1	2	3	1	4		
34-	GRID	1		-0.9579	-0.2814	3.7712				
35-	GRID	2		.0001	.0516	4.0EC3				
36-	GRID	3		.9581	-0.2461	4.1755				
37-	GRID	4		-0.7736	-0.4744	5.4413				
38-	GRID	5		-0.0031	.0226	5.5C23				
39-	GRID	6		.7797	.2247	5.4EE5				
40-	GRID	7		-0.6646	-0.7CE2	7.3062				
41-	GRID	8		-0.0157	.0164	7.4098				
42-	GRID	9		.6303	.5962	7.3237				
43-	GRID	10		-0.5237	-1.1952	9.0520				
44-	GRID	11		-0.0320	-0.0656	10.0079				
45-	GRID	12		.4130	.7329	9.9093				
46-	GRID	101	1	2.375	4.1[illegible]	-0.587	1			
47-	GRID	103	1	2.375	4.1[illegible]	.587	1			
48-	GRID	104	1	2.375	.0.	.587	1			

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AEROELASTIC FLUTTER ANALYSIS

```
                                     S O R T E D   B U L K   D A T A   E C H O
   CARD
   COUNT          .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
    101-          SPC1     500     23      121     123     124     125     127     128
    102-          SPC1     500     45      7       10      12
    103-          SPC1     500     456     101     103     104     105     107     108
    104-          SPC1     500     456     113     115     116     117     119     120
    105-          SPC1     500     456     121     123     124     125     127     128
    106-          STREAML11        1       2       3
    107-          STREAML12        4       5       6
    108-          STREAML13        7       8       9
    109-          STREAML14        10      11      12
    110-          STREAML21        3       2.739   1.75600 3.98420 .58217  .656846 .069472 &STRL 1
    111-          &STRL 1  719.0   47.423
    112-          STREAML22        3       23.534  1.85344 6.06653 .88674  .934368 .066610 &STRL 2
    113-          &STRL 2  1014.2  55.107
    114-          STREAML23        3       44.697  1.86419 8.07620 1.18010 1.153666.064685 &STRL 3
    115-          &STRL 3  1288.1  60.380
    116-          STREAML24        3       62.028  1.86558 9.92791 1.45067 1.502276.059201 &STRL 4
    117-          &STRL 4  1592.6  60.687
                  ENDDATA
```

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Executive Control Card SØL - Solution Number Selection

Description: Selects the solution number which defines the Rigid Format.

Format and Example(s):

$$\text{SØL} \left\{ \begin{matrix} K1 \\ A \end{matrix} \left[\begin{matrix} K2 \\ \underline{0} \end{matrix} \right] \right\}$$

SØL 5

SØL 1,6

SØL 1,6,7,8,9

SØL STEADY STATE

Option	Meaning
K1	Solution number of Rigid Format (see Remarks below and Section 3).
K2	Subset numbers for solution K1, default value = 0.
A	Name of Rigid Format (see Remarks below).

Remarks:

1. When a Direct Matrix Abstraction Program (DMAP) is not used, the solution is mandatory. The subset associated with a solution is optional.

2. For Displacement Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
1	STATICS
2	INERTIA RELIEF
3	MØDES or NØRMAL MØDES or REAL EIGENVALUES
4	DIFFERENTIAL STIFFNESS
5	BUCKLING
6	PIECEWISE LINEAR
7	DIRECT CØMPLEX EIGENVALUES
8	DIRECT FREQUENCY RESPØNSE
9	DIRECT TRANSIENT RESPØNSE
10	MØDAL CØMPLEX EIGENVALUES
11	MØDAL FREQUENCY RESPØNSE
12	MØDAL TRANSIENT RESPØNSE
13	NØRMAL MØDES ANALYSIS WITH DIFFERENTIAL STIFFNESS
14	STATICS CYCLIC SYMMETRY
15	MØDES CYCLIC SYMMETRY
16	STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

3. For Heat Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
1	STATICS
3	STEADY STATE
9	TRANSIENT

4. For Aero Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
9	CØMPRESSOR BLADE CYCLIC MØDAL FLUTTER ANALYSIS
10	MØDAL FLUTTER ANALYSIS
11	MØDAL AERØELASTIC RESPØNSE

5. Subsets cause a reduction in the number of statements in a Rigid Format. The use of a subset is optional. The integer value(s) may be selected from the following table:

K2	Subset Numbers
1	Delete loop control.
2	Delete mode acceleration method of data recovery (modal transient and modal frequency response).
3	Combine subsets 1 and 2.
4	Check all structural and aerodynamic data without execution of the aeroelastic problem.
5	Check only the aerodynamic data without execution of the aeroelastic problem.
6	Delete checkpoint instructions.
7	Delete structure plotting and X-Y plotting.
8	Delete Grid Point Weight Generator.
9	Delete fully stressed design (static analysis).

Multiple subsets may be selected by using multiple integers separated by commas.

15. NCHECK - requests significant digits to indicate numerical accuracy of element stress and force computations.

16. AERØFØRCE - requests frequency dependent aerodynamic laods on interconnection points in aeroelastic response analysis.

17. STRAIN - requests the strains/curvatures in a set of structural elements (applicable to TRIA1 TRIA2, QUAD1, and QUAD2 only).

18. CSP - selects contact surface points to be output.

2.3.3 Subcase Definition

In general, a separate subcase is defined for each loading condition. In statics problems separate subcases are also defined for each set of constraints. In complex eigenvalue analysis and frequency response separate subcases are defined for each unique set of direct input matrices. Subcases may be used in connection with output requests, such as in requesting different output for each mode in a real eigenvalue problem.

The Case Control Deck is structured so that a minimum amount of repetition is required. Only one level of subcase definition is necessary. All items placed above the subcase level (ahead of the first subcase) will be used for all following subcases, unless overridden within the individual subcase.

In statics problems, subcases may be combined through the use of the SUBCØM feature. Individual loads may be defined in separate subcases and then combined by the SUBCØM. If the loads are mechanical, the responses are combined as shown in example 2, which follows. If a thermal load is involved, the responses due to mechanical and thermal loads may be recovered as shown in example 1. By redefining the thermal load(s) at the SUBCØM level, stresses and forces may be recovered.

Case Control Data Card **CSP** - Contact Surface Point Selection

Description: Selects the interface contact surface points for a static aeroelastic analysis.

Format and Examples:

CSP = n

CSP = 31

Option:	Meaning
n	Set identification number of a CSP card (integer > 0).

Remarks:

1. The normal displacement difference will be output for the selected interface contact surface points.

2. This card should select only those points of the interface contact surfaces where "contact" constraint conditions were not invoked. Use the GPFØRCE Case Control Card to select points for which "contact" constraint conditions were invoked.

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Input Data Card CSP Contact Surface Points

Description: Defines interface contact surface points for use in static aeroelastic problems.

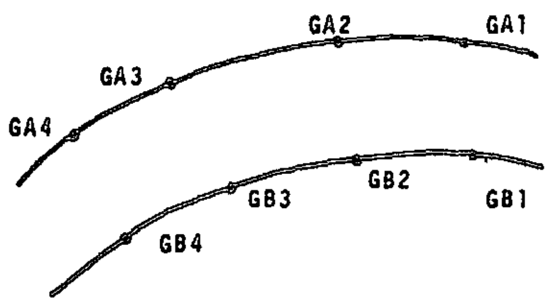
Format and Example:

1	2	3	4	5	6	7	8	9	10
CSP	SID	GA1	GB1	GA2	GB2	GA3	GB3		+ABC
CSP	13	5	9	10	12	13	23		+CSP1
+ABC	GA4	GB4	GA5	GB5	-etc-				
+CSP1									

Field	Contents
SID	Identification number of contact surface set (integer > 0).
GAi, GBi	Grid point identification numbers of node point pairs at interface contact locations (integer > 0).

Remarks:

1. Contact surface sets must be selected in the Case Control Deck (CSP = SID) to be used by NASTRAN
2. The normal displacement difference between each GAi and GBi pair will be output if this SID is selected.
3. Only those points where "contact" constraints were not invoked should be selected here. Contact surface points where "contact" constraints were invoked should be selected by a GPFØRCE data card to output element forces at the contact locations.



Interface contact surfaces represented by node pairs (GA1, GB1), (GA2, GB2), (GA3, GB3) and (GA4, GB4)

Input Data Card FLFACT Aerodynamic Physical Data

Description: Used to specify densities, Mach numbers or interblade phase angles, and reduced frequencies for flutter analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLFACT	SID	F1	F2	F3	F4	F5	F6	F7	ABC
FLFACT	97	.3	.7	3.5					abc
+BC	F8	F9	--etc.--						

Alternate Form:

FLFACT	SID	F1	THRU	FNF	NF	FMID			
FLFACT	201	.200	THRU	.100	11	.133333			

Field	Contents
SID	Set identification number (Unique Integer > 0).
Fi	Aerodynamic factor (Real).

Remarks:

1. These factors must be selected by a FLUTTER data card to be used by NASTRAN.
2. Imbedded blank fields are forbidden.
3. Parameters must be listed in the order in which they are to be used within the looping of flutter analysis.
4. For the alternate form, NF must be greater than 1. F_{mid} must lie between F_1 and F_{NF}, otherwise F_{mid} will be set to $(F_1 + F_{NF})/2$. Then

$$F_i = \frac{F_1(F_{NF}-F_{mid})(NF-i) + F_{NF}(F_{mid}-F_1)(i-1)}{(F_{NF}-F_{mid})(NF-i) + (F_{mid}-F_1)(i-1)} \qquad i = 1,2,\ldots,NF$$

The use of F_{mid} (middle factor selection) allows unequal spacing of the factors. $F_{mid} = 2F_1F_{NF}/(F_1+F_{NF})$ gives equal values to increments of the reciprocal of F_1.

Input Data Card FLUTTER Aerodynamic Flutter Data

Description: Defines data needed to perform flutter analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLUTTER	SID	METHØD	DENS	MACH	RFREQ	IMETH	NVALUE	EPS	
FLUTTER	19	K	119	219	319	S	5	1.-4	

Field	Contents
SID	Set identification number (Unique Integer > 0).
METHØD	Flutter analysis method, "K" for K-method, "PK" for P-K method, "KE" for the K-method restricted for efficiency.
DENS	Identification number of an FLFACT data card specifying density ratios to be used in flutter analysis (Integer $\geq$ 0).
MACH	Identification number of an FLFACT data card specifying MACH numbers or interblade phase angles (m) to be used in flutter analysis (integer $\geq$ 0).
RFREQ (or VEL)	Identification number of an FLFACT data card specifying reduced frequencies (k) to be used in flutter analysis (Integer > 0); for the p-k method, the velocity.
IMETH	Choice of interpolation method for matrix interpolation (BCD: L = linear, S = surface).
NVALUE	Number of eigenvalues for output and plots (Integer > 0).
EPS	Convergence parameter for k; used in the P-K method (Real)(default = 10^{-3}).

Remarks:
1. The FLUTTER data card must be selected in Case Control Deck (FMETHOD = SID).
2. The density is given by DENS · RHØREF, where RHØREF is the reference value given on the AERØ data card.
3. The reduced frequency is given by $k = (REFC \cdot \omega / 2 \cdot V)$, where REFC is given on the AERØ data card, ω is the circular frequency and V is the velocity.
4. An eigenvalue is accepted in the P-K method when $|k - k_{estimate}| <$ EPS.

Input Data Card MKAERØ1 Mach Number - Frequency Table

Description: Provides a table of Mach numbers or interblade phase angles (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ1	m_1	m_2	m_3	m_4	m_5	m_6	m_7	m_8	ABC
MKAERØ1	.1	.7							+ABC
+BC	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	
+BC	.3	.6	1.0						

Field	Contents
m_i	List of Mach numbers (Real; $1 \leq i \leq 8$).
k_j	List of reduced frequencies (Real > 0.0, $1 \leq j \leq 8$).

Remarks:
1. Blank fields end the list, and thus cannot be used for 0.0.
2. All combinations of (m,k) will be used.
3. The continuation card is required.
4. Since 0.0 is not allowed, it may be simulated with a very small number such as 0.0001.
5. Mach numbers are input for wing flutter and interblade phase angles for blade flutter.

Input Data Card MKAERØ2 Mach Number - Frequency Table

Description: Provides a list of Mach numbers or interblade phase angles (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ2	m_1	k_1	m_2	k_2	m_3	k_3	m_4	k_4	
MKAERØ2	.10	.30	.10	.60	.70	.30	.70	1.0	

Field	Contents
m_i	List of Mach numbers (Real > 0.0).
k_i	List of reduced frequencies (Real > 0.0).

Remarks: 1. This card will cause the aerodynamic matrices to be computed for a set of parameter pairs.

2. Several MKAERØ2 cards may be in the deck.

3. Imbedded blank pairs are skipped.

4. Mach numbers are input for wing flutter and interblade phase angle for blade flutter.

y. KMAX - optional in static analysis with cyclic symmetry (rigid format 14). The integer value of this parameter specifies the maximum value of the harmonic index. The default value is ALL which is NSEGS/2 for NSEGS even and (NSEGS-1)/2 for NSEGS odd.

z. KINDEX - required in normal modes with cyclic symmetry (rigid format 15). The integer value of this parameter specifies a single value of the harmonic index.

aa. NØDJE - optional in AERØ rigid formats. A positive integer of this parameter indicates user supplied downwash matrices due to extra points are to be read from tape via the INPUTT2 module in the rigid format. The default value is -1.

ab. P1, P2, and P3 - required in AERØ rigid formats when using NØDJE parameter. See Section 5.5 for tape operation parameters required by INPUTT2 module. The defaults for P1, P2, and P3 are 0,11, and XXXXXXXX, respectively.

ac. VREF - optional in modal flutter analysis (rigid format 10). Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.

ad. PRINT - optional in modal flutter analysis. The BCD value, NØ, of this parameter will suppress the automatic printing of the flutter summary for the k method. The flutter summary table will be printed if the BCD value is YES for wing flutter, or YESB for blade flutter. The default is YES.

ae. ISTART - optional in direct and modal transient response (rigid formats 9 and 12). A positive value of this parameter will cause the second (or alternate) starting method to be used (see Section 11.3 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 will cause the first starting method to be used.

af. KDAMP - optional in AERØ rigid formats. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping. The default is -1.

ag. GUSTAERØ - optional in AERØ rigid formats. An integer value of +1 causes gust loads to be computed. The default is -1.

ah. IFTM - optional in aeroelastic response (rigid format 11). The value of this parameter selects the method for the integration of the Inverse Fourier Transform. The integer value 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.

ai. MACH - optional in AERØ rigid formats. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default is 0.0.

aj. Q - required in aeroelastic response (rigid format 11). The real value of this parameter defines the dynamic pressure.

ak. ØPT - optional in static and normal modes analyses (rigid formats 1, 2, 3, 14, and 15): 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.

aℓ. GRDEQ - optional in static and normal modes analyses (rigid formats 1, 2, 3, 14, and 15). 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. Default is -1.

am. STRESS - optional in static analysis (rigid format 1). 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.

an. STRAIN - optional in static analysis (rigid format 1). 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.

ao. NINTPTS - optional in static analysis (rigid format 1). 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.

ap. APRESS - optional in static aerothermoelastic analysis. A positive integer value will generate aerodynamic pressures. A negative value (the default) will suppress the generation of aerodynamic pressure loads.

aq. ATEMP - optional in static aerothermoelastic analysis. A positive integer value will generate aerodynamic temperature loads. A negative value (the default) will suppress the generation of aerodynamic thermal loads.

ar. STREAML - optional in static aerothermoelastic analysis. 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, -1, suppresses punching of any cards.

as. PGEØM - optional in static aerothermoelastic analysis. 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, -1, suppresses punching of any cards.

at. IPRT - optional in static aerothermoelastic analysis. If IPRT > 0, then intermediate print will be generated in the ALG module based on the print option in the ALGDB data table. If IPRT = 0 (the default), no intermediate print will be generated.

au. SIGN - optional in static aerothermoelastic analysis. Controls the type of analysis being performed. SIGN = 1.0 for a standard analysis. SIGN = -1.0 for a design analysis. The default is 1.0.

av. ZØRIGN, FXCØØR, FYCØØR, FZCØØR - optional in static aerothermoelastic analysis. These are modification factors. The defaults are ZØRIGN = 0.0, FXCØØR = 1.0, FYCØØR = 1.0, and FZCØØR = 1.0.

aw. MINMACH - optional in blade flutter analysis. This is the minimum Mach number above which the supersonic unsteady cascade theory is valid. The default is 1.01.

ax. MAXMACH - optional in blade flutter analysis. This is the maximum Mach number below which the subsonic unsteady cascade theory is valid. The default value is 0.80.

ay. IREF - optional in blade flutter analysis. This defines the reference streamline number. IREF must be equal to a SLN on a STREAML2 bulk data card. The default value, -1, represents the streamline at the blade tip. If IREF does not correspond to a SLN, then the default will be taken.

az. MTYPE - optional in cyclic modal blade flutter analysis. This controls which components of the cyclic modes are to be used in the modal formulation. MTYPE = SINE for sine components and MTYPE = COSINE for cosine components. The default BCD value is COSINE.

aaa. KTØUT - optional in static aerothermoelastic analysis. A positive integer of this parameter indicates that the user wants to save the total stiffness matrix on tape (GINØ file INPT) via the ØUTPUT1 module in the rigid format. The default is -1.

aab. KGGIN - optional in compressor blade cyclic modal flutter analysis. A positive integer of this parameter indicates that the user supplied stiffness matrix is to be read from tape (GINØ file INPT) via the INPUTT1 module in the rigid format. The default is -1.

Input Data Card **STREAML1** Blade Streamline Data

Description: Defines grid points on the blade streamline from blade leading edge to blade trailing edge.

Format and Example:

1	2	3	4	5	6	7	8	9	10
STREAML1	SLN	G1	G2	G3	G4	G5	G6	G7	+ABC
STREAML1	3	2	4	6	8	10			

+ABC	G8	G9	-etc-						
+ABC									

Alternate Form:

STREAML1	SLN	GID1	"THRU"	GID2					
STREAML1	5	6	THRU	12					

Field	**Contents**
SLN	Streamline number (integer > 0).
Gi, GIDi	Grid point identification numbers (integer > 0).

Remarks:

1. This card is required for blade steady aeroelastic and blade flutter problems.

2. There must be one STREAML1 card for each streamline on the blade. For blade flutter problems, there must be an equal number of STREAML1 and STREAML2 cards.

3. The streamline numbers, SLN, must increase with increasing radial distance of the blade section from the axis of rotation. The lowest and the highest SLN, respectively, will be assumed to represent the blade sections closest to and farthest from the axis of rotation.

4. All grid points should be unique.

5. All grid points referenced by GID1 through GID2 must exist.

6. Each STREAML1 card must have the same number of grid points. The nodes must be input from the blade leading edge to the blade trailing edge in the correct positional order.

BULK DATA DECK

Input Data Card STREAML2 Blade Streamline Data

Description: Define aerodynamic data for a blade streamline.

Format and Example:

1	2	3	4	5	6	7	8	9	10
STREAML2	SLN	NSTNS	STAGGER	CHORD	RADIUS	BSPACE	MACH	DEN	+abc
STREAML2	2	3	23.5	1.85	6.07	.886	.934	.066	
+abc	VEL	FLOWA							
+ABC	1014.2	55.12							

Field	Contents
SLN	Streamline number (Integer >0)
NSTNS	Number of computing stations on the blade streamline. ($3 \le$ NSTNS ≤ 10, Integer)
STAGGER	Blade stagger angle (-90.0 < stagger <90.0, degrees)
CHORD	Blade chord (real >0.0)
RADIUS	Radius of streamline (real >0.0)
BSPACE	Blade spacing (real >0.0)
MACH	Relative flow mach number at blade leading edge (real >0.0)
DEN	Gas density at blade leading edge (real >0.0)
VEL	Relative flow velocity at blade leading edge (real >0.0)
FLOWA	Relative flow angle at blade leading edge (-90.0 <FLOWA <90.0, degrees)

Remarks:

1. At least three (3) and no more than fifty (50) STREAML2 cards are required for a blade flutter analysis.

2. The streamline number, SLN, must be the same as its corresponding SLN on a STREAML1 card. There must be a STREAML1 card for each STREAML2 card.

3. It is not required that all streamlines be used to define the aerodynamic matrices used in blade flutter analysis.

RIGID FORMATS

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

1. Static Analysis
2. Static Analysis with Inertia Relief
3. Normal Mode Analysis
4. Static Analysis with Differential Stiffness
5. Buckling Analysis
6. Piecewise Linear 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 Analysis with Differential Stiffness

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

3.1.1 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

3.22 COMPRESSOR BLADE MESH GENERATOR

3.22.1 DMAP Sequence for Compressor Blade Mesh Generator

RIGID FORMAT DMAP LISTING

SERIES 0

DMAP APPROACH, COMPRESSOR BLADE MESH GENERATOR

```
   LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT'  GO    ERR=2   NOLIST  NODECK  NOREF  NOOSCAR

    1  BEGIN $

    2  ALG      CASECC,,,,ALGDB,, / CASECCA,GEOM3A / C,N,-1 / C,N,-1 /
                V,Y,STREAML=1 / V,Y,PGEOM=2 / V,Y,IPRT=1  $

    3  END $
```

3.21.2 Description of DMAP Operations for Compressor Blade Mesh Generator

2. ALG generates GRID, CTRIA2, PTRIA2 and STREAML1 bulk data cards. These cards are output via the system card punch. The GRID and CTRIA2 cards represent a compressor blade mesh. The aerodynamic input data is checked by performing an aerodynamic analysis.

3.22.3 <u>Output for the Compressor Blade Mesh Generator</u>

The GRID, CTRIA2, PTRIA2 and STREAML1 bulk data cards are punched, Aerodynamic output is printed.

3.22.4 <u>Case Control Deck, DTI Table and Parameters for the Compressor Blade Mesh Generator</u>

1. Only TITLE, SUBTITLE and LABEL cards are processed, all other case control cards are ignored.
2. The only required input is the ALGBD data table. This data block is input via Direct Table Input (DTI) bulk data cards. ALGDB contains all the aerodynamic input necessary for the ALG module. For a detailed description of the ALGDB data block input see Section 1.15.3.1 of the User's Manual.

The following user parameters are used by the Compressor Blade Mesh Generator.

1. <u>STREAML</u> - Optional - A value of 1 causes the punching of STREAML1 bulk data cards. A value of 2 causes the punching of STREAML2 bulk data cards. A value of 3 causes the punching of both STREAML1 and STREAML2 cards. The default value, -1, suppresses the punching of all cards.
2. <u>PGEOM</u> - Optional - A value of 1 causes the punching of GRID bulk data cards. A value of 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, -1, suppresses the punching of all cards.
3. <u>IPRT</u> - Optional - a non-negative value of this parameter will allow intermediate print to be generated by the ALG module based on the print option in the ALGDB data table. The default value, 0, suppresses all intermediate print.

3.23 Static Aerothermoelastic Analysis with Differential Stiffness

3.23.1 DMAP Sequence for Static Aerothermoelastic Analysis with Differential Stiffness.

```
RIGID FORMAT DMAP LISTING
SERIES O

DISPLACEMENT APPROACH, RIGID FORMAT 16

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT: GO      ERR=2   NOLIST  NODECK  NOREF   NOOSCAR

    1  BEGIN    NO.16 STATIC AEROTHERMOELASTIC WITH DIFFERENTIAL STIFFNESS $

    2  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
                NOGPDT $

    3  SAVE     LUSET,NOGPDT $

    4  COND     ERROR1,NOGPDT $

    5  CHKPNT   GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

    6  GP2      GEOM2,EQEXIN/ECT $

    7  CHKPNT   ECT $

    8  PARAML   PCDB//C,N,PRES/C,N,/C,N,/C,N,/V,N,NOPCDB $

    9  PARAMR   // C,N,COMPLEX / / V,Y,SIGN / C,N,0.0 / V,N,CSIGN $

   10  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/NOPCDB $

   11  COND     P1,NOPCDB $

   12  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/V,N,NSIL/   V,N,
                JUMPPLOT=-1 $

   13  SAVE     NSIL,JUMPPLOT $

   14  PRTMSG   PLTSETX// $

   15  PARAM    //C,N,MPY/V,N,PLTFLG/C,N,1/C,N,1 $

   16  PARAM    //C,N,MPY/V,N,PFILE/C,N,0/C,N,0 $

   17  COND     P1,JUMPPLOT $

   18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,,,/PLOTX1/   V,N,
                NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $

   19  SAVE     JUMPPLOT,PLTFLG,PFILE $

   20  PRTMSG   PLOTX1// $

   21  LABEL    P1 $

   22  CHKPNT   PLTPAR,GPSETS,ELSETS $
```

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RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
23  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/V,N,NOGRAV $
24  SAVE     NOGRAV $
25  PARAM    //C,N,AND/V,N,NOMGG/V,N,NOGRAV/V,Y,GRDPNT=-1 $
26  CHKPNT   SLT,GPTT $
27  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/V,N,LUSET/   V,N,
             NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $
28  SAVE     NOSIMP,NOGENL,GENEL $
29  COND     ERROR1,NOSIMP $
30  PURGE    OGPST/GENEL $
31  CHKPNT   EST,GPECT,GEI,OGPST $
32  PARAM    //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $
33  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
             N,NOMGG/C,N,/C,N,/C,N,/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 $
34  SAVE     NOKGGX,NOMGG $
35  CHKPNT   KELM,KDICT,MELM,MDICT $
36  COND     JMPKGG,NOKGGX $
37  EMA      GPECT,KDICT,KELM/KGGX,GPST $
38  CHKPNT   KGGX,GPST $
39  LABEL    JMPKGG $
40  COND     JMPMGG,NOMGG $
41  EMA      GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $
42  CHKPNT   MGG $
43  LABEL    JMPMGG $
44  COND     LBL1,GRDPNT $
45  COND     ERROR4,NOMGG $
```

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STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING
SERIES U

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
46  GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
47  OFP       OGPWG,,,,,// $
48  LABEL     LBL1 $
49  EQUIV     KGGX,KGG/NOGENL $
50  CHKPNT    KGG $
51  COND      LBL11,NOGENL $
52  SMA3      GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $
53  CHKPNT    KGG $
54  LABEL     LBL11 $
55  PARAM     //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $
56  GP4       CASECC,GEOM4,EQEXIN,     GPDT,BGPDT,CSTM/RG,YS,USET,ASET/V,N,
              LUSET/V,N,MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,
              NSKIP/V,N,REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $
57  SAVE      MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $
58  COND      ERROR5,NOL $
59  PURGE     GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE/
              UBOOV/OMIT/YBS,PBS,KBFS,KBSS,KDFS,KDSS/SINGLE $
60  CHKPNT    GM,RG,GO,KOO,LOO,PO,UOOV,RUOV,YS,PS,KFS,KSS,USET,ASET,    UBOOV,
              YBS,PBS,KBFS,KBSS,KDFS,KDSS,QG $
61  COND      LBL4D,REACT $
62  JUMP      ERROR2 $
63  LABEL     LBL4D $
64  COND      LBL4,GENEL$
65  GPSP      GPL,GPST,USET,SIL/OGPST/V,N,NOGPST $
66  SAVE      NOGPST $
67  COND      LBL4,NOGPST $
68  OFP       OGPST,,,,,// $
```

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RIGID FORMAT DMAP LISTING
SERIES O

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
69  LABEL    LBL4 $
70  EQUIV    KGG,KNN/MPCF1 $
71  CHKPNT   KNN $
72  COND     LBL2,MPCF2 $
73  MCE1     USET,RG/GM $
74  CHKPNT   GM $
75  MCE2     USET,GM,KGG,,,/KNN,,, $
76  CHKPNT   KNN $
77  LABEL    LBL2 $
78  EQUIV    KNN,KFF/SINGLE $
79  CHKPNT   KFF $
80  COND     LBL3,SINGLE $
81  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
82  CHKPNT   KFS,KSS,KFF $
83  LABEL    LBL3 $
84  EQUIV    KFF,KAA/OMIT $
85  CHKPNT   KAA $
86  COND     LBL5,OMIT $
87  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
88  CHKPNT   GO,KAA,KOO,LOO $
89  LABEL    LBL5 $
90  RBMG2    KAA/LLL $
91  CHKPNT   LLL $
92  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PGNA / V,N,
             LUSET/C,N,1 $
93  CHKPNT   PGNA $
```

STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING
SERIES O

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 94  PARAM    //C,N,AND /V,N,ALOAD /V,Y,APRESS /V,Y,ATEMP $

 95  COND     NUAL,ALOAD $

 96  ALG      CASECC,,EQEXIN,,ALGDB,, / CASECCA1,GEOM3A1 /S,V,APRESS/S,V,
              ATEMP/C,N,-1/C,N,-1/V,Y,IPRTC1/S,N,IFAIL $

 97  COND     FINIS,IFAIL $

 98  PARAM    //C,N,AND /V,N,ALOAD /V,Y,APRESS /V,Y,ATEMP $

 99  COND     NOAL,ALOAD $

100  GP3      GEOM3A1,EQEXIN,GEOM2 /SLTA1,GPTTA1 / V,N,NOGRAV $

101  CHKPNT   SLTA1,GPTTA1 $

102  SSG1     SLTA1,BGPDT,CSTM,SIL,EST,MPT,GPTTA1,EDT,MGG,CASECCA1,DIT /
              PGA1 / V,N,LUSET / C,N,1 $

103  CHKPNT   PGA1 $

104  ADD      PGVA,PGA1 / PG $

105  LABEL    NUAL $

106  EQUIV    PGVA,PG/ALOAD $

107  CHKPNT   PG $

108  EQUIV    PG,PL/NOSET $

109  CHKPNT   PL $

110  COND     LBL10,NOSET $

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

112  CHKPNT   PO,PS,PL $

113  LABEL    LBL10 $

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

115  SAVE     EPSI $

116  CHKPNT   ULV,UOOV,RULV,RUOV $

117  COND     LBL9,IRES $
```

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
118  MATGPR   GPL,USET,SIL,RULV//C,N,L $

119  MATGPR   GPL,USET,SIL,RUOV//C,N,O $

120  LABEL    LBL9 $

121  SDR1     USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/C,N,1/C,N,DSO $

122  CHKPNT   UGV,QG $

123  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,QG,UGV,EST,,PG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/C,N,DSO $

124  PARAM    //C,N,MPY/V,N,CARDNO/C,N,0/C,N,0 $

125  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//V,N,CARDNO $

126  SAVE     CARDNO $

127  COND     P2,JUMPPLOT $

128  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,PUGV1,,GPECT,OES1/
              PLOTX2/V,N,NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $

129  SAVE     PFILE $

130  PRTMSG   PLOTX2// $

131  LABEL    P2 $

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

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

134  CHKPNT   KDGG $

135  COND     NOALO,ALOAD $

136  EQUIV    PGNA,PG $

137  LABEL    NOALO $

138  PARAM    //C,N,ADD/V,N,SHIFT/C,N,-1/C,N,0 $

139  PARAM    //C,N,ADD/V,N,COUNT/V,N,ALWAYS=-1/V,N,NEVER= 1 $

140  PARAMR   //C,N,ADD/V,N,DSEPSI/C,N,0.0/C,N,0.0 $
```

STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
141  PARAML   YS//C,N,NULL/C,N,/C,N,/C,N,/V,N,NOYS $
142  JUMP     OUTLPTOP $
143  LABEL    OUTLPTOP $
144  EQUIV    PG,PG1/NOYS $
145  CHKPNT   PG1 $
146  PARAM    //C,N,KLOCK/V,N,TO $
147  EQUIV    KDGG,KDNN/MPCF2 $
148  CHKPNT   KDNN $
149  COND     LBL2D,MPCF2 $
150  MCE2     USET,GM,KDGG,,,/KDNN,,, $
151  CHKPNT   KDNN $
152  LABEL    LBL2D $
153  EQUIV    KDNN,KDFF/SINGLE $
154  CHKPNT   KDFF $
155  COND     LBL3D,SINGLE $
156  SCE1     USET,KDNN,,,/KDFF,KDFS,KDSS,,, $
157  CHKPNT   KDFF,KDFS,KDSS $
158  LABEL    LBL3D $
159  EQUIV    KDFF,KDAA/OMIT $
160  CHKPNT   KDAA $
161  COND     LBL5D,OMIT $
162  SMP2     USET,GO,KDFF/KDAA $
163  CHKPNT   KDAA $
164  LABEL    LBL5D $
165  ADD      KAA,KDAA / KBLL / C,N,(1.0,0.0) / V,N,CSIGN $
```

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RIGID FORMAT DMAP LISTING

SERIES O

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
166  ADD      KFS,KDFS/ KBFS / C,N,(1.0,0.0) / V,N,CSIGN $
167  ADD      KSS,KDSS/ KBSS / C,N,(1.0,0.0) / V,N,CSIGN $
168  COND     PGOK,NOYS $
169  MPYAD    KBSS,YS,/PSS/C,N,0/C,N,1/C,N,1/C,N,1 $
170  MPYAD    KBFS,YS,/PFS/C,N,0/C,N,1/C,N,1/C,N,1 $
171  UMERGE   USET,PFS,PSS/PN/C,N,N/C,N,F/C,N,S $
172  EQUIV    PN,PGX/MPCF2 $
173  COND     LBL6D,MPCF2 $
174  UMERGE   USET,PN,/PGX/C,N,G/C,N,N/C,N,M $
175  LABEL    LBL6D $
176  ADD      PGX,PG/PGG/C,N,(-1.0,0.0) $
177  EQUIV    PGG,PG1/ALWAYS $
178  LABEL    PGOK $
179  ADD      PG1,/PGG/ $
180  COPY     UGV / AUGV $
181  FBMG2    KBLL/LBLL/V,N,POWER/V,N,DET $
182  SAVE     DET,POWER $
183  CHKPNT   LBLL $
184  PRTPARM  //C,N,0/C,N,DET $
185  PRTPARM  //C,N,0/C,N,POWER $
186  JUMP     INLPTOP $
187  LABEL    INLPTOP $
188  PARAM    //C,N,KLOCK/V,N,TI $
189  COND     NOALL,ALCAD $
190  ALG      CASECC,EDT,EQEXIN,AUGV,ALGDB,CSTM,BGPDT / CASECCA,GEOM3A /S,Y,
              APRESS/S,Y,ATEMP/C,N,-1/C,N,-1/V,Y,IPRTCL/S,N,IFAIL/V,Y,SIGN/V,
```

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
                 Y,ZORIGN/V,Y,FXCOOR/V,Y,FYCOOR/V,Y,FZCOOR $
191  COND        DONE,IFAIL $
192  PARAM       //C,N,MPY /V,Y,IPRTCL /C,N,0 $
193  PARAM       //C,N,AND /V,N,ALOAD /V,Y,APRESS /V,Y,ATEMP $
194  COND        NOAL1,ALOAD $
195  GP3         GEOM3A,EQEXIN,GEOM2/SLTA,GPTTA/V,N,NOASL/V,N,NOGRAV/V,N,NOATL $
196  SSG1        SLTA,BGPDT,CSTM,SIL,EST,MPT,GPTTA,EDT,MGG,CASECCA,DIT /PGA /V,
                 N,LUSET /C,N,1$
197  ADD         PG1,PGA / PG2 $
198  LABEL       NOAL1 $
199  EQUIV       PG1,PG2 / ALOAD $
200  CHKPNT      PG2 $
201  SSG2        USET,GM,YS,KOFS,GO,,PG2 /,PBO,PBS,PBL $
202  SSG3        LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/C,N,-1/V,Y,IRES/V,N,NOSKIP/V,N,
                 EPSI $
203  SAVE        EPSI $
204  CHKPNT      UBLV,RUBLV $
205  COND        LBL9D,IRES $
206  MATGPR      GPL,USET,SIL,RUBLV//C,N,L $
207  LABEL       LBL9D $
208  SDR1        USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/C,N,1/C,N,DS1 $
209  CHKPNT      UBGV,QBG $
210  COND        NOAL2,ALOAD $
211  EQUIV       UBGV,AUGV $
212  LABEL       NOAL2 $
213  ADD         UBGV,UGV/DUGV/C,N,(-1.0,0.0) $
```

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
214  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/V,N,
               DSCOSET $
215  CHKPNT   DKDGG $
216  MPYAD    DKDGG,UBGV,PGO/PGI1/C,N,0/C,N,1/C,N,1/C,N,1 $
217  ADD      PGI1,PGA / PGI2 $
218  DSCHK    PG2,PGI2,UBGV //C,Y,EPSIO=1.E-5 /V,N,DSEPSI / C,Y,NT=10 /V,N,
               TO /V,N,TI /V,N,DONE /V,N,SHIFT /V,N,COUNT/C,Y,BETAD=4 $
219  SAVE     DSEPSI,DONE,SHIFT,COUNT $
220  COND     DONE,DONE $
221  COND     SHIFT,SHIFT $
222  EQUIV    PG,PG1/NEVER $
223  EQUIV    PGI1,PG1/ALWAYS $
224  EQUIV    PG1,PGI1/NEVER $
225  REPT     INLPTOP,1000 $
226  TABPT    PGI1,PG1,PG,,// $
227  LABEL    SHIFT $
228  ADD      DKDGG,KDGG/KDGG1/C,N,(-1.0,0.0) $
229  CHKPNT   KDGG1 $
230  EQUIV    UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $
231  CHKPNT   KDGG $
232  EQUIV    KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $
233  REPT     OUTLPTOP,1000 $
234  TABPT    KDGG1,KDGG,UGV,,// $
235  LABEL    DONE $
236  PARAM    //C,N,NOP / V,Y,KTOUT=-1 $
237  COND     JMPKTOUT,KTOUT $
```

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STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
238  ADD      KGG,KDGG / KTOTAL / C,N,(1.0,0.0) / V,N,CSIGN $
239  OUTPUT1  KTOTAL,,,, // C,Y,LOCATION=-1 / C,Y,INPTUNIT=0 $
240  OUTPUT1, ,,,, // C,N,-3 / C,N,0 $
241  LABEL    JMPKTOUT $
242  CHKPNT   CSTM $
243  ALG      CASECC,EDT,EQEXIN,UBGV,ALGDB,CSTM,BGPDT / CASECCB,GEOM3B /C,N,
              -1/C,N,-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 $
244  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,QBG,UBGV,EST,,/,
              OUBG1,OUBGV1,OESB1,OEFB1,PUBGV1 /C,N,DS1 $
245  OFP      OUBGV1,OQBG1,OEFB1,OESB1,,//V,N,CARDNO $
246  SAVE     CARDNO $
247  SDR1     USET,PG2,UBLV,,YS,GO,GM,PBS,KBFS,KBSS, / AUBGV,APGG,AQBG /C,N,
              1 /C,N,DS1 $
248  GPFDR    CASECC,AUBGV,KELM,KDICT,ECT,EQEXIN,GPECT,APGG,AQBG /ONRGY1,
              OGPFB1 / C,N,STATICS $
249  OFP      ONRGY1,OGPFB1,,,, // $
250  COND     P3,JUMPPLOT $
251  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,PUBGV1,,GPECT,
              OESB1/PLOTX3/V,N,NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,
              PFILE $
252  SAVE     PFILE $
253  PRTMSG   PLOTX3// $
254  LABEL    P3 $
255  JUMP     FINIS $
256  LABEL    ERROR1 $
257  PRTPARM  //C,N,-1/C,N,DIFFSTIF $
258  LABEL    ERROR2 $
259  PRTPARM  //C,N,-2/C,N,DIFFSTIF $
```

RIGID FORMAT DMAP LISTING
SERIES D

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
260  LABEL     ERROR4 $
261  PRTPARM   //C,N,-4/C,N,DIFFSTIF $
262  LABEL     ERROR5 $
263  PRTPARM   //C,N,-5/C,N,DIFFSTIF $
264  LABEL     FINIS $
265  END       $
```

NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM

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3.23.2 Description of DMAP Operations for Static Aerothermoelastic Analysis with Differential Stiffness

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

4. Go to DMAP No. 256 if no grid point definition table.

6. GP2 generates Element Connection Table with internal indices.

9. PARAMR sets CSIGN=(SIGN, 0.0), where SIGN is +1.0 or -1.0 for analysis or design type run.

11. Go to DMAP No. 21 if no plot package is present.

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

14. PRTMSG prints error messages associated with structure plotter.

17. Go to DMAP No. 21 if no undeformed structure plot request.

18. PLØT generates all requested undeformed structure plots.

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

23. 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. 256 and print error message if no structural elements.

33. EMG generates structural element matrix tables and dictionaries for later assembly.

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

37. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

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

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

44. Go to DMAP No. 48 if no weight and balance request.

45. Go to DMAP No. 260 and print error message if no mass matrix exists.

46. GPWG generates weight and balance information.

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

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

51. Go to DMAP No. 54 if no general elements.

52. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

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

58. Go to DMAP No. 262 and print error message if no independent degrees of freedom are defined.

61. Go to DMAP No. 63 if no free-body supports supplied, otherwise go to DMAP No. 258.

64. Go to DMAP No. 67 if general elements present.

65. GPSP determines if possible grid point singularities remain.

67. Go to DMAP No. 69 if no Grid Point Singularity Table.

68. ØFP formats table of possible grid point singularities and places it on the system output file for printing.

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

72. Go to DMAP No. 77 if MCE1 and MCE2 have already been executed for current set of multipoint constraints.

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

75. 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

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

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

80. Go to DMAP No. 83 if no single-point constraints.

81. SCE1 partitions out single-point constraints.

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

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

86. Go to DMAP No. 89 if no omitted coordinates.

87. 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 $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

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

92. SSG1 generates non-aerodynamic static load vectors $\{P_g^{NA}\}$.

95. Go to DMAP No. 105 if no aerodynamic loads.

96. ALG generates aerodynamic load data.

102. SSG1 generates aerodynamic load vector $\{P_g^A\}$.

104. Add $\{P_g^{NA}\}$ and $\{P_g^A\}$ to form total load vector $\{P_g\}$.

106. Equivalence $\{P_g\}$ to $\{P_g^{NA}\}$ if no aerodynamic loads.

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

110. Go to DMAP No. 113 if no constraints applied.

111. SSG2 applies constraints to static load vectors

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

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

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

114. 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

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

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

117. Go to DMAP No. 120 if residual vectors are not to be printed.

118. Print residual vector for independent coordinates (RULV).

119. Print residual vector for omitted coordinates (RUØV).

121. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} ,$$

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

$$\{u_m\} = [G_m]\{u_n\}, \qquad \left\{\begin{array}{c} u_n \\ -- \\ u_m \end{array}\right\} = \{u_g\} ,$$

and recovers single-point forces of constraint

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

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

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

127. Go to DMAP No. 131 if no static deformed structure plots are requested.

128. PLØT generates all requested static deformed structure plots.

130. PRTMSG prints plotter data and engineering data for each deformed plot generated.

132. TA1 generates element tables for use in differential stiffness matrix assembly.

133. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

135. Go to DMAP No. 137 if no aerodynamic loads.

136. Equivalence $\{P_g^{NA}\}$ to $\{P_g\}$ to remove aerodynamic loads from total load vector before entering differential stiffness loop. New aerodynamic loads will be generated in loop.

142. Go to next DMAP instruction if cold start or modified restart. ØUTLPTØP will be altered by the Executive System to the proper location inside the loop for unmodified restarts within the loop.

143. Beginning of outer loop for differential stiffness iteration.

144. Equivalence $\{P_g\}$ to $\{P_g\}$ if no enforced displacements.

147. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ if no multipoint constraints.

149. Go to DMAP No. 152 if no multipoint constraints.

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

153. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ if no single-point constraints.

155. Go to DMAP No. 158 if no single-point constraints.

156. SCE1 partitions out single-point constraints

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

159. Equivalence $[K_{ff}^d]$ to $[K_{aa}^d]$ if no omitted coordinates.

161. Go to DMAP No. 164 if no omitted coordinates.

162. SMP2 partitions constrained differential stiffness matrix

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

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

165. ADD $[K_{aa}]$ and $[K_{aa}^d]$.CSIGN to form $[K_{\ell\ell}^b]$.

166. ADD $[K_{fs}]$ and $[K_{fs}^d]$.CSIGN to form $[K_{fs}^b]$.

167. ADD $[K_{ss}]$ and $[K_{ss}^d]$.CSIGN to form $[K_{ss}^b]$.

168. Go to DMAP No. 178 if no enforced displacements.

169. MPYAD multiply $[K_{ss}^b]$ and $\{Y_s\}$ to form $\{P_{ss}\}$.

170. MPYAD multiply $[K_{fs}^b]$ and $\{Y_s\}$ to form $\{P_{fs}\}$.

171. UMERGE expand $\{P_{fs}\}$ and $\{P_{ss}\}$ to form $\{P_n\}$.

174. UMERGE expand $\{P_n\}$ to form $\{P_g^x\}$.

176. ADD $-\{P_g^x\}$ and $\{P_g\}$ to form $\{P_{gg}\}$.

177. Equivalence $\{P_{gg}\}$ to $\{P_{g1}\}$.

179. ADD $\{P_{g1}\}$ and nothing to create $\{P_{go}\}$.

180. Copy $\{u_g\}$ to $\{u_g^A\}$ to initialize aerodynamic displacements.

181. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix.

$$[K_{\ell\ell}^b] = [L_{\ell\ell}^b][U_{\ell\ell}^b].$$

184. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

185. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and the elastic stiffness matrix.

186. Go to next DMAP instruction if cold start or modified restart. INLPTØP will be altered by the executive system to the proper location inside the loop for unmodified restarts within the loop.

187. Beginning of inner loop for differential stiffness iteration.

189. Go to DMAP No. 194 if no aerodynamic loads.

190. ALG generates aerodynamic load data.

191. Go to DMAP No. 235 if ALG fails to converge while generating aerodynamic load data.

196. SSG1 generates aerodynamic load vector $\{P_g^A\}$.

197. ADD $\{P_{g1}\}$ and $\{P_g^A\}$ to form total load vector $\{P_{g2}\}$.

201. SSG2 applies constraints to static load vectors

$$\{P_{g2}\} = \begin{Bmatrix} \bar{p}_n^b \\ \hline p_m^b \end{Bmatrix} , \qquad \{p_n^b\} = \{\bar{p}_n^b\} + [G_m^T]\{p_m^b\} ,$$

$$\{p_n^b\} = \begin{Bmatrix} \bar{p}_f^b \\ \hline p_s^b \end{Bmatrix} , \qquad \{P_f\} = \{\bar{p}_f^b\} - [K_{fs}^d]\{Y_s\},$$

$$\{p_f^b\} = \begin{Bmatrix} p_a^b \\ \hline p_o^b \end{Bmatrix} \quad \text{and} \quad \{p_\ell^b\} = \{p_a^b\} + [G_o^T]\{p_o^b\} .$$

202. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u_\ell^b\} = [K_{\ell\ell}^b]^{-1}\{p_\ell^b\}$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

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

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

205. Go to DMAP No. 207 if residual vector for current differential stiffness solution is not to be printed.

206. Print residual vector for current differential stiffness solution.

208. SDR1 recovers dependent displacements for current differential stiffness solution

$$\{u_o^b\} = [G_o]\{u_\ell^b\} + \{u_o^{ob}\} , \quad \left\{\begin{array}{c} u_\ell^b \\ \hline u_o^b \end{array}\right\} = \{u_f^b\} ,$$

$$\left\{\begin{array}{c} u_f^b \\ \hline Y_s^b \end{array}\right\} = \{u_n^b\} , \quad \{u_m^b\} = [G_m]\{u_n^b\} ,$$

$$\left\{\begin{array}{c} u_n^b \\ \hline u_m^b \end{array}\right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b]\{u_f^b\} + [K_{ff}^b]\{Y_s^b\} .$$

210. Go to DMAP No. 212 if no aerodynamic loads.

211. Equivalence $\{u_g^B\}$ to $\{u_g^A\}$.

213. ADD $-\{U_g^b\}$ and $\{U_g\}$ to form $\{U_g^d\}$.

214. DSMG1 generates differential stiffness matrix $[\delta K_{gg}^d]$.

216. MPYAD form load vector for inner loop iteration.

$$\{P_{g_{I1}}\} = [\delta K_{gg}^d]\{U_g^b\} + \{P_{go}\}$$

217. ADD $\{P_{g_{I1}}\}$ and $\{P_g^A\}$ to form $\{P_{g_{I2}}\}$.

218. DSCHK performs differential stiffness convergence checks.

220. Go to DMAP No. 235 if differential stiffness iteration is complete.

221. Go to DMAP No. 227 if additional differential stiffness matrix changes are necessary for further iteration.

222. Equivalence breaks previous equivalence of $\{P_g\}$ to $\{P_{g1}\}$.

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223. Equivalence $\{P_{g_{I1}}\}$ to $\{P_{g1}\}$.

224. Equivalence breaks previous equivalence of $\{P_{g1}\}$ to $\{P_{g_{I1}}\}$.

225. Go to DMAP No. 187 for additional inner loop differential stiffness iteration.

226. TABPT table prints vectors $\{P_{g_{I1}}\}$, $\{P_{g1}\}$, and $\{P_g\}$.

228. ADD $-[\delta K^d_{gg}]$ and $[K^d_{gg}]$ to form $[K^d_{gg1}]$.

230. Equivalence $\{U^b_g\}$ to $\{U_g\}$ and $[K^d_{gg1}]$ to $[K^d_{gg}]$.

232. Equivalence breaks previous equivalence of $[K^d_{gg}]$ to $[K^d_{gg}]$ and $\{U_g\}$ to $\{U^b_g\}$.

233. Go to DMAP No. 143 for additional outer loop differential stiffness iteration.

234. TABPT table prints $[K^d_{gg1}]$, $[K^d_{gg}]$ and $\{U_g\}$.

237. Go to DMAP No. 241 if the total stiffness matrix is not to be saved on tape.

238. ADD $[K_{gg}]$ and $[K^d_{gg}]$ to form [KTOTAL].

239. OUTPUT1 outputs [KTOTAL] to tape.

240. OUTPUT1 prints the names of the data blocks on the output tape.

243. ALG generates final aerodynamic results and generates GRID and STREAML2 bulk data cards on the system punch, if requested.

244. SDR2 calculates element forces and stresses (ØEFB1, ØESB1) and prepares displacement vectors and single-point forces of constraint for output (ØUBGV1, PUBGV1, ØOBG1) for all differential stiffness solutions.

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

247. SDR1 recovers dependent displacements after differential stiffness loop for grid point force balance.

248. GPFDR calculates for requested sets the grid point force balance and element strain energy for output.

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

250. Go to DMAP No. 254 if no deformed differential stiffness structure plots are requested.

251. PLØT generates all requested deformed differential stiffness structure plots.

253. PRTMSG prints plotter data and engineering data for each deformed plot generated.

255. Go to DMAP No. 264 and make normal exit.

257. STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

259. STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY-SUPPØRTS NØT ALLØWED.

STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

261. STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIONS.

263 STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - NØ INDEPENDENT DEGREES OF FREEDØM HAVE BEEN DEFINED.

3.23.3 Automatic Output for Static Aerothermoelastic 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 an unexpected interruption of the iteration procedure prior to the time the subroutine has had a chance to perform necessary checks and tests. Not much more has happened other than to initialize the exit mode to REASON 0.

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 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.

3.23.4 Case Control Deck DTI Table and Parameters for Static Aerothermoelastic Analysis with Differential Stiffness

The following items relate to subcase definition and data selection for Static Aerothermoelastic 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(LOAD), or DEFORM 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 leve.

7. Aerodynamic input for the Aerodynamic Load Generator (ALG) module is input via data block ALGDB. This data block must be input using Direct Table Input (DTI) bulk data cards. For a detailed description of the ALGDB data block input see Section 1.15.3.1 of the User's Manual.

STATIC AEROTHERMOELASTIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

The following output may be requested for Static Aerothermoelastic Analysis with Differential Stiffness:

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. Undeformed and deformed plots of the structural model.

1. GRDPNT - optional - a positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.

2. WTMASS - optional - the terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMG.

3. IRES - optional - a positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.

4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional - these parameters will 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. BETAD - optional- the integer value of this parameter is the assumed number of iterations for the inner loop in shift decisions for iterated differential stiffness. The default value is 4 iterations.

6. NT - optional - the integer value of this parameter limits the maximum number of iterations. The default value is 10 iterations.

7. EPSIØ - optional - the real value of this parameter is used to test the convergence of iterated differential stiffness. The default value is 10^{-5}.

8. APRESS - optional in static aerothermoelastic analysis. A positive integer value will generate aerodynamic pressures. A negative value (the default) will suppress the generation of aerodynamic pressure loads.

9. ATEMP - optional in static aerothermoelastic analysis. A positive integer value will generate aerodynamic temperature loads. A negative value (the default) will suppress the generation of aerodynamic thermal loads.

10. STREAML - optional in static aerothermoelastic analysis. 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, -1, suppresses punching of any cards.

11. PGEØM - optional in static aerothermoelastic analysis. PGEOM=1 causes the punching of GRID bulk data cards. PGEOM=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, -1, suppresses punching of any cards.

12. IPRT - optional in static aerothermoelastic analysis. If IPRT > 0, then intermediate print will be generated in the ALG module based on the print option in the ALGDB data table. If IPRT = 0 (the default), no intermediate print will be generated. (IPRTCI, IPRTCL, IPRTCF)

13. SIGN - optional in static aerothermoelastic analysis. Controls the type of analysis being performed. SIGN = 1.0 for a standard analysis. SIGN = -1.0 for a design analysis. The default is 1.0.

14. ZØRIGN, FXCØØR, FYCØØR, FZCØØR - optional in static aerothermoelastic analysis. These are modification factors. The defauls are ZØRIGN = 0.0, FXCOOR = 1.0, FYCOOR = 1.0, and FZCOOR = 1.0.

15. KTOUT - optional in static aerothermoelastic analyses. A positive integer of this parameter indicates that the user wants to save the total stiffness matrix on tape (GINO file INPT) via the OUTPUT1 module in the rigid format. The default is -1.

3.24 COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

3.24.1 DMAP Sequence For Compressor Blade Cyclic Modal Flutter Analysis

```
RIGID FORMAT DMAP LISTING
SERIES D

AERO APPROACH, RIGID FORMAT 9

   LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT: GO      ERR=2   NOLIST  NODECK  NOREF   NOUSCAR

   1  BEGIN    AERO NO.9 COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS $

   2  FILE     PHIHL=APPEND/AJJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/CLAMAL=
               APPEND/OVG=APPEND/UHHL=APPEND $

   3  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
               NOGPDT $

   4  SAVE     LUSET,NOGPDT $

   5  COND     ERROR1,NOGPDT $

   6  CHKPNT   GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

   7  PURGE    D1JE,D2JE/NODJE $

   8  GP2      GEOM2,EQEXIN/ECT $

   9  CHKPNT   ECT $

  10  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/V,N,NOGRAV $

  11  CHKPNT   GPTT $

  12  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/V,N,LUSET/   V,N,
               NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $

  13  SAVE     NOGENL,NOSIMP,GENEL $

  14  COND     ERROR1,NOSIMP $

  15  PURGE    OGPST/GENEL $

  16  CHKPNT   EST,GPECT,GEI,OGPST $

  17  PARAM    //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $

  18  PARAM    //C,N,ADD/V,N,NOMGG/C,N,1/C,N,0 $

  19  PARAM    // C,N,NOP / V,Y,KGGIN=-1 $

  20  COND     JMPKGGIN,KGGIN $

  21  PARAM    //C,N,ADD /V,N,NOKGGX /C,N,-1 /C,N,0 $

  22  INPUTT1  /KTOTAL,,,,/C,Y,LOCATION=-1 /C,Y,INPTUNIT=0 $
```

RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
23  EQUIV   KTOTAL,KGGX $
24  CHKPNT  KGGX $
25  LABEL   JMPKGGIN $
26  EMG     EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
            N,NOMGG/C,N,/C,N,/C,N,/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  SAVE    NOKGGX,NOMGG $
28  CHKPNT  KELM,KDICT,MELM,MDICT $
29  COND    JMPKGGX,NOKGGX $
30  EMA     GPECT,KDICT,KELM/KGGX,GPST $
31  CHKPNT  KGGX,GPST $
32  LABEL   JMPKGGX $
33  COND    ERROR1,NOMGG $
34  EMA     GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $
35  CHKPNT  MGG $
36  COND    LGPWG,GRDPNT $
37  GPWG    BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
38  OFP     OGPWG,,,,,// $
39  LABEL   LGPWG $
40  EQUIV   KGGX,KGG/NOGENL $
41  CHKPNT  KGG $
42  COND    LBL11,NOGENL $
43  SMA3    GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $
44  CHKPNT  KGG $
45  LABEL   LBL11 $
46  GP4     CASECC,GEOM4,EQEXIN,     GPDT,BGPDT,CSTM/RG,,USET,ASET/  V,N,
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COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING
SERIES 0

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
             LUSET/V,N,MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/C,N,0/
             V,N,REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $
47  SAVE     MPCF1,SINGLE,OMIT,REACT,NOSET,MPCF2,REPEAT,NOL,NOA $
48  PARAM    //C,N,NOT/V,N,REACDATA /V,N,REACT $
49  COND     ERROR5,REACDATA $
50  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,QPC/SINGLE $
51  GPCYC    GEOM4,EQEXIN,USET /CYCD/ V,Y,CTYPE / V,N,NOGO $
52  SAVE     NOGO $
53  CHKPNT   CYCD $
54  COND     ERROR6,NOGO $
55  COND     LBL4,GENEL $
56  GPSP     GPL,GPST,USET,SIL/OGPST/V,N,NOGPST $
57  SAVE     NOGPST $
58  COND     LBL4,NOGPST $
59  OFP      OGPST,,,,,// $
60  LABEL    LBL4 $
61  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
62  CHKPNT   KNN,MNN $
63  COND     LBL2,MPCF1 $
64  MCE1     USET,RG/GM $
65  CHKPNT   GM $
66  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
67  CHKPNT   KNN,MNN $
68  LABEL    LBL2 $
69  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
70  CHKPNT   KFF,MFF $
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RIGID FORMAT DMAP LISTING
SERIES D

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
71  COND     LBL3,SINGLE $
72  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
73  CHKPNT   KFF,KFS,MFF $
74  LABEL    LBL3 $
75  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
76  CHKPNT   KAA,MAA $
77  COND     LBL5,OMIT $
78  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
79  CHKPNT   GO,KAA $
80  SMP2     USET,GO,MFF/MAA $
81  CHKPNT   MAA $
82  LABEL    LBL5 $
83  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/V,
             N,LUSET/V,N,LUSETD/V,N,NOTFL/V,N,NODLT/V,N,NOPSDL/V,N,NOFRL/V,
             N,NONLFT/V,N,NOTRL/V,N,NOEED/C,N,/V,N,NOUE $
84  SAVE     LUSETD,NOUE,NOEED $
85  COND     ERROR2,NOEED $
86  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
87  CYCT2    CYCD,KAA,MAA,,, /KKK,MKK,,, / C,N,FORE / V,Y,NSEGS=-1 /V,Y,
             KINDEX=-1 / V,Y,CYCSEQ=-1 / C,N,1 / V,N,NOGO $
88  SAVE     NOGO $
89  CHKPNT   KKK,MKK $
90  COND     ERROR6,NOGO $
91  READ     KKK,MKK,,,EED,,CASECC / LAMK,PHIK,  ,OEIGS / C,N,MODES /V,N,
             NEIGV $
92  SAVE     NEIGV $
93  CHKPNT   LAMK,PHIK,  OEIGS $
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COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING
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AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 94  PARAM    //C,N,MPY / V,N,CARDNO / C,N,0 / C,N,0 $
 95  OFP      OEIGS,LAMK,,,, // V,N,CARDNO $
 96  SAVE     CARDNO $
 97  COND     ERROR4,NEIGV $
 98  CYCT2    CYCD,,,,PHIK,LAMK /,,,PHIA,LAMA / C,N,BACK / V,Y,NSEGS /V,V,
              KINDEX / V,Y,CYCSEQ / C,N,1 / V,N,NOGO $
 99  SAVE     NOGO $
100  CHKPNT   LAMA,PHIA $
101  COND     ERROR6,NOGO $
102  SDR1     USET,,PHIA,,,GO,GM,,KFS,, / PHIG,, / C,N,1 / C,N,REIG $
103  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,,PHIG,EST,, / ,,
              OPHIG,,, / C,N,REIG $
104  OFP      OPHIG,,,,,// V,N,CARDNO $
105  SAVE     CARDNO $
106  APDB     EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO / AERO,ACPT,FLIST,GTKA,PVECT/
              V,N,NK/V,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/V,Y,MTYPE/V,N,
              NEIGV/V,Y,KINDEX=-1 $
107  SAVE     NK,NJ $
108  CHKPNT   AERO,ACPT,FLIST,GTKA,PVECT $
109  PARTN    PHIA,PVECT, / PHIAX,,, / C,N,1 $
110  SMPYAD   PHIAX,MAA,PHIAX,,, / MI / C,N,3/C,N,1/C,N,1/C,N,0/C,N,1 $
111  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/V,N,LUSETD/V,N,
              NOK2PP/V,N,NOM2PP/V,N,NOB2PP $
112  SAVE     NOK2PP,NOM2PP,NOB2PP $
113  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
114  EQUIV    M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $
115  CHKPNT   K2PP,M2PP,B2PP,K2DD,M2DD,B2DD $
116  GKAD     USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/C,N,
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RIGID FORMAT DMAP LISTING
SERIES O

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
             CMPLEV/C,N,DISP/C,N,MODAL/C,N,0.0/C,N,0.0/C,N,0.0/V,N,NOK2PP/V,
             N,NOM2PP/V,N,NOB2PP/V,N,MPCF1/V,N,SINGLE/V,N,OMIT/V,N,NOUE/ C,
             N,-1/C,N,-1/C,N,-1/C,N,-1 $
117 CHKPNT   K2DD,M2DD,B2DD,GOD,GMD $
118 GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASECC / MHH,BHH,KHH,
             PHIDH / V,N,NOUE/C,Y,LMODES=999999/C,Y,LFREQ=0.0/C,Y,HFREQ=0.0/
             V,N,NOM2PP/V,N,NOB2PP/V,N,NOK2PP/V,N,NONCUP/V,N,FMODE/C,Y,
             KDAMP=-1 $
119 SAVE     NONCUP,FMODE $
120 CHKPNT   MHH,BHH,KHH,PHIDH $
121 PARAML   PCDB//C,N,PRES/C,N,/C,N,/C,N,/V,N,NOPCDB $
122 PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS / NOPCDB $
123 COND     P2,NOPCDB $
124 PLTSET   PCDB,EQDYN,ECT / PLTSETX,PLTPAR,GPSETS,ELSETS / V,N,NSIL1 /V,N,
             JUMPPLOT=-1 $
125 SAVE     NSIL1,JUMPPLOT $
126 PRTMSG   PLTSETX // $
127 PARAM    //C,N,MPY/V,N,PLTFLG/C,N,1/C,N,1 $
128 PARAM    //C,N,MPY/V,N,PFILE/C,N,0/C,N,0 $
129 COND     P2,JUMPPLOT $
130 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQDYN,,,,,/PLOTX1/V,N,NSIL1/
             V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $
131 SAVE     JUMPPLOT,PLTFLG,PFILE $
132 PRTMSG   PLOTX1 // $
133 LABEL    P2 $
134 COND     ERROR2,NOEED $
135 PARAM    //C,N,ADD/V,N,DESTRY/C,N,0/C,N,1 $
136 AMG      AERO,ACPT/AJJL,SKJ,D1JK,D2JK/V,N,NK/V,N,NJ/V,N,DESTRY $
137 SAVE     DESTRY $
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COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING
SERIES 0

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
138  CHKPNT    AJJL,SKJ,D1JK,D2JK $
139  COND      NODJE,NODJE $
140  INPUTT2   /D1JE,D2JE,,,/C,Y,POSITION=-1/C,Y,UNITNUM=11/   C,Y,USRLABEL=
               TAPEID $
141  LABEL     NODJE $
142  PARAM     //C,N,ADD/V,N,XQHHL/C,N,1/C,N,0 $
143  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,,  /V,
               N,NOUE/V,N,XQHHL $
144  SAVE      XQHHL $
145  CHKPNT    QHHL $
146  PARAM     //C,N,MPY/V,N,NOP/C,N,-1/C,N,1 $
147  PARAM     //C,N,MPY/V,N,NOP/C,N,1/C,N,1 $
148  PARAM     //C,N,MPY/V,N,NOH/C,N,0/C,N,1 $
149  PARAM     //C,N,MPY/V,N,FLOOP/V,Y,NODJE=-1/C,N,0 $
150  JUMP      LOOPTOP $
151  LABEL     LOOPTOP $
152  FA1       KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/V,N,FLOOP/V,
               N,TSTART $
153  SAVE      FLOOP,TSTART $
154  CEAD      KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS/V,N,EIGVS $
155  SAVE      EIGVS $
156  COND      LBLZAP,EIGVS $
157  COND      LBL16,NOH $
158  VDR       CASECC,EQDYN,USETD,PHIH,CLAMA,,/OPHIH,/C,N,CEIGEN/C,N,MODAL/C,
               N,123/V,N,NOH/V,N,NOP/V,N,FMODE $
159  SAVE      NOH,NOP $
160  COND      LBL16,NOH $
```

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RIGID FORMAT DMAP LISTING
SERIES J

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
161  OFP      OPHIH,,,,,//V,N,CARDNO $
162  SAVE     CARDNO $
163  LABEL    LBL16 $
164  FA2      PHIH,CLAMA,FSAVE/PHIHL,CLAMAL,CASEYY,OVG/V,N,TSTART/C,Y,VREF=
              1.0/C,Y,PRINT=YESB $
165  SAVE     TSTART $
166  CHKPNT   PHIHL,CLAMAL,CASEYY,OVG $
167  COND     CONTINUE,TSTART $
168  LABEL    LBLZAP $
169  COND     CONTINUE,FLOOP $
170  REPT     LOOPTOP,100  $
171  JUMP     ERROR3 $
172  LABEL    CONTINUE $
173  CHKPNT   OVG $
174  PARAML   XYCDB//C,N,PRES/C,N,/C,N,/C,N,/V,N,NOXYCDB $
175  COND     NOXYOUT,NOXYCDB $
176  XYTRAN   XYCDB,OVG,,,,/XYPLTCE/C,N,VG/C,N,PSET/V,N,PFILE/V,N,CARDNO $
177  SAVE     PFILE,CARDNO $
178  XYPLOT   XYPLTCE// $
179  LABEL    NOXYOUT $
180  PARAM    //C,N,AND/V,N,PJUMP/V,N,NOP=-1/V,N,JUMPPLOT $
181  COND     FINIS,PJUMP $
182  MODACC   CASEYY,CLAMAL,PHIHL,CASECC,,/CLAMAL1,CPHIH1,CASEZZ,,/C,N,
              CEIGN $
183  DDR1     CPHIH1,PHIDH/CPHID $
184  CHKPNT   CPHID $
```

ORIGINAL PAGE IS
OF POOR QUALITY

COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING
SERIES D

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
185  EQUIV    CPHID,CPHIP/NOA $
186  COND     LBL14,NOA $
187  SDR1     USETD,,CPHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/C,N,1/C,N,DYNAMICS $
188  LABEL    LBL14 $
189  CHKPNT   CPHIP,QPC $
190  EQUIV    CPHID,CPHIA/NOUE $
191  COND     LBLNOE,NOUE $
192  VEC      USETD/RP/C,N,D/C,N,A/C,N,E $
193  PARTN    CPHID,,RP/CPHIA,,,/C,N,1/C,N,3 $
194  LABEL    LBLNOE $
195  SDR2     CASEZZ,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDT,CLAMAL1,QPC,CPHIP,EST,,/
              ,UQPC1,UCPHIP,UESC1,UEFC1,PCPHIP/C,N,CEIGN $
196  CHKPNT   PCPHIP $
197  OFP      UCPHIP,UQPC1,UESC1,UEFC1,,//V,N,CARDNO $
198  COND     P3,JUMPPLOT $
199  PLOT     PLTPAR,GPSETS,ELSETS,CASEZZ,BGPDT,EQDYN,SILD,,PCPHIP,,/PLOTX3/
              V,N,NSIL1/V,N,LUSET/V,N,JUMPPLOT /V,N,PLTFLG/V,N,PFILE $
200  PRTMSG   PLOTX3// $
201  LABEL    P3 $
202  JUMP     FINIS $
203  LABEL    ERROR1 $
204  PRTPARM  //C,N,-1/C,N,FSUBSCN $
205  LABEL    ERROR2 $
206  PRTPARM  //C,N,-2/C,N,FSUBSCN $
207  LABEL    ERROR3 $
208  PRTPARM  //C,N,-3/C,N,FSUBSCN $
```

RIGID FORMAT DMAP LISTING
SERIES 0

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
LABEL     ERROR4 $
PRTPARM   //C,N,-4/C,N,FSUBSON $
LABEL     ERROR5 $
PRTPARM   // C,N,-4 / C,N,CYCMODES $
LABEL     ERROR6 $
PRTPARM   // C,N,-5 / C,N,CYCMODES $
LABEL     FINIS $
END       $
```

NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM

3.24.2 Description of DMAP Operations for Compressor Blade Cyclic Modal Flutter Analysis

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

5. Go to DMAP No. 203 and print error message if no grid points are present.

8. GP2 generates Element Connection Table with internal indices.

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

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

14. Go to DMAP No. 203 and print error message if no elements have been defined.

20. Go to DMAP No. 25 if stiffness matrix is not user input.

21. Set parameter NOKGGX = -1 so that the stiffness matrix will not be generated in DMAP No. 26.

22. INPUTT1 reads the user supplied stiffness matrix from tape (GINO file INPT).

23. Equivalence $[K_{gg}^x]$ to $[K_{gg}^{IN}]$.

26. EMG generates structural element matrix tables and dictionaries for later assembly.

29. Go to DMAP No. 32 if no stiffness matrix is to be assembled.

30. EMA assembles stiffness matrix $[K_{gg}^x]$ and Grid Point Singularity Table.

33. Go to DMAP No. 203 and print error message if no mass matrix exists.

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

36. Go to DMAP No. 39 if no weight and balance request.

37. GPWG generates weight and balance information.

38. ØFP formats weight and balance information and places it on the system output file for printing.

40. Equivalence $[K_{gg}^x]$ to $[K_{gg}]$ if no general elements.

42. Go to DMAP No. 45 if no general elements.

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

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

49. Go to DMAP No. 211 and print error message if free-body supports are present.

51. GPCYC prepares segment boundary table.

54. Go to DMAP No. 213 and print error message if CYJOIN data is inconsistent.

55. Go to DMAP No. 60 if general elements present.

56. GPSP determines if possible grid point singularities remain.

58. Go to DMAP No. 60 if no grid point singularities remain.

59. ØFP formats the table of possible grid point singularities and places it on the system output file for printing.

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

63. Go to DMAP No. 68 if MCE1 and MCE2 have already been executed for current set of multipoint constraints.

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

66. MCE2 partitions stiffness and mass matrices

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

and performs matrix reductions

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

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

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

71. Go to DMAP No. 74 if no single-point constraints.

72. SCE1 partitions out single-point constraints.

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

75. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted degrees of freedom.

77. Go to DMAP No. 82 if no omitted coordinates.

78. SMP1 partitions constrained stiffness matrix

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

and 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. 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

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

83. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating internal and external grid point numbers, including extra points introduced for dynamic analysis, and prepares Transfer Function Pool and Eigenvalue Extraction Data.

85. Go to DMAP No. 205 and print error message if no Eigenvalue Extraction Data.

86. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if no extra points introduced for dynamic analysis.

87. CYCT2 transforms matrices from symmetric components to solution set.

90. Go to DMAP No. 213 and print error message if CYCT2 error was found.

91. READ extracts real eigenvalues from the equation

$$[K_{kk} - \lambda M_{kk}]\{u_k\} = 0 \quad ,$$

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

1) Unit value of selected coordinate
2) Unit value of largest components
3) Unit value of generalized mass.

95. ØFP formats eigenvalues and summary of eigenvalue extraction information and places them on the system output file for printing.

97. Go to DMAP No. 209 and exit if no eigenvalues found.

98. CYCT2 finds symmetric components of eigenvectors from solution set eigenvectors.

101. Go to DMAP No. 213 and print error mess*** if CYCT2 error was found.

102. SDR1 recovers dependent components of th... ...envectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \begin{Bmatrix} \phi_a \\ \hline \phi_o \end{Bmatrix} = \{\phi_f\} \quad ,$$

$$\begin{Bmatrix} \phi_f \\ \hline \phi_s \end{Bmatrix} = \{\phi_n\} \quad , \qquad \{\phi_m\} \;\; [G_m]\{\phi_n\} \quad ,$$

$$\begin{Bmatrix} \phi_n \\ \hline \phi_m \end{Bmatrix} = \{\phi_g\}$$

103. SDR2 prepares eigenvectors for output (ØPHIG).

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

106. APDB processes the aerodynamic data cards from EDT. AERO 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.

109. PARTN partitions the eigenvector into all sine or all cosine components.

110. SMPYAD calculates modal mass matrix

$$[M] = [\phi_a^x]^T \, [M_{aa}] \, [\phi_a^x]$$

111. MTRXIN selects the direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$, and $[B_{pp}^2]$.

114. 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 no constraints applied.

116. GKAD applies constraints to direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$, and $[M_{dd}^2]$, and $[B_{dd}^2]$ (see Section 9.3.3 of the Theoretical Manual) and forms $[G_{md}]$ and $[G_{od}]$.

118. GKAM selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, matrices and damping matrices in modal coordinates:

$$[K_{hh}] = \begin{bmatrix} k_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] \ ,$$

$$[M_{hh}] = \begin{bmatrix} m_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}] \ ,$$

$$[B_{hh}] = \begin{bmatrix} b_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] \ .$$

where

<u>KDAMP = 1</u>	<u>KDAMP = -1 (default)</u>
m_i = modal masses	m_i = modal masses
$b_i = m_i \ 2\pi \ f_i g(f_i)$	$b_i = 0$
$k_i = m_i \ 4\pi^2 \ f_i$	$k_i = (1+ig(f_i)) \ 4\pi^2 f_i^2 m_i$

123. Go to DMAP No. 133 if no plot package is present.

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

126. PRTMSG prints error messages associated with structure plotter.

129. GO to DMAP No. 133 if no undeformed aerodynamic structure plot request.

130. PLØT generates all requested undeformed structure plots.

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

134. Go to DMAP No. 205 and print error message if no Eigenvalue Extraction Data.

136. AMG forms the aerodynamic materix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D^1_{jk}]$ and $[D^2_{jk}]$.

139. Go to DMAP No. 141 if no user-supplied downwash coefficients.

140. INPUTT2 provides the user-supplied downwash factors due to extra points($[D^1_{je}]$, $[D^2_{je}]$).

143. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] \qquad [G_{ki}] = [G_{ka}^T]^T[\phi_{ai}]$$

$$[D_{jh}^1] \leftarrow [D_{ji}^1 \mid D_{je}^1] \qquad [D_{ji}^1] = [D_{jk}^1]^T[G_{ki}]$$

$$[D_{jh}^2] \leftarrow [D_{ji}^2 \mid D_{je}^2] \qquad [D_{ji}^2] = [D_{jk}^2]^T[G_{ki}]$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2]$$

for each group:

$$[Q_{jh}] = [A_{jj}^T]^{-1}{}_{group}\,[D_{jh}]\ group$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}]$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

$$[Q_{hh}] \leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right]$$

149. PARAM initializes the flutter loop couter (FLØØP) to zero.

150. Go to next DMAP instruction if cold start or modified restart. LØØPTØP will be altered by the Executive System to the proper location inside the loop for unmodified restarts within the loop.

151. Beginning of loop for flutter.

152. 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

$$M_{hh}^x = (k^2/b^2)M_{hh} + (\rho/2)\,Q_{hh} \;,$$

$$K_{hh}^x = K_{hh} \;,$$

$$B_{hh}^x = 0$$

154. CEAD extracts complex eigenvalues 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 largest component.

156. Go to DMAP No. 168 if no complex eigenvalues found.

157. Go to DMAP No. 163 if no output request for the extra points introduced for dynamic analysis or modal coordinates.

158. VDR prepares eigenvectors for output, using only the extra points introduced for dynamic analysis and modal coordinates.

160. Go to DMAP No. 163 if no output request for the extra points introduced for dynamic analysis or modal coordinates.

161 ØFP formats eigenvectors for extra points introduced for dynamic analysis and modal coordinates and places them on the system output file for printing.

164. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to ØVG.

167. Go to DMAP No. 172 if there is insufficient time for another flutter loop.

169. Go to DMAP No. 172 if flutter loop complete.

171. Go to DMAP No. 207 for additional aerodynamic configuration triplet values.

175. Go to DMAP No. 179 if no X-Y plot package is present.

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

178. XYPLØT prepares requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads or single-point forces of constraint vs. time.

181. Go to DMAP No. 215 if no output requests involve dependent degrees of freedom or forces and stresses.

182. MØDACC selects a list of eigenvalues and vectors whose imaginary parts (velocity in input units) are close to a user input list.

183. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$[\phi^c_d] = [\phi_{dh}][\phi_h] \quad .$$

185. Equivalence $[\phi^c_p]$ to $[\phi^c_p]$ if no constraints applied.

186 Go to DMAP No. 188 if no constraints applied.

187. SDR1 recovers dependent components of eigenvectors

$$\{\phi_d^c\} = [G_o^d]\{\phi_d^c\} \quad , \qquad \begin{Bmatrix}\phi_d \\ \hline \phi_o\end{Bmatrix} = \{\phi_f^c + \phi_e^c\} \quad ,$$

$$\begin{Bmatrix}\phi_f^c + \phi_e^c \\ \hline \phi_s^c\end{Bmatrix} = \{\phi_n^c + \phi_e^c\} \quad , \qquad \{\phi_m^c\} = [G_m^d]\{\phi_n^c + \phi_e^c\} \quad .$$

$$\begin{Bmatrix}\phi_f^c + \phi_e^c \\ \hline \phi_e^c\end{Bmatrix} = \{\phi_p^c\}$$

and recovers single-point forces of constraint $\{q_s\} =$

$$[K_{fs}^T]\{\phi_f\}, \begin{Bmatrix} 0 \\ \hline q_s\end{Bmatrix} = \{Q_p^c\} \quad .$$

190. Equivalence $[\phi_d^c]$ to $[\phi_a^c]$ if no extra points introduced for dynamic analysis.

191. Go to DMAP No. 194 if no extra points present.

192. VEC generates a d-size partitioning vector (RP) for the a and e sets.

193. PARTN performs partition of $[\phi_d^c]$ using RP.

$$\{\phi_d^c\} = \begin{Bmatrix}\phi_a^c \\ \hline \phi_e^c\end{Bmatrix}$$

195. SDR2 calculates element forces and stresses (ØEFC1, ØESC1) and prepares eigenvectors and single-point forces of constraint for output (ØCPHIP, ØQPC1). It also prepares PCPHIP for deformed plotting.

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

198. Go to DMAP No. 194 if no deformed structure plots are requested.

199. PLØT prepares all deformed structure plots.

200. PRTMSG prints plotter data and engineering data for each deformed plot generated.

202. Go to DMAP No. 215 and make normal exit.

204. MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATIØN.

206. MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

208. MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TO EXECUTE MØRE THAN 100 LØØPS.

210. MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

212. NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - FREE BØDY SUPPØRTS NØT ALLØWED.

214. NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 5 - CYCLIC SYMMETRY DATA ERRØR.

3.24.3 Output for Compressor Blade Modal Flutter Analysis

The Real Eigen value Summary Table and the Real Eigenvalue Analysis summary, as described under Normal Mode Analysis, are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The grid point singularities from the structural model are also output.

A flutter summary for each value of the configuration parameters is printed out if PRINT=YESB. This shows ρ, k, 1/k, σ, $\sigma * V_{sound}$, V, g and f for each complex eigenvalue.

V-g and V-f plots may be requested by the XYOUT 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 (SORT1) and (m, k, ρ) may be requested for all complex eigenvalues kept, 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, extra points) or SØLUTION 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 elements.

3.24.4 Case Control Deck and Parameters for Compressor 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.

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.

The following user parameters are used in Compressor Blade Cyclic Modal Flutter Analysis.

1. GRDPNT - optional - A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional - The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in SMA2. Not recommended for use in hydroelastic problems.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional - These parameters will 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. <u>LFREQ and HFREQ</u> - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is lower limit and HFREQ is upper limit) of the modes to be used in the modal formulation. To use this option, LMØDES must be set to 0.

5. <u>LMØDES</u> - 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 defalult value will request all modes to be used.

6. <u>NØDJE</u> - optional in modal flutter analysis. A positive integer of this parameter indicates that user supplied downwash matrices due to extra points are to be read from tape via the INPUTT2 module in the rigid format. The default value is -1.

7. <u>P1, P2 and P3</u> - required in modal flutter analysis when using NØDJE parameter. See Section 5.3.2 for tape operation parameters required by INPUTT2 module. The defaults for P1, P2, and P3 are -1, 11 and TAPEID, respectively.

8. <u>VREF</u> - optional in modal flutter analysis. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.

9. <u>PRINT</u> - optional in modal flutter analysis. The BCD value NØ, of this parameter will suppress the automatic printing of the flutter summary for the k method. The flutter summary table will be printed if the BCD value is YES for wing flutter, or YESB for blade flutter. The default is YES.

10. <u>CTYPE</u> - 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 anti-symmetric components

11. <u>NSEGS</u> - required - the integer value of this parameter is the number of identical seqments in the structural model.

12. 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 for alternating the cosine and sine terms. The default value is -1.

13. KINDEX - required in compressor blade cyclic modal flutter analysis. The integer value of this parameter specifies a single value of the harmonic index.

14. MINMACH - optional in blade flutter analysis. This is the minimum Mach number above which the supersonic unsteady cascade theory is valid. The default is 1.01.

15. MAXMACH - optional in blade flutter analysis. This is the maximum Mach number below which the subsonic unsteady cascade theory is valid. The default value is 0.80.

16. IREF - optional in blade flutter analysis. This defines the reference streamline number. IREF must be equal to a SLN on a STREAML2 bulk data card. The default value, -1, represents the streamsurface at the blade tip. If IREF does not correspond to a SLN, then the default will be taken.

17. MTYPE - optional in cyclic modal blade flutter analysis. This controls which components of the cyclic modes are to be used in the modal formulation. MTYPE = SINE for sine components and MTYPE = COSINE for cosine components. The default BCD value is COSINE.

18. KGGIN - optional in blade flutter analysis. A positive integer of this parameter indicates that the user supplied stiffness matrix is to be read from tape (GINO file INPT) via the INPUTT1 module in the rigid format. The default is -1.

6.1.1.16 Rigid Format Error Messages for Static Aerothermoelastic Analysis with Differential Stiffness

NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

The differential stiffness matrix is null because no structural elements have been defined with Connection cards.

NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

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.

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.

6.1.3.3 Rigid Format Error Messages for Compressor Blade Cyclic Modal Flutter Analysis.

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.

NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS

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

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 FA2.

NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

NØ. 5 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Statics with Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØ. 6 - CYCLIC SYMMETRY DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

A	P	Parameter value used to control utility module MATGPR print of A-set matrices.
ABFL	DBM	$[A_{b,f\ell}]$ - Hydroelastic boundary area factor matrix.
ABFLT	DBM	Transpose of $[A_{b,f\ell}]$.
ACCE	IC	Abbreviated form of ACCELERATIØN.
ACCE	IS	Acceleration output requests.
ACCELERATIØN	IC	Output request for acceleration vector. (UM-2.3, 4.2)
ACPT	DBT	Aerodynamic Connection and Property Data.
Active column	PH	Column containing at least one nonzero term outside the band.
ADD	FMM	Functional module to add two matrices together.
ADD	M	Parameter constant used in utility module PARAM.
ADD5	FMM	Functional module to add up to five matrices together.
ADR	FMS	Aerodynamic data recovery.
ADUMi	IB	Defines attributes of dummy elements 1 through 9.
AEFACT	IB	Used to input lists of real numbers for aeroelastic analysis.
AERØ	DBT	Aerodynamic Matrix Generation Data.
AERØ	IB	Gives basic aerodynamic parameters.
AERØF	IC	Aerodynamic force output request.
AERØFØRCE	IC	Requests frequency dependent aerodynamic loads on interconnection points in aeroelastic response analysis.
AJJL	DBML	Aerodynamic Influence Matrix List.
ALG	FMS	Aerodynamic load generator.
ALGDB	DBT	Aerodynamic Load input for ALG (D-16).
ALL	IC	Output request for all of a specified type of output.
ALLEDGE TICS	IC	Request tic marks on all edges of X-Y plot.
ALOAD	P	Set negative if no aerodynamic loads (D-16).
ALTER	IA	Alter statement for DMAP or rigid format.
ALWAYS	P	Parameter set to -1 by a PARAM statement.
AMG	FMA	Aerodynamic Matrix Generator.
AMP	FMA	Aerodynamic Matrix Processor.
AND	M	Parameter constant used in executive module PARAM.
AØUT$	M	Indicates restart with solution set output request,
APD	FMA	Aerodynamic pool distributor and element generator.
APDB	FMS	Aerodynamic pool distributor for blades.

APP	IA	Control card which specifies approach (DISP, DMAP, HEAT or AERØ)
APP	P	Approach flag used for modules with several functions.
APPEND	M	File may be extended (see FILE).
APRESS	PU	Positive Value generates aerodynamic pressures.
ASDMAP	FMSS	Assemble substructure DMAP.
ASET	IB	Analysis set coordinate definition card.
ASET1	IB	Analysis set coordinate definition card.
ATEMP	PU	Positive value generates aerodynamic temperatures.
AUTØ	IC	Requests X-Y plot of autocorrelation function.
AUTØ	DBT	Autocorrelation function table.
AXES	IC	Defines orientation of object for structure plot.
AXIC	DBT	Generated by Input File Processor 3 (IFP3) for axisymmetric conical shell problems.
AXIC	IB	Axisymmetrical conical shell definition card. When this card is present, most other bulk data cards may not be used.
AXIF	IB	Controls the formulation of a hydroelastic problem.
AXISYM$	M	Indicates restart with conical shell or hydroelastic elements.
AXISYMMETRIC	IC	Selects boundary conditions for axisymmetric shell problems or specifies the existence of hydroelastic fluid harmonics.
AXSLØT	IB	Controls the formulation of acoustic analysis problems.

CSLØT3	IB	Triangular slot element connection definition card for acoustic analysis.
CSLØT4	IB	Quadrilateral slot element connection definition card for acoustic analysis.
CSP	IC	Selects a set of contact surface points.
CSP	IB	Contact surface point set definition.
CSTM	DBS	Local coordinate system transformation matrices.
CSTM	DBT	Coordinate System Transformation Matrices.
CSTMA	DBT	Coordinate System Transformation Matrices - Aerodynamics.
CTETRA	IB	Tetrahedron element connection definition card.
CTØRDRG	IB	Toroidal ring element connection card.
CTRAPRG	IB	Trapezoidal ring element connection card.
CTRBSC	IB	Basic bending triangular element connection definition card.
CTRIA1	IB	General triangular element connection definition card.
CTRIA2	IB	Homogeneous triangular element connection definition card.
CTRIARG	IB	Triangular ring element connection card.
CTRIM	IB	Linear strain triangular element connection.
CTRMRM	IB	Triangular membrane element connection definition card.
CTRPLT	IB	Triangular bending element connection definition card.
CTRPLT1	IB	Triangular element connection.
CTRSHL	IB	Triangular shell element connection.
CTUBE	IB	Tube element connection definition card.
CTWIST	IB	Twist panel element connection definition card.
CTYPE	PU	Defines the type of cyclic symmetry.
CURVLINESYMBØL	IC	Request to connect points with lines and/or to use symbols for X-Y plots.
CVISC	IB	Viscous damper element connection definition card.
CWEDGE	IB	Wedge element connection definition card.
CYCIØ	PU	A parameter which specifies the form of the input and output data using cyclic symmetry.
CYCSEQ	PU	A parameter which specifies the procedure for sequencing the equations in the solution set using cyclic symmetry.

FMØDE	P	Mode number of first mode selected by user in modal dynamics formulations.
FØL	DBT	Frequency response output frequencies.
FØRCE	IB	Static load definition (vector).
FØRCE	IC	Request for output of element forces.
FØRCE1	IB	Static load definition (magnitude and two grid points).
FØRCE2	IB	Static load definition (magnitude and four grid points).
FØRCEAX	IB	Static load definition for conical shell problem.
FREEPT	IB	Defines point on a free surface of a fluid for output purposes.
FREQ	IB	Frequency list definition.
FREQ$	M	Indicates restart with change in frequencies to be solved.
FREQ1	IB	Frequency list definition (linear increments).
FREQ2	IB	Frequency list definition (logarithmic increments).
FREQRESP	P	Parameter used in SDR2 to indicate a frequency response problem.
FREQUENCY	IC	Selects the set of frequencies to be solved in frequency response problems.
FREQY	P	Selects between frequency and transient in aeroelastic response.
FRL	DBT	Frequency Response List.
FRLG	FMA	Frequency response load generator.
FRQSET	P	Used in FRRD to indicate user selected frequency set.
FRRD	FMS	Frequency and Random Response - Displacement approach.
FRRD2	FMA	Frequency response, with aerodynamic matrix capability.
FSAVE	DBT	Flutter Storage Save Table.
FSLIST	IB	Defines a free surface of a fluid in a hydroelastic problem.
Functional Module	PH	An independent group of subroutines that perform a structural analysis function.
FXCOOR	PU	Aerodynamic modification factor (D-16).
FYCOOR	PU	Aerodynamic modification factor (D-16).
FZCOOR	PU	Aerodynamic modification factor (D-16).

IC	IC	Transient analysis initial condition set selection.
ID	IA	The first card of any data deck is the identification (ID) card. The two data items on this card are BCD values.
IFAIL	P	Set negative by ALG if convergence fails (D-16).
IFP	EM	Input File Processor. The preface module which processes the sorted Bulk Data Deck and outputs various data blocks depending on the eard types present in the Bulk Data Deck.
IFP1	EM	Input File Processor 1. The preface module which processes the Case Control Deck and writes the CASECC, PCDB and XYCDB data blocks.
IFP3	EM	Input File Processor 3. The preface module which processes bulk data cards for a conical shell problem.
IFP4	EM	Input File Processor 4. The preface module which processes bulk data cards for a hydroelastic problem.
IFT	FMA	Inverse Fourier transformation.
IFTM	PU	A parameter which selects the method for integration of the Inverse Fourier Transform.
IFTSKP	L	Used to skip IFT module.
IMAG	IC	Output request for real and imaginary parts of some quantity such as displacement, load, single point force of constraint element force, or stress.
IMPL	P	Parameter constant used in executive module PARAM.
INCLUDE	IC	Used in set definition for structure plots.
INERTIA	P	Used in printing rigid format error messages for Static Analysis with Inertia Relief (D-2).
INERTIA RELIEF	IA	Selects rigid format for static analysis with inertia relief.
INPT	M	A reserved NASTRAN physical file which must be set up by the user when used.
INPUT	FMU	Generates most of bulk data for selected academic problems.
Input Data Block	PH	A data block input to a module. An input data block must have been previously output from some module and may not be written on.
Input Data Cards	PH	The card input data to the NASTRAN system are in 3 sets, the Executive Control Deck, the Case Control Deck, and the Bulk Data Deck.
INPUTT1	FMU	Reads data blocks from GINØ-written user tapes.
INPUTT2	FMU	Reads data blocks from FØRTRAN-written user tapes.
INPUTT3	FMX	Auxiliary input file processor.
INPUTT4	FMX	Auxiliary input file processor.
Internal Sort	PH	Same order as external sort except when SEQGP or SEQEP bulk data cards are used to change the sequence.

INV	IB	Inverse power eigenvalue analysis option - specified on EIGR, EIGB or EIGC cards.
IPRT	PU	Controls printing of aerodynamic results.
IREF	PU	Defines reference streamline for blade flutter.
IRES	PU	Causes printout of residual vectors in statics rigid formats when set nonnegative via a PARAM bulk data card. (D-1, D-2, D-4, D-5, D-6).
ISTART	PU	A parameter which causes the alternate starting method to be used in transient analysis.
ITEMS	IS	Specifies data items to be copied in or out.
JUMP	EM	Unconditional transfer DMAP statement.
JUMPPLØT	P	Parameter used by structure plotter modules PLTSET and PLØT.

KDSS	DBM	$[K^d_{ss}]$ - Partition of differential stiffness matrix.
KE	PH	Flutter analysis method.
KFF	DBM	$[K_{ff}]$ - Partition of stiffness matrix.
KFS	DBM	$[K_{fs}]$ - Partition of stiffness matrix.
KGG	DBM	$[K_{gg}]$ - Stiffness matrix generated by Structural Matrix Assembler.
KGGIN	PU	Positive value selects KGGX from INPUTT1.
KGGIN	DBM	Sum of elastic and differential stiffness matrices (D-16, A-9).
KGGL	DBM	$[K^{\ell}_{gg}]$ - Stiffness matrix for linear elements. Used only in the Piecewise Linear Analysis Rigid Format (D-6).
KGGLPG	P	Purge flag for KGGL matrix. If set to -1, it implies that there are no linear elements in the structural model. (D-6).
KGGNL	DBM	$[K^{n\ell}_{gg}]$ - Stiffness matrix for the nonlinear elements. Used in the Piecewise Linear Analysis Rigid Format only.
KGGSUM	DBM	Sum of KGGNL and KGGL. Used in the Piecewise Linear Analysis Rigid Format only. (D-6).
KGGX	DBM	$[K^x_{gg}]$ - Stiffness matrix excluding general elements.
KGGXL	DBM	$[K^{x\ell}_{gg}]$ - Stiffness matrix for linear elements (excluding general elements). Used in the Piecewise Linear Rigid Format only. (D-6).
KGGY	DBM	$[K^y_{gg}]$ - Stiffness matrix of general elements.
KHH	DBM	$[K_{hh}]$ - Stiffness matrix used in modal formulation of dynamics problems (D-10 thru D-12).
KINDEX	PU	A parameter which specifies a single value of the harmonic index using cyclic symmetry.
KLL	DBM	$[K_{\ell\ell}]$ - Stiffness matrix used in solution of problems in static analysis (D-1, D-2, D-4, D-5, D-6).
KLR	DBM	$[K_{\ell r}]$ - Partition of stiffness matrix.
KMAX	PU	A parameter which specifies the maximum value of the harmonic index using cyclic symmetry.
KMTX	DBS	Stiffness matrix.
KNN	DBM	$[K_{nn}]$ - Partition of stiffness matrix.
KØA	DBM	$[K_{oa}]$ - Stiffness matrix partition.
KØØ	DBM	$[K_{oo}]$ - Partition of stiffness matrix.
KRR	DBM	$[K_{rr}]$ - Partition of stiffness matrix.
KSS	DBM	$[K_{ss}]$ - Partition of stiffness matrix.
KTOTAL	DBM	Sum of elastic and differential stiffness matrices (D-16, A-9).
KTOUT	PU	Postive value outputs KTOTAL to OUTPUT1.
KXHH	DBM	Total modal stiffness matrix - h-set.

MATT5	IB	Specifies table references for temperature-dependent, anisotropic, thermal material properties.
MAX	IB	Eigenvector normalization option - used on EIGR, EIGB and EIGC cards.
MAXIMUM DEFØRMATIØN	IC	Indicates scale for deformed structure plots.
MAXIT	PU	Limits maximum number of iterations in nonlinear heat transfer analysis.
MAXLINES	IC	Maximum printer output line count - default value is 20000.
MAXMACH	PU	Controls subsonic unsteady cascade calculations.
MCE1	FMS	Multipoint Constraint Eliminator - part 1.
MCE2	FMS	Multipoint Constraint Eliminator - part 2.
MDD	DBM	$[M_{dd}]$ - Mass matrix used in direct formulation of dynamics problems (D-7 thru D-9).
MDEMA	P	Parameter indicating equivalence of MDD and MAA.
MDLCEAD	P	Used in printing rigid format error messages for modal complex eigenvalue analysis (D-10).
MDLFRRD	P	Used in printing rigid format error messages for modal frequency response (D-11).
MDLTRD	P	Used in printing rigid format error messages for modal transient response (D-12).
MEF1	DBT	Modal element forces, Sort 1 for ØFP.
MEF2	DBT	Modal element forces, Sort 2 for ØFP.
MERGE	FMM	Matrix merge functional module.
MES1	DBT	Modal element stresses, Sort 1 for ØFP.
MES2	DBT	Modal element stresses, Sort 2 for ØFP.
METHØD	IC	Selects method for real eigenvalue analysis.
METHØD	IS	Identifies EIGR Bulk Data card.
METHØD$	M	Indicates restart with change in eigenvalue extraction procedures.
MFF	DBM	$[M_{ff}]$ - Partition of mass matrix.
MGG	DBM	$[M_{gg}]$ - Mass matrix generated by Structural Matrix Assembler.
MHH	DBM	$[M_{hh}]$ - Mass matrix used in modal formulation of dynamics problems (D-10 thru D-12).
MI	DBM	$[m]$ - Modal mass matrix.
MIND	P	Minimum diagonal term of $[U_{oo}]$.
MINMACH	PU	Controls supersonic unsteady cascade calculations.
MKAERØ1	IB	Provides table of Mach numbers and reduced frequencies (k).
MKAERØ2	IB	Provides list of Mach numbers (m) and reduced frequencies (k).

PDUMi	IB	Property definition card for dummy elements 1 through 9.
PELAS	IB	Scalar elastic property definition card.
PEN	IC	Selects pen size for structure plots using table plotters.
PENSIZE	IC	Selects pen size for X-Y plots using table plotters.
PERSPECTIVE	IC	Specifies perspective projection for structure plots.
PFILE	P	Parameter used by PLØT module.
PG	DBM	Incremental load vector used in Piecewise Linear Analysis (D-6).
PG	DBM	Statics load vector generated by SSG1.
PGEOM	PU	Controls punching of GRID, CTRIA2, PTRIA2 and DTI cards from ALG.
PG1	DBM	Static load vector for Piecewise Linear Analysis (D-6).
PGG	DBM	Appended static load vector (D-1, D-2).
PGV1	DBM	Matrix of successive sums of incremental load vectors used only in Piecewise Linear Analysis Rigid Format (D-6).
PHASE	IC	Requests magnitude and phase form of complex quantities.
Phase 1	PH	An operation to create matrices and load vectors for substructuring analysis.
Phase 2	PH	An operation to combine and reduce matrices and load vectors for substructuring analysis.
Phase 3	PH	An operation to recover detailed data reduction for substructuring analysis.
PHBDY	IB	Boundary element property definition card for heat transfer analysis.
PHF	DBM	Total frequency response loads, modal.
PHFI	DBM	Non-gust frequency response loads, modal.
PHIA	DBM	$[\phi_a]$ - Real eigenvectors - solution set.
PHIAH	DBM	Eigenvectors, A-set.
PHID	DBM	$[\phi_a]$ - Complex eigenvectors - solution set, direct formulation.
PHIDH	DBM	$[\phi_{dh}]$ - Transformation matrix between modal and physical coordinates.
PHIG	DBM	$[\phi_g]$ - Real eigenvectors.
PHIH	DBM	$[\phi_h]$ - Complex eigenvectors - solution set, modal formulation.
PHIHL	DBM	Appended complex mode shapes - h-set.
PHIK	DBM	Eigenvectors, aerodynamic box points.
PHIL	DBS	Left side eigenvector matrix from unsymmetric CREDUCE operation.
PHIP	DBM	Eigenvectors, P-set.
PHIPA	DBM	Eigenvectors, PA-set.

PUNCH	IC	Output media request (PRINT or PUNCH)
PUNPRT	IA	Used to punch and print the problem deck from UMF or copy the problem deck from UNF onto NUMF and punch and print it.
PURGE	EM	DMAP statement which causes conditional purging of data blocks.
Purge	PH	A data block is said to be purged when it is flagged in the FIAT so that it will not be allocated to a physical file and so that modules attempting to access it will be signaled.
PUVPAT	DBT	Displacement vector used for plots, PA-set for aeroelastic
PVEC	DBS	Load vectors.
PVECT	DBM	Partitioning vector for cyclic modes (A-9).
PVISC	IB	Viscous element property definition card.
PVT	PH	Parameter value table. The PVT contains BCD names and values of all parameters input by means of PARAM bulk data cards. It is generated by the preface module IFP and is written on the Problem Tape.
P1	PU	INPUTT2 rewind option.
P2	PU	INPUTT2 unit number.
P3	PU	INPUTT2 tape id.

SET	IC	Definition of a set of elements, grid and/or scalar and/or extra points, frequencies, or times to be used in selecting output.
SET1	IB	Defines a set of structural grid points by a list.
SET2	IB	Defines a set of structural grid points by aerodynamic macro elements.
SETVAL	FMU	Parameter value initiator.
SGEN	FMSS	Substructure table generator.
SHEAR	IC	Requests structure plot for all shear panel elements.
SIGMA	PU	Defines Stefan-Boltzmann constant in heat transfer analysis.
SIGN	PU	Controls the type of static aerothermo-elastic analysis performed.
SIL	DBT	Scalar Index List for all grid points and extra scalar points introduced for dynamic analysis.
SILGA	DBT	Scalar Index List - Aerodynamic boxes only.
SINCØN	PU	Controls the automatic stiffness matrix singularity removal.
SINE	IC	Conical shell request for sine set boundary conditions.
SING	P	-1 if $[K_{oo}]$ is singular.
SINGLE	P	No single-point constraints.
SKIP BETWEEN FRAMES	IC	Request to insert blank frames on SC 4020 plotter for X-Y plots.
SKJ	DBM	Integration matrix.
SKPMGG	P	Parameter used in statics to control execution of functional module SMA2.
SKPPLT	L	Used to skip plot.
SLBDY	IB	Defines list of points on interface between axisymmetric fluid and radial slots.
SLØAD	IB	Scalar point load definition.
SLT	DBT	Static Loads Table.
SMA1	FMS	Structural Matrix Assembler - phase 1 - generates stiffness matrix $[K_{gg}]$ and structural damping matrix $[K^4_{gg}]$.
SMA2	FMS	Structural Matrix Assembler - phase 2 - generates mass matrix $[M_{gg}]$ and viscous damping matrix $[B_{gg}]$.
SMA3	FMS	Structural Matrix Assembler - phase 3 - add general element contributions to the stiffness matrix $[K_{gg}]$.
SMP1	FMS	Structural Matrix Partitioner - part 1.
SMP2	FMS	Structural Matrix Partitioner - part 2.
SMPYAD	FMM	Performs multiply-add matrix operation for up to five multiplications and one addition.

Spill	PH	Secondary storage devices are used because there is insufficient main storage to perform a matrix calculation or a data processing operation.
SPLINE	DBT	Splining Data Table.
SPLINE1	IB	Defines surface spline.
SPLINE2	IB	Defines beam spline.
SPLINE3	IB	User data to interpolate deflections at aerodynamic degrees of freedom.
SPØINT	IB	Scalar point definition card.
SSG1	FMS	Static Solution Generator - part 1.
SSG2	FMS	Static Solution Generator - part 2.
SSG3	FMS	Static Solution Generator - part 3.
SSG4	FMS	Static Solution Generator - part 4.
SSGHT	FMH	Solution generator for nonlinear heat transfer analysis.
STATIC	IC	Requests deformed structure plot for problem in Static Analysis.
STATIC ANALYSIS WITH CYCLIC SYMMETRY	IA	Selects rigid format for static analysis using cyclic symmetry.
STATIC HEAT TRANSFER ANALYSIS	IA	Selects rigid format for linear static analysis using heat transfer.
STATICS	IA	Selects statics rigid format for heat transfer or structural analysis.
STATICS	P	Parameter used in SDR2 to indicate Static Analysis.
STEADY STATE	IA	Selects rigid format for nonlinear static heat transfer analysis.
STEPS	IS	Frequency or time step output request for substructuring.
STEREØSCØPIC	IC	Requests stereoscopic projections for structure plot.
STREAML	PU	Controls the punching of STREAML1 and STREAML2 cards from ALG.
STREAML1	IB	Gives blade streamline data.
STREAML2	IB	Gives blade streamline data.
STRESS	IC	Requests the stresses in a set of structural elements or the velocity components in a fluid element in acoustic cavity analysis.
Structural Element	PH	One of the finite elements used to represent a part of a structure.
STST	NP	Defines the singularity tolerance in EMG.
SUBCASE	IC	Subcase definition.
SUBCASES	IS	Subcase output request.
SUBCØM	IC	This subcase is a linear combination of previous subcases.
SUBPH1	FMSS	Substructure, Plase 1.

YTMAX	IC	Do not plot points whose Y value lies above this value for upper half frame.
YTMIN	IC	Do not plot points whose Y value lies below this value for upper half frame.
YTITLE	IC	Y-axis title for upper half frame.
YTVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval for upper half frame.
YVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval.
YZ	IC	Requests Y and Z vectors for deformed structure plot.
Z	IC	Requests Z vector for deformed structure plot.
ZORIGN	PU	Aerodynamic modification factor (D-16).

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PROGRAMMER'S MANUAL UPDATES (LEVEL 17.7)

This section contains new and replacement pages for Level 17.7 of the NASTRAN Programmer's Manual, NASA SP-223(03).

These updates pertain to new and modified Functional Modules and Rigid Formats.

Pages to be inserted or replaced are:

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2.3.24.3	PS	SSG2	2.3-104
2.3.47.1	PSDF	RANDØM	2.3-222
2.3.29.8	PSDL	DPD	2.3-152
2.3.44.2	PSF	FRRD	2.3-195
2.3.74.4	PSS	RCØVR3	2.3-274
2.3.57.2	PST	TRLG	2.3-240
2.3.28.24	PUBGV1	SDR2	2.3-139
2.3.28.26	PUGV	SDR2	2.3-141
2.3.28.23	PUGV1	SDR2	2.3-138
2.3.28.27	PUPVC1	SDR2	2.3-142
2.3.87.4	PVECT	APDB	2.3-296
2.3.75.1	PVX	REDUCE	2.3-276
2.3.84.1	PX	CYCT1	2.3-292
2.3.74.2	QAS	RCØVR3	2.3-274
2.3.27.6	QBG	SDR1	2.3-112
2.3.27.3	QG	SDR1	2.3-111
2.3.36.3	QG1	PLA2	2.3-173
2.3.65.1	QHHL	AMP	2.3-256
2.3.65.2	QJHL	AMP	2.3-256
2.3.27.15	QP	SDR1	2.3-114
2.3.27.12	QPC	SDR1	2.3-113
2.3.24.1	QR	SSG2	2.3-104
2.3.13.1	RG	GP4	2.3-79
2.3.25.6	RUBLV	SSG3	2.3-108
2.3.25.3	RULV	SSG3	2.3-107
2.3.25.4	RUØV	SSG3	2.3-107
2.3.85.4	RUXV	CYCT2	2.3-294
2.3.76.7	SIL	SGEN	2.3-279
2.3.3.6	SIL	GP1	2.3-45

2.2.2 Index for Data Block Descriptions Sorted Alphabetically by Module

Record	Word	Type	Item
	179	I	Aerodynamic gust load set
	180	I	Same as 10-12 for element strain/curvature output
	181	I	
	182	I	
	173	I	Contact surface point set
	:		Not used
	LCC-1		
	LCC	I	Length of symmetry sequence (LSEM)
	LCC+1	R	Coefficients for symmetry sequence
	LCC+LSEM	R	
	LCC+LSEM+1	I	Set ID — Repeated for each set. End of record terminates.
	LCC+LSEM+2	I	Length of the set (LSET)
	LCC+LSEM+3		Set members
	.		
	.		
	.		
	LCC+LSEM+LSET	I	

Note

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

Table Trailer

Word 1 = number of records on CASECC
Word 2 = 0
Word 3 = maximum length of CASECC
Word 4 = 0
Word 5 = 0
Word 6 = 0

2.3.1.2 PCDB (TABLE)

Description

Plot Control Data Table for the structure plotter.

Table Format

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

Table Trailer

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

2.3.2.4 GEØM4 (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
ASET	5561	76	215
ASET1	5571	77	216
BDYC	910	9	175
BDYS	1210	12	177
BDYS1	1310	13	178
CØNCT	210	2	168
CØNCT1	110	41	167
CRIGDR	8210	82	297
CRIGD1	5310	53	279
CRIGD2	5410	54	284
CRIGD3	8310	83	298
CSP	3291	91	291
CYJØIN	5210	52	257
GTRAN	1510	15	187
LØADC	500	5	171
MPC	4901	49	17
MPCADD	4891	60	83
MPCAX	4015	40	149
MPCS	1110	11	176
ØMIT	5001	50	15
ØMIT1	4951	63	92
ØMITAX	4315	43	150
PØINTAX	4915	49	152
RELES	410	4	170
RINGAX	5615	56	145
SECTAX	6015	60	153
SPC	5501	55	16
SPC1	5481	58	12
SPCADD	5491	59	13
SPCAX	6215	62	148
SPCD	5110	51	256
SPCS	810	8	174
SPCS1	710	7	173
SPCSD	610	6	172
SUPAX	6415	64	151
SUPØRT	5601	56	14
TRANS	310	3	169

Card Type Formats:

ASET (2 words)	ID	C	

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

ASET1 (Open Ended)	C	G	G
	...	G	-1
BDYC (Open Ended)	ID	NAME1	SID1
	NAME2	SID2	...
	...	(blank)	-1

Card Type Formats Cont'd.:

BDYS (Open Ended)	SID	G1	C1
	G2	C2	...
	...	-1	-1
BDYS1 (Open Ended)	SID	C	G1
	G2	...	-1
CØNCT (Open Ended)	SID	C	SUBA
	SUBB	GA	GB
	GA	GB	...
	...	-1	-1
CØNCT1 (Open Ended)	NSUB	SID	NAME1
	...	$NAME_{NSUB}$	C1
	G11	...	$G_{1,NSUB}$
	C2	G21	...
	$G_{2,NSUB}$	...	-1
CRIGDR (4 words)	EID	G	G1
	C1		
CRIGD1 (Open Ended)	EID	IG	G1
and	G11	G12	G13
CRIGD2 (Open Ended)	G14	G15	G16
	G2	G21	G22
	G23	G24	G25
	G26	...	GM
	GM1	GM2	GM3
	GM4	GM5	GM6
	-1	N	-1
	-1	-1	-1
	-1		
CRIGD3 (Open Ended)	EID	IG1	IG11
	IG12	IG13	IG14
	IG15	IG16	IG2
	IG21	IG22	IG23
	IG24	IG25	IG26
	...	...	IGM
	IGM1	IGM2	IGM3
	IGM4	IGM5	IGM6
	MSET	DG1	DG11
	DG12	DG13	DG14
	DG15	DG16	DG2
	DG21	DG22	DG23
	DG24	DG25	DG26
	...	...	DGN
	DGN1	DGN2	DGN3
	DGN4	DGN5	DGN6
	-1	-K	-1
	-1	-1	-1
	-1		
CØP (open ended)	SID	GA1	GB1
	GA2	GB2	...
	...	GAn	GBn
	-1	-1	
CYJØIN (Open Ended)	SIDE	C	G1
	G2	...	-1
GTRAN (4 words)	TID	NAME	GID
	TRAN		

2.3.2.8 EDT (TABLE)

Card Types and Header Information:

Card Type	Header Word 1 Card Type	Header Word 2 Trailer Bit Position	Header Word 3 Internal Card Number
AEFACT	4002	40	273
AERØ	3202	32	265
CAERØ1	3002	30	263
CAERØ2	4301	43	301
CAERØ3	4401	44	302
CAERØ4	4501	45	303
CAERØ5	5001	50	309
DEFØRM	104	1	81
FLFACT	4102	41	274
FLUTTER	3902	39	272
MKAERØ1	3802	38	271
MKAERØ2	3702	37	270
PAERØ1	3102	31	264
PAERØ2	4601	46	304
PAERØ3	4701	47	305
PAERØ4	4801	48	306
PAERØ5	5101	51	310
SET1	3502	35	268
SET2	3602	36	269
SPLINE1	3302	33	266
SPLINE2	3402	34	267
SPLINE3	4901	49	307
STREAML1	3292	92	292
STREAML2	3293	93	293
VARIAN	4202	42	290

Card Type Formats:

AEFACT (Open Ended)	SID	F1	F2
	etc.	-1	
AERØ (6 words)	ACSID	VSØUND	BREF
	RHØREF	SVMXZ	SYMXX
CAERØ1 (16 words)	PID	CP	NSPAN
	NCHØRD	LSPAN	LCHØRD
	0	X1	Y1
	Z1	X12	X4
	Y4	Z4	X43
CAERØ2 (16 words)	EID	PID	CP
	NSB	MINT	LSB
	LDNT	IGID	X1
	Y1	Z1	X12
	...	...	...
	...		
CAERØ3 (16 words)	EID	PID	LP
	LISTW	LISTC1	LISTC2
	...	...	X1
	Y1	Z1	X12
	X4	Y4	Z4
	X43		

Card Type Formats (Cont.):

SET2 (8 words)	SID	EID	SP1
	SP2	CH1	CH2
	Z1	Z2	
SPLINE1 (6 words)	EID	CAERØ	BØX1
	BØX2	SETG	DZ
SPLINE2 (10 words)	EID	CAERØ	BØX1
	BØX2	SETG	DZ
	DTØR	CID	DTHX
	DTHY		
SPLINE3 (Open Ended)	SID	CAERØ	UFID
	CØMP	G1	C1
	A1	...	GM
	CM	AM	-1
STREAML1 (open ended)	SLN	G1	G2
	G3	G4	G5
	G6	...	Gn
	-1		
STREAML 2 (10 words)	SLN	NSTNS	STAGGER
	CHØRD	RADIUS	BSPACE
	MACH	DEN	VEL
	FLOWA		
VARIAN (Open Ended)	$DB\ell_2$	$DB\ell_2$	etc.

2.3.93 Data Blocks Output from Module ALG

2.3.93.1 CASECCA (Table)

Description

See description and format of CASECC table - Section 2.3.1.1.

2.3.93.2 GEOM3A (Table)

Description

See description and format of GEOM3 table - Section 2.3.2.3.

2.3.94 Data Blocks Output from Module APDB

2.3.94.1 AERØ (Table)

Description

See description and format of AERØ table - Section 2.3.62.8.

2.3.94.2 FLIST (Table)

Description

See description and format of FLIST table - Section 2.3.62.11.

2.3.94.3 GTKA (Matrix)

Description

See description and format of GTKA matrix - Section 2.3.63.1.

2.3.94.4 PVECT (Matrix)

Description

{ PVECT } - Partitioning vector for cyclic modes.

Matrix Trailer

Number of columns	= 1
Number of rows	= NEIGV (for KINDEX > 0, 2 · NEIGV)
Form	= rectagular
Type	= real-single precision

2.3.97.5 ACPT (Table)

Description

Aerodynamic connection and property table for compressor blades. Contains one record for each compressor blade.

Table Format

Record	Word	Type	Item	
0	1-2	B	Data block name (ACPT)	
1	1	I	Key word, 6 for compressor blades	
	2	I	IREF parameter	
	3	R	MINMACH parameter	
	4	R	MAXMACH parameter	
	5	I	Number of blade streamlines, NLINES	
	6	I	Number of stations on blade, NSTNS	
	7	I	Streamline number, SLN	REPEAT NLINES TIMES
	8	I	Number of stations on streamline, NSTNSX	
	9	R	Stagger angle, STAGGER	
	10	R	Chord length, CHORD	
	11	R	Radius of streamline, RADIUS	
	12	R	Blade spacing, BSPACE	
	13	R	Mach number, MACH	
	14	R	Gas density, DEN	
	15	R	Flow velocity, VEL	
	16	R	Flow angle, FLOWA	
	17	R	X-coordinate, basic	REPEAT NSTNS TIMES
	18	R	Y-coordinate, basic	
	19	R	Z-coordinate, basic	
2			Additional records for other blade	

Table Trailer

Word 1 = 1
Word 2-6 = zero

Notes

1. Words 7-19 are repeated for each streamline. There are NLINES streamlines and they are from the blade root to the blade tip. These data items are taken from the STREAML2 bulk data cards.

2. Words 17-19 are repeated for each node on the streamline. There are NSTNS triplets (X, Y, Z). They are from the blade leading edge to the blade trailing edge.

M O D U L E   P R O P E R T I E S   L I S T

MPLID	NWDS	WD1	MOD-NAME	TYP	IN	OUT	SCR	TOT	PARAMETERS ID	TYP	P	DEFAULT (IF ANY)	W1-W2 FLG
184	15	2648	MTRXTEST	1	1	2	10	13					
									1.	INT	2655	31	1
									2.	INT	2657	0	2
									3.	INT	2659	-99025015	3
									4.	INT	2661	-5099099	4
185	11	2663	EMA	1	3	2	3	8					
									1.	INT	2670	-1	1
									2.	RSP	2672	1.0000E+00	2
186	9	2674	(NONE)										
187	29	2257	ALG	1	7	2	4	13					
									1.	INT	2264	-1	1
									2.	INT	2266	-1	2
									3.	INT	2268	-1	3
									4.	INT	2270	-1	4
									5.	INT	2272	0	5
									6.	INT	2274	0	6
									7.	RSP	2276	1.0000E 00	7
									8.	RSP	2278	0.0	8
									9.	RSP	2280	1.0000E 00	9
									10.	RSP	2282	1.0000E 00	10
									11.	RSP	2284	1.0000E 00	11
188	7	2286	CSA	1	4	1	1	6	----- NO PARAMETERS EXIST -----				
189	20	2293	APDB	1	7	5	5	17					
									1.	INT	2300	-- NO DEFAULT --	1
									2.	INT	2301	-- NO DEFAULT --	2
									3.	RSP	2302	1.0100E 00	3
									4.	RSP	2304	8.0000E-01	4
									5.	INT	2306	-1	5
									6.	BCD	2308	COSINE	6- 7
									7.	INT	2311	-- NO DEFAULT --	8
									8.	INT	2312	-- NO DEFAULT --	9

*** END OF MPL PRINTOUT

*** THE MPL CONTAINS 189 ENTRYS. OF THESE, 20 ARE PAD ENTRYS.

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4.1.2 Alphabetical Index of Module Functional Descriptions

Section Number	Module Name	Section Number	Module Name
4.78	ADD	4.32	GPSP
4.96	ADD5	4.29	GPWG
4.162	ALG	4.21	GP1
4.114	AMG	4.22	GP2
4.115	AMP	4.25	GP3
4.112	APD	4.31	GP4
4.163	APDB		
4.217	ASDMAP		
***	BEGIN	4.5	IFP*
4.90	BMG	4.3	IFP1
4.56	CASE	4.6	IFP3*
4.59	CEAD	4.89	IFP4*
4.10	CHKPNT	4.91	IFP5*
4.128	CØMB1	4.97	INPUT
4.129	CØMB2	4.98	INPUTT1
4.13	CØND	4.99	INPUTT2
4.148	CØPY	**	INPUTT3
4.110	CYCT1	**	INPUTT4
4.111	CYCT2	4.12	JUMP
**	DDR	**	LABEL
4.141	DDRMM	4.72	MATGPR
4.67	DDR1	4.71	MATPRN
4.68	DDR2	4.73	MATPRT
4.81	DECØMP	4.33	MCE1
4.143	DIAGØNAL	4.34	MCE2
4.47	DPD	4.84	MERGE
4.121	DSCHK	**	MØDA
4.49	DSMG1	4.126	MØDACC
4.51	DSMG2	**	MØDB
**	DUMMØD1	**	MØDC
**	DUMMØD2	4.79	MPYAD
**	DUMMØD3	4.57	MTRXIN
**	DUMMØD4	4.70	ØFP
		4.120	ØPTPR1
4.123	EMA	4.142	ØPTPR2
4.124	EMG	**	ØUTPUT
4.18	END	4.100	ØUTPUT1
4.17	EQUIV	4.101	ØUTPUT2
4.130	EXIØ	4.102	ØUTPUT3
4.14	EXIT	**	ØUTPUT4
4.116	FA1	4.19	PARAM
4.117	FA2	4.118	PARAML
4.82	FBS	4.119	PARAMR
***	FILE	4.83	PARTN
4.61	FRRD	**	PARTVEC
		4.52	PLA1
4.113	GI	4.53	PLA2
4.58	GKAD	4.54	PLA3
4.66	GKAM	4.55	PLA4
4.109	GPCYC	4.24	PLØT
4.146	GPFDR		

* Executive System Internal Module, ** Dummy Module,
*** Executive System Instruction (No Module Functional Descriptions)

4.1.3 Alphabetical Index of Entry Point in Module Functional Descriptions

MODULE FUNCTIONAL DESCRIPTIONS

MODULE FUNCTIONAL DESCRIPTIONS

MODULE FUNCTIONAL DESCRIPTIONS

GENERAL COMMENTS AND INDEXES

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Name	Length	Meaning	Initiated to
ISTR	1	Storage flag for IFP1G titles	1
ISUB	1	Subcase or master CASECC pointer	1
K2PP B2PP M2PP	1 1 1	Key words for direct input matrix selection	K2PP B2PP M2PP
DSCØ	1	Key word for differential stiffness set selection	DSCØ
REPC	1	Key word for repeat subcase subcase	REPC
LENCC	1	Length of Case Control Record	200
LINE	1	Key word for LINE/page count	LINE
ØM	1	Word to distinguish between SUBCØM SUBCASE	ØMbb
TFL	1	Key word for transfer function set selection	TFL
DEFA	1	Key word for default specification	DEFA
ELST	1	Key word for element stress set selection	ELST
MAT	1	Key word for thermal material set selection	MATE
ØFRE	1	Key word for output frequency set selection	ØFRE
IMAG	1	Key word for real/imaginary printout	IMAG
PHAS	1	Key word for magnitude/phase printout	PHAS
REAL	1	Key word for real or real/imaginary printout	REAL
CMET	1	Key word for complex eigenvalue set selection	CMET
SDAM	1	Key word for Structural Damping Table for use in modal formulation	SDAM
INER	1	Key word for Inertia Relief Element set selection	INER
ADIS	1	Key word for solution set displacement selection	SDIS
AVEL	1	Key word for solution set velocity selection	SVEL
AACC	1	Key word for solution set acceleration selection	SACC
NØNL	1	Key word for non-linear load set selection	NØNL
CØNF	1	Not used	
XYPL	1	Key word for XYPLØT packet delimiter	XYPL
PLCØ	1	Key word for Piecewise Linear set selection	PLCØ

Name	Length	Meaning	Initiated to
AXIS	1	Key word for selection of Axis symmetric boundary condition	AXIS
NLLØ	1	Key word for non-linear output set selection	NLLØ
DELE	1	Key word for element deletion set selection	DELE
XYCB	1	GINØ file name of XY control data block	XYCB
ØNEB	1	BCD one	1bbb
HARM	1	Key word for harmonic output control	HARM
SINE	1	Key word for sine boundary conditions	SINE
CØSI	1	Key word for cosine boundary conditions	CØSI
FLUID	1	Key word for fluid boundary conditions	FLUI
SUBS	1	Key word for SUBSEQ	SUBS
AVEC	1	Key word for solution set vector output	SVEC
FØRC	1	Not used	
RAND	1	Key word for random set selection	RAND
XYØU	1	Key word for XYPLØT packet delimiter	XYØU
ØLØA	1	Key word for output load set selection	ØLØA
PLT1	1	GINØ file name of BCD plot tape	PLT1
PLT2	1	GINØ file name of binary plot tape	PLT2
XTIT	1	Key words for XY output titles	XTIT
YTIT	1		YTIT
TCUR	1		TCUR
YTTI	1		YTTI
YBTI	1		YBTI
IBEN		Right shifted blank '000b'	----
EQUAL		Right shifted equal '000='	----
PRES	1	Alternate displacement key word	PRES
TEMP	1	Alternate displacement key word	TEMP
CSP	1	Contact surface point set key word	CSP

4. Interface with /SYSTEM/ (See Section 2.4).

IFP1 can set the following cells of SYSTEM:

a. NØGØ - (NØGØ flag). If a fatal error is detected.

b. NLPP - (Number of lines per page). If a LINE card is supplied by the user.

c. STFTEM - (Material Temperature Set ID). If a TEMP(MATE) card is supplied.

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Table 1(h). Bulk Data Cards Processed by IFP Sorted by Internal Card Number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
291	CTRIM6	8	GEØM2	-2	12	16	913	1	6101	81	S1	6101	-1	41D3
292	PTRIM6	8	GEØM2	-2	8	12	802	1	6201	82	S1	6201	-1	41D4
293	CTRPLT1	8	GEØM2	-2	12	16	913	1	6301	83	S1	6301	-1	41D5
294	PTRPLT1	2	EPT	-2	8	20	1089	1	6401	84	S1	6401	-1	41D6
295	TEMPG	9	GEØM3	-2	-8	20	-1	0	8509	85	S4	6501	-1	41E1
296	TEMPP4	9	GEØM3	-2	-8	20	-1	0	8609	86	S4	6601	-1	41E2
297	CRIGDR	10	GEØM4	-2	4	8	37	1	8210	82	S3	6000	-1	41E3
298	CRIGD3	10	GEØM4	-2	-3	48	-1	1	8301	83	S3	7000	-1	41E4
299	CTRSHL	8	GEØM2	-2	12	16	913	1	7501	75	S1	7501	-1	41E5
300	PTRSHL	2	EPT	-2	20	24	1005	1	7601	76	S1	7601	-1	41E6
301	CAERØ2	4	EDT	0	12	16	39	1	4301	43	S5	6400	-1	42A1
302	CAERØ3	4	EDT	0	16	16	39	1	4401	44	S5	6400	-1	42A2
303	CAERØ4	4	EDT	0	16	16	39	1	4501	45	S5	6400	-1	42A3
304	PAERØ2	4	EDT	0	16	16	1162	1	4601	46	S5	6510	-1	42A4
305	PAERØ3	4	EDT	0	4	24	801	1	4701	47	S5	6520	-1	42A5
306	PAERØ4	4	EDT	0	-4	8	-1	1	4801	48	S5	6530	-1	42A6
307	SPLINE3	4	EDT	0	-4	16	-1	0	4901	49	S5	6850	-1	42B1
308	GUST	5	DIT	0	4	8	165	0	1005	10	S5	7600	-1	42B2
309	CAERØ5	4	EDT	0	16	16	39	1	5001	50	S5	6400	-1	42B3
310	PAERØ5	4	EDT	0	-4	8	-1	1	5101	51	S5	7700	-1	42B4
311	DAREAS	7	DYNAMICS	0	-4	9	1080	0	9027	90	S5	3300	-1	42B5
312	DELAYS	7	DYNAMICS	0	-4	9	1080	0	9137	91	S5	3300	-1	42B6
313	DPHASES	7	DYNAMICS	0	-4	9	1080	0	9277	92	S5	3300	-1	42C1
314	TICS	7	DYNAMICS	0	-4	9	1153	0	9307	93	S5	3350	-1	42C2
315	CSP	10	GEOM4	0	-4	8	-1	0	3291	91	S3	2910	-1	4103
316	STREAML1	4	EDT	0	-4	9	-1	1	3292	92	S3	2920	-1	4104
317	STREAML2	4	EDT	0	12	16	45	1	3293	93	S3	3010	-1	4105

Table 2(d). Bulk Data Cards Processed by IFP, Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
65	CMASS1	8	GEØM2	0	4	12	337	1	1001	10	S1	3620	-1	13A5
66	CMASS2	8	GEØM2	0	4	12	397	1	1101	11	S1	3623	-1	13A6
67	CMASS3	8	GEØM2	0	4	8	37	0	1201	12	S1	3674	-1	13B1
68	CMASS4	8	GEØM2	0	4	8	409	0	1301	13	S1	3697	-1	13B2
258	CNGRNT	8	GEØM2	0	-4	16	-1	0	5008	50	S1	5245	-1	33C6
168	CØNCT	10	GEØM4	0	-4	12	-1	0	210	2	S5	2900	-1	23C6
167	CØNCT1	10	GEØM4	0	-4	20	-1	0	110	41	S5	2800	-1	23C5
63	CØNM1	8	GEØM2	0	8	28	349	1	1401	14	S1	3580	-1	13A3
64	CØNM2	8	GEØM2	0	8	20	377	1	1501	15	S1	3600	-1	13A4
47	CØNRØD	8	GEØM2	0	8	12	277	1	1601	16	S1	3260	-1	12C5
6	CØRD1C	1	GEØM1	0	4	8	37	0	1701	17	S1	600	-1	11A6
5	CØRD1R	1	GEØM1	0	4	8	37	0	1801	18	S1	500	-1	11A5
7	CØRD1S	1	GEØM1	0	4	8	37	0	1901	19	S1	700	-1	11B1
9	CØRD2C	1	GEØM1	0	12	16	45	1	2001	20	S1	900	-1	11B3
8	CØRD2R	1	GEØM1	0	12	16	45	1	2101	21	S1	800	-1	11B2
10	CØRD2S	1	GEØM1	0	12	16	45	1	2201	22	S1	1000	-1	11B4
60	CQDMEM	8	GEØM2	0	8	12	325	1	2601	26	S1	3460	-1	12E6
249	CQDMEM1	8	GEØM2	0	8	12	325	0	2008	20	S1	3460	-1	33B3
259	CQDMEM2	8	GEØM2	0	8	12	325	0	5308	53	S1	3460	-1	33D1
261	CQDMEM3	8	GEØM2	0	8	12	325	0	5408	54	S1	3460	-1	33D3
59	CQDPLT	8	GEØM2	0	8	12	325	1	2701	27	S1	3460	-1	12E5
280	CQUADTS*	8	GEØM2	0	8	20	1045	1	4108	41	S4	2020	-1	41B4
57	CQUAD1	8	GEØM2	0	8	12	325	1	2801	28	S1	3460	-1	12E3
58	CQUAD2	8	GEØM2	0	8	12	325	1	2901	29	S1	3460	-1	12E4
297	CRIGDR	10	GEØM4	-2	4	8	37	1	8210	82	S3	6000	-1	41E3
279	CRIGD1	10	GEØM4	-2	-3	48	-1	1	5310	53	S3	2010	-1	41B3
284	CRIGD2	10	GEØM4	-2	-4	48	-1	1	5410	54	S3	2060	-1	41C2
298	CRIGD3	10	GEØM4	-2	-3	48	-1	1	8310	83	S3	7000	-1	41E4
48	CRØD	8	GEØM2	0	4	8	37	0	3001	30	S1	3281	-1	12C6
61	CSHEAR	8	GEØM2	0	8	12	337	1	3101	31	S1	3540	-1	13A1
227	CSLØT3	8	GEØM2	0	8	8	877	1	4408	44	S1	4500	0	32C5
228	CSLØT4	8	GEØM2	0	8	16	877	1	4508	45	S1	4600	0	32C6
315	CØP	10	GEØM4	0	-4	8	-1	0	3291	91	S3	2910	-1	41D3
217	CTETRA	8	GEØM2	0	8	8	337	1	5508	55	S4	4100	-1	32B1
104	CTØRDRG	8	GEØM2	0	4	12	750	1	1908	19	S4	1040	-1	21C2
287	CTRAPAX	15	AXIC	-2	4	8	325	1	7042	74	S3	2040	0	41C5
80	CTRAPRG	8	GEØM2	0	8	12	737	1	1808	18	S4	800	-1	13D2
54	CTRBSC	8	GEØM2	0	8	12	313	1	3201	32	S1	3360	-1	12D6
285	CTRIAAX	15	AXIC	-2	4	8	313	1	7012	70	S3	2111	0	41C3
52	CTRIA1	8	GEØM2	0	8	12	313	1	3301	33	S1	3360	-1	12D4
53	CTRIA2	8	GEØM2	0	8	12	313	1	3401	34	S1	3360	-1	12D5
79	CTRIARG	8	GEØM2	0	8	12	738	1	1708	17	S4	790	-1	13D1
282	CTRIATS*	8	GEØM2	0	8	20	1047	1	5908	59	S4	2021	-1	41B6
291	CTRIM6	8	GEØM2	-2	12	16	913	1	6101	81	S1	6101	-1	41D3
56	CTRMEM	8	GEØM2	0	8	12	313	1	3501	35	S1	3360	-1	12E2
55	CTRPLT	8	GEØM2	0	8	12	313	1	3601	36	S1	3360	-1	12E1
293	CTRPLT1	8	GEØM2	-2	12	16	913	1	6301	83	S1	6301	-1	41D5
299	CTRSHL	8	GEØM2	-2	12	16	913	1	7501	75	S1	7501	-1	41E5
49	CTUBE	8	GEØM2	0	4	8	37	0	3701	37	S1	3282	-1	12D1
62	CTWIST	8	GEØM2	0	8	12	337	1	3801	38	S1	3540	-1	13A2
50	CVISC	8	GEØM2	0	4	8	37	0	3901	39	S1	3283	-1	12D2
218	CWEDGE	8	GEØM2	0	8	8	525	1	5608	56	S4	4200	-1	32B2
257	CYJØIN	10	GEØM4	0	-4	16	-1	0	5210	52	S1	5240	-1	33C5
182	DAREA	7	DYNAMICS	0	4	8	101	0	27	17	S3	1820	0	31A2
311	DAREAS	7	DYNAMICS	0	-4	9	1080	0	9027	90	S5	3300	-1	42B5
81	DEFØRM	4	EDT	0	4	8	157	0	104	1	S1	2500	-1	13D3
183	DELAY	7	DYNAMICS	0	4	8	101	0	37	18	S3	1820	0	31A3
312	DELAYS	7	DYNAMICS	0	-4	9	1080	0	9137	91	S5	3300	-1	42B6
123	DLØAD	7	DYNAMICS	0	4	8	-1	1	57	5	S3	4060	0	22A3
119	DMI	12	PØØL	0	-4	16	-1	0	0	0	S2	1190	0	21E5
221	DMIAX	14	MATPØØL	0	-4	9	-1	0	214	2	S4	4500	-1	32B5

Table 2(1). Bulk Data Cards Processed by IFP, Sorted Alphabetically by Card Name.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ø IJHK
207	RINGFL	15	AXIC	0	4	8	497	1	8315	83	S4	3300	-1	31E3
131	RLØAD1	7	DYNAMICS	0	8	8	337	1	5107	51	S3	1310	0	22B5
132	RLØAD2	7	DYNAMICS	0	8	8	337	1	5207	52	S3	1310	0	22B6
245	SAME*	10	GEØM4	0	-4	10	-1	0	7810	78	S5	4600	-1	33A5
246	SAME1*	10	GEØM4	0	-8	9	-1	0	7910	79	S5	5	-1	33A6
153	SECTAX	15	AXIC	0	4	12	177	1	6015	60	S3	1530	0	23A3
135	SEQEP	7	DYNAMICS	0	4	8	37	0	5707	57	S1	40	-1	22C3
4	SEQGP	1	GEØM1	0	4	8	37	0	5301	53	S1	40	-1	11A4
268	SET1	4	EDT	0	-4	16	-1	0	3502	35	S1	5300	-1	33E4
269	SET2	4	EDT	0	4	8	197	0	3602	36	S5	5600	-1	33E5
231	SLBDY	15	AXIC	0	-4	8	-1	0	1415	14	S1	4900	0	32D3
25	SLØAD	9	GEØM3	0	4	8	157	0	5401	54	S1	2500	-1	11E1
16	SPC	10	GEØM4	0	4	8	101	0	5501	55	S1	1600	-1	11C4
13	SPCADD	10	GEØM4	0	4	8	-1	1	5491	59	S3	4020	-1	11C1
148	SPCAX	15	AXIC	0	4	12	485	0	6215	62	S3	1480	0	22E4
256	SPCD	10	GEØM4	0	4	8	101	0	5110	51	S1	1600	-1	33C4
174	SPCS	10	GEØM4	0	-4	12	-1	0	810	8	S5	3500	-1	23D6
172	SPCSD	10	GEØM4	0	6	9	1000	0	610	6	S5	3300	-1	23D4
173	SPCS1	10	GEØM4	0	-4	12	-1	0	710	7	S5	3400	-1	23D5
12	SPC1	10	GEØM4	0	-4	9	-1	0	5481	58	S3	3980	-1	11B6
266	SPLINE1	4	EDT	0	8	12	42	1	3302	33	S5	6700	-1	33E2
267	SPLINE2	4	EDT	0	12	16	1025	1	3402	34	S5	6800	-1	33E3
307	SPLINE3	4	EDT	0	-4	16	-1	0	4901	49	S5	6850	-1	42B1
105	SPØINT	8	GEØM2	0	-4	9	794	0	5551	49	S4	1050	-1	21C3
175	SS15***								4710	47				23E1
316	STREAML1	4	EDT	0	-4	9	-1	1	3292	92	S3	2920	-1	41D4
317	STREAML2	4	EDT	0	12	16	45	1	3293	93	S3	3010	-1	41D5
151	SUPAX	15	AXIC	0	4	8	337	0	6415	64	S3	1500	0	23A1
14	SUPØRT	10	GEØM4	0	4	8	37	0	5601	56	S1	1400	-1	11C2
162	TABDMP1	5	DIT	0	-4	16	-1	1	15	21	S2	930	0	23B6
133	TABLED1	5	DIT	0	-4	16	-1	1	1105	11	S2	930	0	22C1
134	TABLED2	5	DIT	0	-4	16	-1	1	1205	12	S2	930	0	22C2
140	TABLED3	5	DIT	0	-4	16	-1	1	1305	13	S2	930	0	22D2
141	TABLED4	5	DIT	0	-4	16	-1	1	1405	14	S2	960	0	22D3
93	TABLEM1	5	DIT	0	-4	16	-1	1	105	1	S2	930	0	21A3
94	TABLEM2	5	DIT	0	-4	16	-1	1	205	2	S2	930	0	21A4
95	TABLEM3	5	DIT	0	-4	16	-1	1	305	3	S2	930	0	21A5
96	TABLEM4	5	DIT	0	-4	16	-1	1	405	4	S2	960	0	21A6
97	TABLES1	5	DIT	0	-4	16	-1	1	3105	31	S2	930	-1	21B1
191	TABRND1	5	DIT	0	-4	16	-1	1	55	25	S2	930	0	31B5
188	TABRNDG	5	DIT	0	4	8	1	0	56	26	S2	1000	0	31C2
27	TEMP	9	GEØM3	0	4	8	157	0	5701	57	S1	2500	-1	11E3
155	TEMPAX	15	AXIC	0	4	8	237	0	6815	68	S3	1550	0	23A5
98	TEMPD	9	GEØM3	0	4	12	269	0	5641	65	S4	980	-1	21B2
295	TEMPG	9	GEØM3	-2	-8	20	-1	0	8509	85	S4	6501	-1	41E1
201	TEMPP1	9	GEØM3	0	-4	10	-1	0	8109	81	S4	2100	-1	31D3
202	TEMPP2	9	GEØM3	0	-4	10	-1	0	8209	82	S4	2200	-1	31D4
203	TEMPP3	9	GEØM3	0	-4	10	-1	0	8309	83	S4	2300	-1	31D5
296	TEMPP4	9	GEØM3	-2	-8	20	-1	0	8609	86	S4	6601	-1	41E2
204	TEMPRB	9	GEØM3	0	-4	10	-1	0	8409	84	S4	2400	-1	31D6
136	TF	7	DYNAMICS	0	8	12	-1	0	6207	62	S1	1360	0	22C4
137	TIC	7	DYNAMICS	0	4	12	713	0	6207	66	S1	1370	0	22C5
314	TICS	7	DYNAMICS	0	-4	9	1153	0	9307	93	S5	3350	-1	42C2
138	TLØAD1	7	DYNAMICS	0	8	8	681	1	7107	71	S3	1380	0	22C6
139	TLØAD2	7	DYNAMICS	0	8	16	689	1	7207	72	S3	1390	0	22D1
169	TRANS	10	GEØM4	0	12	16	45	1	310	3	S5	3000	-1	23D1
142	TSTEP	7	DYNAMICS	0	4	8	-1	1	8307	83	S1	1420	0	22D4
192	UDEF	10	GEØM4	0	-4	16	-1	0	0	0	S5	4300	0	31B6
193	USET	10	GEØM4	0	-4	0	1065	0	110	1	S5	4400	0	31C1
194	USET1	10	GEØM4	0	-4	10	-1	0	210	2	S5	4500	0	31C2
290	VARIAN	4	EPT	0	-4	16	-1	0	4202	42	S3	1410	0	41D2
289	VIEW	2	EPT	0	4	8	326	1	2606	26	S1	5175	0	41D1

The influence coefficients are computed by MBCAP, then SKJ (Identity) is output, and finally MBDPDH is called to compute and output the AJJL contribution.

Section two is a call to STPPT2 with outputs D1JK (Identity) and D2JK (Null).

4.114.7.4 Strip Theory Method

Section one of the Strip Theory Method is driven by Subroutine STPDA. STPDA reads the ACPT, fills in common STRIPL, and sets up pointers to common STRIPX where the various arrays will be stored. After all the input arrays have been set up an SKJ (Identity) matrix is built.

STPDA then calls: STPBG to build a BM and GM matrix for each strip; STPPHI to build the PHI functions for each strip; and finally STPAIC to combine these matrices and build AJJL.

Section two is a call to STPPT2 which output D1JK (Identity) and D2JK (Null).

4.114.7.5 Piston Theory Method

Section one of the Piston Theory method is driven by subroutine PSTAMG. PSTAMG reads the ACPT and sets up the core pointer to the arrays. Then SKJ (Identity) is output and PSTA is called to build AJJL.

Section two is a call to STPPT2 with outputs D1JK (Identity) and D2JK (Null),

4.114.7.6 Compressor Blade Method

The flow for Section one of the compressor blade method is as follows. Subroutine AMGB1 is the driver for this method. It reads in the ACPT record for this method and locates reference parameters from the reference streamline on the blade. If there is enough core available, it calls AMGB1A to output one matrix of the AJJL list. When AMGB1A is through, AMGB1 bumps NRØW and returns. Subroutine AMGB1S is called to output columns of SKJ.

Subroutine AMGB1A outputs a portion of the AJJL matrix for each streamline on the compressor blade. Each streamline may be subsonic, transonic or supersonic, depending on the Mach number for that streamline. Subroutine AMGB1B calculates terms for subsonic streamlines. Subroutine AMGB1C calculates terms for supersonic streamlines and subroutine AMGB1D calculates terms for transonic streamlines.

Each submatrix of AJJL corresponds to a blade streamline and is of order NSTNS X NSTNS, where NSTNS is the number of computing stations on the blade. The submatrices are located along the diagonal of AJJL.

The flow for Section two of the compressor blade method is as follows. Subroutine AMGB2 prepares all the computations necessary. It reads the ACPT record and locates the reference streamline parameters. Subroutine AMGB2A is called to calculate matrix $[F^{-1}]$ for each streamline. AMGB2 outputs the NSTNS X NSTNS submatrix for each streamline to [D1JK]$_a$

Each submatrix of [SKJ] and [D1JK] has the following form:

$$[SKJ] = W \cdot [F^{-1}]^T$$

and

$$[D1JK] = [F^{-1}]^T$$

The [D2JK] matrix is null.

4.114.8 Subroutines

Besides the module driver AMG, the subroutines of Section one are divided into groups by method:

For the Doublet Lattice Methods five subroutines are shared:

SNPDF, INCRØ, TKER, IDF1, and IDF2

The Doublet Lattice Method without Bodies also uses:

DLAMG, GEND, DPPS, and SUBP

The Doublet Lattice Method with Bodies also uses:

DLAMBY, SUBI, AMGBFS, FZY2, FWMW, BFSMAT, AMGRØD, AMGSBA, GENDSB, DPPSB, DPZY, DYPZ, DZPY, SUBB, SUBPB, DZY, FLLD, TVØR, DZYMAT, and RØWDZY

ALPH - Alpha array (angle of attack)

THI - Theta array (thickness ratio)

AJJL - GINØ file number

4.114.8.61 Subroutine Name: AMGB1

1. Entry Point: AMGB1

2. Purpose: Driver for the compressor blade method for AJJL and SKJ generation.

3. Calling Sequence: CALL AMGB1 (INPUT, MATØUT, SKJ)

   INPUT = GINØ file number for ACPT

   MATØUT = GINØ file number for AJJL
   SKJ = GINØ file number for SKJ

4.114.8.62 Subroutine Name: AMGB1A

1. Entry Point: AMGB1A

2. Purpose: Output all the columns of AJJL associated with a record of ACPT.

3. Calling Sequence: CALL AMGB1A (INPUT, MATØUT, AJJ, AJJT, TØØNX, TAMACH, TREFD)

INPUT = GINØ file number of ACPT

MATØUT = GINØ file number of AJJL

AJJ = Storage for AJJL submatrices - complex

AJJT = Storage for one column of AJJL

TØØNX = Stores position of transonic submatrix in AJJL for a particular transonic streamline

TAMACH = Stores Mach numbers of transonic streamlines

TREFD = Stores reduced frequencies of transonic streamlines

4.114.8.63 Subroutine Name: AMGB1B

1. Entry Point: AMGB1B

2. Purpose: Calculates AJJL terms for subsonic streamlines.

3. Calling Sequence: CALL AMGB1B (AJJL)

AJJL = Location to put subsonic AJJL submatrix for this streamline

4.114.8.64 Subroutine Name: AMGB1C

1. Entry Point: AMGB1C

2. Purpose: Calculates AJJL terms for supersonic streamlines.

3. Calling Sequence: CALL AMGB1C (AJJL)

AJJL = Location to put supersonic AJJL submatrix for this streamline

4.114.8.65 Subroutine Name: AMG81D

1. Entry Point: AMG81D

2. Purpose: Calculates AJJL terms for transonic streamlines.

3. Calling Sequence: CALL AMGB1D (AJJL, TSØNX, TAMACH, TREDF)

AJJL = AJJL submatrices for all subsonic and supersonic streamlines. It also contains space for transonic submatrices.

TSØNX = (integer) - vector - non-zero indicates transonic streamline zero if known streamline

TAMACH = Vector of streamline Mach numbers

TREDF = Vector of streamline reduced frequencies

4.114.8.66 Subroutine Name: INTERT

1. Entry Point: INTERT

2. Purpose: To linearly interpolate by Mach number a transonic general Air Force matrix given two known streamline matrices.

3. Calling Sequence: CALL INTERT (NL, NL1, NL2, NM, AJJ, TA)

NL = Streamline number of unknown transonic

NL1, NL2 = Two known streamlines

NM = Size of matrix in AJJ = 2 * NSTNS * NSTNS

AJJ = Contains all generalized Air Force matrices for all streamlines

TA = Vector of streamline Mach numbers

4.114.8.67 Subroutine Names: SUBA, SUBB, SUBC, SUBD, ALAMDA, AKP2, AKAPPA, DLKAPM, ASYCON, AKAPM, DRKAPM

1. Entry Points: The same as name

2. Purpose: Called by AMGB1C

4.114.8.68 Subroutine Name: GAUSS

1. Entry Point: GAUSS

2. Purpose: Equation Solver used by AMGB1B.

3. Calling Sequence: CALL GAUSS (A, N, NL)

4.114.8.69 Subroutine Name: AMGB2

1. Entry Point: AMGB2

2. Purpose: To output the compressor blade parts for matrices D1JK and D2JK.

3. Calling Sequence: CALL AMGB2 (INPUT, W1JK, W2JK)

   INPUT = GINØ file number for ACTP

   W1JK = GINØ file number for D1JK
   W2JK = GINØ file number for D2JK

4.114.8.70 Subroutine Name: AMGB2A

1. Entry Point: AMGB2A

2. Purpose: Calculate $[F^{-1}]$ matrix used in the generation of D1JK.

3. Calling Sequence: CALL AMGB2A (INPUT, FMAT, XYZB, INDEX)

   INPUT = GINØ file number of ACPT
   FMAT = Location for $[F^{-1}]$ matrix
   XYZB = Location for basic coordinates of nodes on streamline
   INDEX = Work storage for INVERS

4.114.8.71 Subroutine Name: AMGB1S

1. Entry Point: AMGB1S

2. Purpose: Calculate $[F^{-1}]$ matrix and W factor used in the generation of SKJ.

3. Calling Sequence: CALL AMGB1S (INPUT, FMAT, XYZB, INDEX, RADII, WFACT, NLINE)

INPUT = GINØ file number of ACPT

FMAT = Location for $[F^{-1}]$ matrix

XYZB = Location for basic coordinates of nodes on streamline

INDEX = Work storage for INVERS

WFACT = Factor for output

NLINE = Number of streamlines

RADII = Streamline radius

4.114.9 Design Requirements

For Section one, four buffers are allocated at the bottom of core. For Section two, three buffers are allocated at the bottom of core. Each method may have its own open core common block but they must not overlap these buffers.

4.114.9.1 Common Blocks

AMGMN - Doublet Lattice without Bodies Communication

Words

1-7	MCB	- Trailer for AJJL	
8	NRØW	- Last row number output for any method on AJJL	
9	ND	- Y-symmetry flag	1 record of AERØ Data Block
10	NE	- Z-symmetry flag	
11	REFC	- Reference card	
12	FMACH	- Mach number (M)	Pairs from 2 record of AERØ Data Block
13	RFK	- Reduced frequency	
14-20	TSKJ	- Trailer for SKJ	
21	ISK	- Row number to start building on SKJ	
22	NSK	- Last row number output for any method on SKJ	

AMGP2 - Section Two Communication

Words

1-7	TW1JK	- trailer for D1JK
8-14	TW2JK	- trailer for D2JK

DLCØM - Doublet Lattice without Bodies Communication

Words

1	NP	- number of panels
2	NSTRIP	- number of strips

STRIPX - Strip Theory Open Core

Strip Theory Arrays from ACPT
FREE
4 Buffers: SKJ, AJJL, AERØ, ACPT

PSTØNC - Piston Theory Communication

Words

1-9 Words 2-10 of ACPT record

PSTØNX - Piston Theory Open Core

Piston Theory Arrays from ACPT
FREE
4 Buffers: SKJ, AJJL, AERØ, ACPT

BAMG1L and BAMG2L – Common Blocks for Compressor Blade Method

Words:

1	IREF	- Reference streamline number
2	MINMAC	- Parameter MINMACH
3	MAXMAC	- Parameter MAXMACH
4	NLINES	- Number of streamlines on blade
5	NSTNS	- Number of stations on blade
6	REFSTG	- Reference blade stagger angle
7	REFCRD	- Reference blade chord
8	REFMAC	- Reference Mach number
9	REFDEN	- Reference density
10	REFVEL	- Reference velocity
11	REFFLØ	- Reference flow angle
12	SLN	- Streamline number
13	NSTNSX	- Number of stations on streamline
14	STAGER	- Blade stagger angle
15	CHØRD	- Blade chord
16	RADIUS	- Radius of streamline
17	BSPACE	- Blade spacing
18	MACH	- Relative flow Mach number at blade leading edge
19	DEN	- Gas density at blade leading edge
20	VEL	- Relative flow velocuty at blade leading edge
21	FLØWA	- Relative flow angle at blade leading edge
22	AMACH	- Internal Mach number
23	REDF	- Internal reduced frequency
24	BLSPC	- Internal blade spacing
25	AMACHR	- Internal reference Mach number
26	TSØNIC	- Transonic indicator

BAMGXX - Open Core for Compressor Blades

Words 6 to End of Record on ACPT
Column of AJJL 2*NJ
Free
4 Buffers: SKJ, AJJL, AERØ, ACPT

BAMG2X - Open core for Section two

Record of ACPT
Free
3 Buffers: D2JK, D1JK, ACPT

4.114.10 Diagnostic Messages

System fatal messages 3001, 3002, 3003, 3007, 3008 and (10) 3061. User fatal messages 2264 and 2265.

4.115.8 Subroutines

Numerous utility subroutines are used by the functional phases as shown below.

AMPA	AMPB	AMPC	AMPD	AMPE	AMPF
CYCT2B	CALCV	CYCT2B	CYCT2B	CYCT2B	CYCT2B
	SSG2B	SSG2C	SSG2B	SSG2B	SSG2B
	MERGED	CFACTR	SKPREC	SSG2A	CFACTR
	PARTN	CFBSØR		SKPREC	CFBSØR
		FILSWI			FILSWI
		TRANP1			SKPREC
		SSG2B			

4.115.8.1 Subroutine Name: AMPA

1. Entry Point: AMPA

2. Purpose: To provide a scenario for later phases and to prepare for use of the appended output files.

3. Calling Sequence: CALL AMPA (AERØ, QJHL, QHHL, AJJL, QHHLØ, QJHLØ, INDEX, IMAX, IANY)

AERØ, QJHL, QHHL, and AJJL are the GINØ file numbers of their respective data blocks.

QHHLØ and QJHLØ are the GINØ file numbers of two scratch files to hold valid submatrices from QHHL and QJHL on restart.

INDEX is the GINØ file number of the scenario data block. Its contents are as follows:

Record No.	Word	Contents
0	1	Header
1	1	M column number
	2	K column number
	3	AJJL column number
	4	QHHLØ column number (0 implies recompute)
⋮		
IMAX		

4.117 FUNCTIONAL MODULE FA2 (FLUTTER ANALYSIS - PHASE 2)

4.117.1 Entry Point: FA2

4.117.2 Purpose

To collect data for reduction and presentation for each loop through the configuration parameters. .

4.117.3 DMAP Calling Sequence

FA2 PHIH,CLAMA,FSAVE / PHIHL,CLAMAL,CASEYY,ØVG / V,N,TSTART / C,Y,VREF=1.0 / C,Y,PRINT=YES $

4.117.4 Input Data Blocks

PHIH - Complex eigenvectors - h set, modal formulations.

CLAMA - Complex eigenvalue output table.

FSAVE - Flutter storage save table.

Note: No input data block may be purged.

4.117.5 Output Data Blocks

PHIHL - Appended complex mode shapes - h set.

CLAMAL - Appended complex eigenvalue output table.

CASEYY - Appended case control data table.

ØVG - Output aeroelastic curve requests (V-g or V-f).

Notes:

1. No output data block may be purged.

2. All output data blocks are read (DMAP attribute APPEND) on subsequent calls (FLØØP from FSAVE ≠ 1 if the method is K).

4.117.6 Parameters

TSTART - Integer-input/output-no default value. On input TSTART is the CPU time at the start of the DMAP flutter loop. On output TSTART will be -1 if there is insufficient time for another DMAP loop.

VREF - Real-user input; no default. V_{out} will be scaled by VREF:

$$V_{out} = V/V_{ref}$$

PRINT - BCD-user input-default = YES. If PRINT = NØ, no flutter summary will be printed. For YES the wing flutter summary will be printed. For YESB the blade summary will be printed.

4.162 FUNCTIONAL MODULE ALG (AERODYNAMIC LOAD GENERATOR)

4.162.1 Entry Point: UD0300

4.162.2 Purpose

The principal function of ALG is to generate an aerodynamic pressure and/or temperature distribution for compressor blades. The ALG module may also be used as a compressor blade mesh generator to punch GRID, CTRIA2 and PTRIA2 bulk data cards. Bulk data cards STREAML1 and STREAML2 can also be generated by ALG by user request.

4.162.3 DMAP Calling Sequence

ALG CASECC, EDT, EQEXIN, $\left\{\begin{matrix}\text{AUGV}\\ \text{UBGV}\end{matrix}\right\}$, ALGDB, CSTM, BGPDT/ CASECCA, GEØM3A/
S, Y, APRESS/ S, Y, ATEMP/ V, Y, STREAML/ V, Y, PGEØM/ V, Y, IPRT/
S, N, IFAIL/ V, Y, SIGN/ V, Y, ZØRIGN/ V, Y, FXCØØR/ V, Y, FYCØØR/
V, Y, FZCØØR $

4.162.4 Input Data Blocks

CASECC - Case control data table

EDT - Aerodynamic bulk data cards

EQEXIN - Equivalence between external grid or scalar numbers and internal numbers

AUGV }
UBGV } - Displacement vector matrix giving displacements in the g-set

ALGDB - Compressor blade data table

CSTM - Coordinate system transformation matrices

BGPDT - Basic grid point definition table

Notes:

1. CASECC and ALGDB cannot be purged.

2. AUGV or UBGV can be purged.

3. EQEXIN, CSTM and BGPDT can be purged if AUGV is purged.

4. EDT can be purged if AUGV is purged and parameter STREAML = -1.

5. ALGDB may be input via DTI bulk data cards.

4.162.5 Output Data Blocks

CASECCA - Revised case control data table

GEØM3A - Static load and temperature table

Note:

1. CASECCA and GEØM3A may not be purged.

4.162.6 Parameters

APRESS - Input - integer - default = -1. If APRESS > 0, then aerodynamic pressures will be generated.

ATEMP - Input - integer - default = -1. If ATEMP > 0, then aerodynamic temperatures will be generated.

STREAML - Input - integer - default = -1. Controls the punching of STREAML1 and STREAML2 cards. STREAML = 1, punch STREAML1 cards. STREAML = 2, punch STREAML2 cards. STREAML = 3, punch both STREAML1 and STREAML2 cards.

PGEØM - Input - integer - default = -1. Controls the punching of blade geometry bulk data cards. PGEØM = 1, punch GRID cards. PGEØM = 2, punch GRID, CTRIA2 and PTRIA2 cards. PGEOM = 3, punch GRID cards and the modified ALGDB table on DTI cards.

IPRT - Input - integer - default = 0. If IPRT > 0, then intermediate print will be generated based on the print option in ALGDB data table.

IFAIL - Output - integer - default = 0. Set to -1 if there is a convergence failure.

SIGN - Input - real - default = 1.0. Controls the type of analysis being performed. SIGN = 1.0 for standard blade analysis. SIGN = -1.0 for design analysis.

ZØRIGN - Input - real - default = 0.0. Modification factor.

FXCØØR - Input - real - default = 1.0. Modification factor.

FYCØØR - Input - real - default = 1.0. Modification factor.

FZCØØR - Input - real - default = 1.0. Modification factor.

4.162.7 Method

(a) Data block ALGDB contains all the input needed to generate the aerodynamic pressures and temperatures on the compressor blade. However, the aerodynamic loads are a function of the blade shape and the data defined in ALGDB must first be modified to account for any change in the blade shape or input via the displacement vector matrix AUGV. If AUGV is purged, then ALGDB is not modified. The ALGDB data block is read and the aerodynamic loads are calculated for the compressor blade being analyzed.

(b) The CASECC data block is read and a copy of it is output to CASECCA with changes to data items 4 and 7 for all subcases. In CASECCA, word 4 is set to 60 if aerodynamic pressure loads were generated, and word 7 is set to 70 if aerodynamic thermal loads were generated.

(c) The GEØM3A data block contains aerodynamic load and temperature data. If parameter APRESS > 0, then PLØAD2 cards with set identification number 60 are stored on GEØM3A. If parameter ATEMP > 0, then TEMP and TEMPD cards with set identification number 70 are stored on GEØM3A

(d) Parameters STREAML and PGEØM control the punching of bulk data cards STREAML1, STREAML2, GRID, CTRIA2, PTRIA2 and DTI. The ALG module may be used in a one module DMAP program as a compressor blade mesh and geometry generator as follows:

```
BEGIN $

ALG CASECC,,,,ALGDB,,/CASECCA,GEØM3A/C,N,-1/C,N,-1/C,N,3/C,N,2/C,N,1$

END $
```

4.162.8 Subroutines Called

4.162.8.1 Utility subroutines GMMATS, PRETRS and TRANSS are called.

4.162.8.2 Subroutine Name: UD03PR

1. Entry Point: UD03PR

2. Purpose: Modify ALGDB data block.

3. Calling Sequence: CALL UD03PR (IERR)

4.162.8.3 Subroutine Name: UD03PB

1. Entry Point: UD03PB

2. Purpose: Identify data fields as being either BCD alpha, real or integer.

3. Calling Sequence: CALL UD03PB (IDAT, NTYPE)

4.162.8.4 Subroutine Name: UD03PØ

1. Entry Point: UD03PØ

2. Purpose: Generate data blocks CASECCA and GEØM3A.

3. Calling Sequence: CALL UD03PØ (SCR1)

4.162.8.5 Subroutine Name: UD03AP

1. Entry Point: UD03AP

2. Purpose: Punch the modified ALGDB table data block on DTI Bulk Data cards if parameter PGEØM - 3.

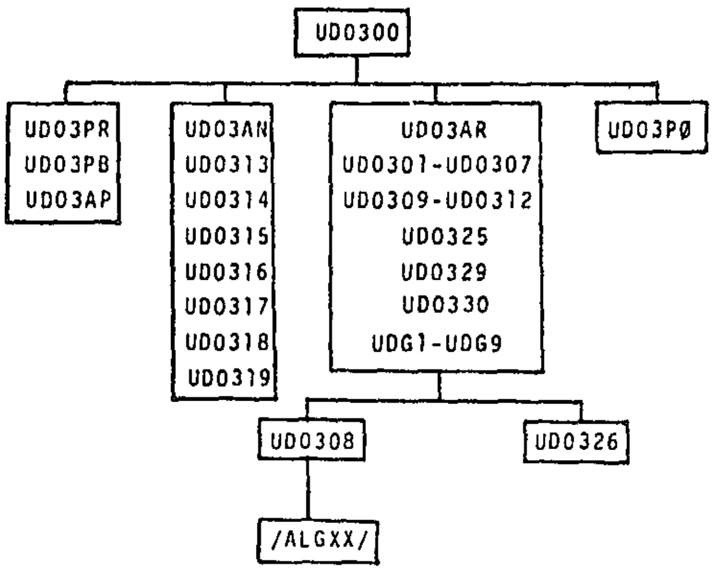
3. Calling Sequence: CALL UD03AP (IFNAME, IFNM)

4.162.8.6 Subroutines: UD03AN, UD03AR, UD0301-UD0319, UD0325, UD0326, UD0329, UD0330 and UDG1-UDG9 are described in references ARL-72-0171, AD-756879; and ARL-75-0001, AD-A009273.

4.162.9 <u>Design Requirements</u>

1. ALG uses 4 scratch files.

2. Overlay considerations - to maximize open core, ALG could look as follows:



4.162.10 <u>Diagnostic Messages</u>

The following messages may occur: 3001, 3002, 3003 and 3008.

4.163 FUNCTIONAL MODULE APDB (AERODYNAMIC POOL DISTRIBUTOR FOR BLADES)

4.163.1 Entry Point: APDB

4.163.2 Purpose

Bulk data cards which control the solution of aerodynamic problems are processed and assembled into various blocks for convenience and efficiency in the solution of the aerodynamic problem. APDB also generates the transformation matrix $[G_{ka}]^T$ (GTKA) and the partitioning vector PVECT.

4.163.3 DMAP Calling Sequence

```
APDB     EDT, USET, BGPDT, CSTM, EQEXIN, GM, GØ/ AERØ, ACPT, FLIST, GTKA,
         PVECT/ V, N, NK/ V, N, NJ/ V, Y, MINMACH/ V, Y, MAXMACH/ V, Y, IREF/
         V, Y, MTYPE/ V, N, NEIGV/ V, Y, KINDEX = -1 $
```

4.163.4 Input Data Blocks

EDT - Aerodynamic bulk data cards

USET - Displacement set definition table

BGPDT - Basic grid point definition table

CSTM - Coordinate system transformation matrices

EQEXIN - Equivalence between external points and scalar index values

GM - Multipoint constraint transformation matrix

GØ - Structural matrix partitioning transformation matrix

Notes:

1. EDT, USET, BGPDT and EQEXIN cannot be purged.

2. CSTM may be purged if all points are in the basic system.

3. GM and GØ may be purged if there are no multipoint or no omitted points.

4.163.5 Output Data Blocks

AERØ - Control information for control of aerodynamic matrix generation and flutter analysis

ACPT - Information pertaining to each independent group of aerodynamic elements

FLIST - Contains AERØ, FLFACT and FLUTTER cards copied from EDT

GTKA - Aerodynamic transformation matrix - K set to a set

PVECT - Cyclic modes partitioning vector for matrix PHIA from module CYCT2

Notes:

1. AERØ, ACPT, FLIST and GTKA cannot be purged.

2. PVECT may be purged if there are no cyclic modes to be partitioned.

4.163.6 Parameters

NK - Output - integer - no default. Degrees of freedom in the NK displacement set.

NJ - Output - integer - no default. Degrees of freedom in the NJ displacement set.

MAXMACH - Input - real - default = 0.8. This is the maximum Mach number below which the subsonic unsteady cascade theory is valid.

MINMACH - Input - real - default = 1.01. This is the minimum Mach number above which the supersonic unsteady cascade theory is valid.

IREF - Input - integer - default = -1. This defines the streamline number of the reference stream surface. IREF must equal an SLN on a STREAML2 card. The default value, -1, represents the stream surface at the blade tip. If IREF does not correspond to an SLN, then the default will be taken.

MYTPE - Input - BCD - default = CØSINE. This controls which components of the cyclic modes are to be used in the modal formulation. MTYPE = SINE for sine components and MTYPE = CØSINE for cosine components.

NEIGV - Input - BCD - no default. The number of eigenvalues found. Usually output by the READ module.

KINDEX - Input - BCD - default = -1. Harmonic index number used in cyclic analyses.

4.163.7 Method

Subroutine APDB is the main control program for this module. It allocates buffers, reads input files, and initializes output files. APDB creates the AERØ, ACPT and FLIST tables and generates the PVECT partitioning vector. Subroutine APDB1 generates the GTKA transformation matrix. APDB1 reduces $[G^T_{Kg}]$ to $[G^T_{Ka}]$, much like module SSG2, using the following matrix operations:

$$[G^T_{Kg}] \rightarrow \left[\begin{array}{c}\bar{G}^T_{KN}\\ \hline G^T_{KM}\end{array}\right]$$

$$[G^T_{KN}] = [G_M]^T\,[G^T_{KM}] + [\bar{G}^T_{KN}]$$

$$[G^T_{KN}] \rightarrow \left[\begin{array}{c}G^T_{Kf}\\ \hline G^T_{KS}\end{array}\right]$$

$$[G^T_{Kf}] \rightarrow \begin{bmatrix} \bar{G}^T_{Ka} \\ \hline G^T_{K\phi} \end{bmatrix}$$

$$[G^T_{Ka}] = [G_\phi]^T \, [G^T_{K\phi}] + [\bar{G}^T_{Ka}]$$

At each step where a matrix multiply is indicated, the multiply is skipped if the result is known to be zero (i.e., U_n or U_ϕ are null).

4.163.8 <u>Subroutines Called</u>

Utility routines BISLØC, CALCV, SSG2B, TRANSS and GMMATS all called.

4.163.8.1 Subroutine Name: APDB1

1. Entry Point: APDB1

2. Purpose: To generate transformation matrix $[G^T_{Ka}]$.

3. Calling Sequence: CALL APDB1 (IBUF1, IBUF2, NEXT, LEFT, NSTNS, NLINES, LCSTM, ACSTM, NØDEX, NØDEI, ISILC, XYZB).

4.163.9 <u>Design Requirements</u>

Open core is located at /APDBZZ/. APDB uses five scratch files.

4.163.10 <u>Diagnostic Messages</u>

System fatal messages 3001, 3002, 3003, 3008 and 3037 may occur. The APDB module also generates its own messages that are not numbered. These messages are self-explanatory.

7.22 RESTART TABLES FOR STATIC AEROELASTIC ANALYSIS

7.22.1 Bit Positions for Card Name Restart Table

Card Name	Bit Pos.
AXIC	1
AXIF	1
CELAS1	1
CELAS2	1
CELAS3	1
CELAS4	1
CMASS1	1
CMASS2	1
CMASS3	1
CMASS4	1
CORD1C	1
CORD1R	1
CORD1S	1
CORD2C	1
CORD2R	1
CORD2S	1
GRDSET	1
GRID	1
GRIDB	1
POINTAX	1
RINGAX	1
RINGFL	1
SECTAX	1
SEQGP	1
SPCINT	1
ADUM1	2
ADUM2	2
ADUM3	2
ADUM4	2
ADUM5	2
ADUM6	2
ADUM7	2
ADUM8	2
ADUM9	2
BAROR	2
CBAR	2
CCONEAX	2
CDUM1	2
CDUM2	2
CDUM3	2
CDUM4	2
CDUM5	2
CDUM6	2
CDUM7	2
CDUM8	2
CDUM9	2
CHEXA1	2
CHEXA2	2
CIHEX1	2
CIHEX2	2
CIHEX3	2
CONROD	2
CQDMEM	2
CQDMEM1	2
CQDMEM2	2
CQDMEM3	2
CQDPLT	2
CQUAD1	2
CQUAD2	2
CQUADTS	2
CROD	2
CSHEAR	2
CTETRA	2
CTORDRG	2
CTRAPAX	2
CTRAPRG	2
CTRBSC	2
CTRIA1	2
CTRIA2	2
CTRIAAX	2
CTRIARG	2
CTRIATS	2
CTRMEM	2
CTRPLT	2
CTUBE	2
CTWIST	2
CWEDGE	2
PBAR	3
PCONEAX	3
PDUM1	3
PDUM2	3
PDUM3	3
PDUM4	3
PDUM5	3
PDUM6	3
PDUM7	3
PDUM8	3
PDUM9	3
PIHEX	3
PQDMEM	3
PQDMEM1	3
PQDMEM2	3
PQDMEM3	3
PQDPLT	3
PQUAD1	3
PQUAD2	3
PQUADTS	3
PROD	3
PSHEAR	3
PTORDRG	3
PTRAPAX	3
PTRBSC	3
PTRIA1	3
PTRIA2	3
PTRIAAX	3
PTRIATS	3
PTRMEM	3
PTRPLT	3
PTUBE	3
PTWIST	3
GENEL	4
CONM1	5
CONM2	5
PELAS	6
PMASS	7
MAT1	8
MAT2	8
MAT3	8
MATT1	8
MATT2	8
MATT3	8
TABLEM1	8
TABLEM2	8
TABLEM3	8
TABLEM4	8
TEMPMT$	8
TEMPMX$	8
AXISYM$	9
CRIGD1	9
CRIGD2	9
MPC	9
MPCADD	9
MPCAX	9
MPC$	9
SPC	10
SPC1	10
SPCADD	10
SPCAX	10
SPC$	10
ASET	11
ASET1	11
OMIT	11
OMIT1	11
OMITAX	11
SUPAX	12
SUPORT	12
TEMP	13
TEMPAX	13
TEMPD	13
TEMPP1	13
TEMPP2	13
TEMPP3	13
TEMPRB	13
WTMASS	14
GRDPNT	15
PLOTEL	16
IRES	17
PLOT$	18
POUT$	19
LOOP$	22
LOOP1$	23
COUPMASS	24
CPBAR	24
CPQDPLT	24
CPQUAD1	24
CPQUAD2	24
CPROD	24
CPTRBSC	24
CPTRIA1	24

Card Name	Bit Pos.
CPTRIA2	24
CPTRPLT	24
CPTUBE	24
CSP$	25
STREAML1	26
DTI	26
APRESS	26
ATEMP	26
SIGN	26
ZORIGN	26
FXCOOR	26
FYCOOR	26
FZCOOR	26
STREAML	27
PGEOM	27
KTOUT	28
DEFORM	59
DEFORM$	59
LOADS	59
RFORCE$	59
SPCD	59
FORCE	60
FORCE1	60
FORCE2	60
FORCEAX	60
LOAD	60
MOMAX	60
MOMENT	60
MOMENT1	60
MOMENT2	60
PLOAD	60
PLOAD1	60
PLOAD2	60
PLOAD3	60
PRESAX	60
SLOAD	60
GRAV	61
RFORCE	61
TEMPLDS	62

7.22 .2 Bit Positions for File Name Restart Table

File Name	Bit Pos.
BGPDT	94
CSTM	94
EQEXIN	94
GPDT	94
GPL	94
SIL	94
ECT	95
GPTT	96
SLT	96
EST	97
GEI	97
GPECT	97
GPST	98
KGGX	98
MGG	99
KGG	100
RG	101
USET	101
YS	101
OGPST	102
GM	103
KNN	104
KFF	105
KFS	105
KSS	105
GO	106
KAA	106
KOO	106
LOO	106
LLL	107
PG	108
PL	109
PO	109
PS	109
RULV	110
RUOV	110
ULV	110
UOOV	110

File Name	Bit Pos.
PG1	111
QG	111
UGV	111
OEF1	112
OES1	112
OPG1	112
OQG1	112
OUGV1	112
PUGV1	112
KDDICT	113
KDELM	113
KDGG	113
KDNN	114
KDFF	115
KDFS	115
KDSS	115
KDAA	116
KBLL	117
KBFS	117
KBSS	117
PBL	117
PBS	117
YBS	117
LBLL	118
UBLV	119
RUBLV	119
QBG	120
UBGV	120
OEFB1	121
OESB1	121
OQBG1	121
OUBGV1	121
PUBGV1	121
ELSETS	122
GPSETS	122
PLTPAR	122
PLTSETX	122
KDICT	123
KELM	123
MDICT	123
MELM	123
CASECCA1	124
GEOM3A1	124
SLTA1	125
GPTTA1	125
PGA1	126
CASECCA	127
GEOM3A	127
SLTA	128
GPTTA	128
PGA	129
PG2	130
GEOM3b	131
PGNA	132
AUGV	133
PGI2	134

7.22 .3 Card Name Restart Table

```
DMP                                     Bit Position
Inst.     1        10        20        30        40        50        60

BEGIN     1234567890123456789  234                                  9012
GP1       1
SAVE      1
COND      1
CHKPNT    1
$SS            6
GP2       12 45          6
CHKPNT    12 45          6
$SS            6
PARAML                     8
$SS             7
PARAMR                            6
PURGE                      8
$SS             7
COND                       8
$SS             7
PLTSET                     8
$SS             7
SAVE                       8
$SS             7
PRTMSG                     8
$SS             7
PARAM                      8
$SS             7
PARAM                      8
$SS             7
COND                       8
$SS             7
PLOT                       8
$SS             7
SAVE                       8
$SS             7
PRTMSG                     8
$SS             7
LABEL                      8
$SS             7
CHKPNT                     8
$SS            67
GP3       12          3                                              01
SAVE      12          3                                              01
PARAM     12          3 5                                            01
CHKPNT    12          3                                              01
$SS            6
TA1       1234567     3
SAVE      1234567     3
COND      12345678    3
PURGE     1234567     3
CHKPNT    1234567     3
$SS            6
PARAM     1234 6
EMG       12345678
```

DMP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60	61–
SAVE	12345678						
CHKPNT	12345678						
$SS	6						
COND	1234 6 8						
EMA	1234 6 8						
CHKPNT	1234 6 8						
$SS	6						
LABEL	12345 78	4	4				
COND	12345 78	4	4				
EMA	12345 78	4	4				
CHKPNT	12345 78	4	4				
$SS	6						
LABEL	12345 78	4	4				
COND	123 5 78	45	4				
$SS	8						
COND	123 5 78	45	4				
$SS	8						
GPWG	123 5 78	45	4				
$SS	8						
OFP	123 5 78	45	4				1
$SS	8						
LABEL	123 5 78	45	4				
$SS	8						
EQUIV	1234 6 8						
CHKPNT	1234 6 8						
$SS	6						
COND	1234 6 8						
SMA3	1234 6 8						
CHKPNT	1234 6 8						
$SS	6						
LABEL	1234 6 8						
PARAM	1 90	1					
GP4	1 90	1				9	
SAVE	1 90	1				9	
COND	1 90	1				9	
PURGE	1 90	1				9	
CHKPNT	1234 6 890	1				9	
$SS	6						
COND	1	2					
JUMP	1	2					
LABEL	1	2					
COND	123 6 890						
GPSP	123 6 890						
SAVE	123 6 890						
COND	123 6 890						
OFP	123 6 890						
LABEL	123 6 890						
EQUIV	1234 6 89						
CHKPNT	1234 6 89						
$SS	6						
COND	1234 6 89						

RIGID FORMAT RESTART TABLES

DMP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60	61–
MCE1	1 9						
CHKPNT	1 9						
$SS	6						
MCE2	1234 6 89						
CHKPNT	1234 6 89						
$SS	6						
LABEL	1234 6 89						
EQUIV	1234 6 890						
CHKPNT	1234 6 890						
$SS	6						
COND	1234 6 890						
SCE1	1234 6 890						
CHKPNT	1234 6 890						
$SS	6						
LABEL	1234 6 890						
EQUIV	1234 6 890	1					
CHKPNT	1234 6 890	1					
$SS	6						
COND	1234 6 890	1					
SMP1	1234 6 890	1					
CHKPNT	1234 6 890	1					
$SS	6						
LABEL	1234 6 890	1					
RBMG2	1234 6 890	1					
CHKPNT	1234 6 890	1					
$SS	6						
SSG1	123 5678	3				90	12
CHKPNT	123 5678	3				90	12
$SS	6						
PARAM	123 5678	3	6			90	12
COND	123 5678	3	6			90	12
ALG	123 5678	3	67			90	12
COND	123 5678	3	6			90	12
PARAM	123 5678	3	6			90	12
COND	123 5678	3	6			90	12
GP3	123 5678	3	6			90	12
CHKPNT	123 5678	3	6			90	12
$SS	6						
SSG1	123 5678	3	6			90	12
CHKPNT	123 5678	3	6			90	12
$SS	6						
ADD	123 5678	3	6			90	12
LABEL	123 5678	3	6			90	12
EQUIV	123 5678	3	6			90	12
CHKPNT	123 5678	3	6			90	12
$SS	6						
EQUIV	123 567890	1 3	6			90	12
CHKPNT	123 567890	1 3	6			90	12
$SS	6						
COND	123 567890	1 3	6			90	12
SSG2	123 567890	1 3	6			90	12

DMAP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60	61–
CHKPNT	123 567890	1 3	6			90	12
$SS	6						
LABEL	123 567890	1 3	6			90	12
SSG3	1234567890	1 3	6			90	12
SAVE	1234567890	1 3	6			90	12
CHKPNT	1234567890	1 3	6			90	12
$SS	6						
COND	1234567890	1 3 7	6			90	12
MATGPR	1234567890	1 3 7	6			90	12
MATGPR	1234567890	1 3 7	6			90	12
LABEL	1234567890	1 3 7	6			90	12
SDR1	1234567890	1 3	6			90	12
CHKPNT	1234567890	1 3	6			90	12
$SS	6						
SDR2		9					
PARAM		9					
OFP		9					
SAVE		9					
COND		8					
$SS	7						
PLOT		8					
$SS	7						
SAVE		8					
$SS	7						
PRTMSG		8					
$SS	7						
LABEL		8					
$SS	7						
TA1	1234567890	1	6			90	12
DSMG1	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
COND	123 5678	3	6			90	12
EQUIV	123 5678	3	6			90	12
LABEL	123 5678	3	6			90	12
PARAM	1234567890	1	6			90	12
PARAM	1234567890	1	6			90	12
PARAMR	1234567890	1	6			90	12
PARAML	1234567890	1	6			90	12
JUMP	1234567890	1	6			90	12
LABEL	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
PARAM	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
COND	1234567890	1	6			90	12
MCE2	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12

RIGID FORMAT RESTART TABLES

DMAP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60	61–
$SS	6						
LABEL	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
COND	1234567890	1	6			90	12
SCE1	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
LABEL	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
COND	1234567890	1	6			90	12
SMP2	1234567890	1	6			90	12
CHKPNT	1234567890	1	6			90	12
$SS	6						
LABEL	1234567890	1	6			90	12
ADD	1234567890	1	6			90	12
ADD	1234567890	1	6			90	12
ADD	1234567890	1	6			90	12
COND	1234567890	1	6			90	12
MPYAD	1234567890	1	6			90	12
MPYAD	1234567890	1	6			90	12
UMERGE	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
COND	1234567890	1	6			90	12
UMERGE	1234567890	1	6			90	12
LABEL	1234567890	1	6			90	12
ADD	1234567890	1	6			90	12
EQUIV	1234567890	1	6			90	12
LABEL	1234567890	1	6			90	12
ADD	1234567890	1	6			90	12
COPY	1234567890	1	6			90	12
RBMG2	1234567890	1	23 6			90	12
SAVE	1234567890	1	23 6			90	12
CHKPNT	1234567890	1	23 6			90	12
$SS	6						
PRTPARM	1234567890	1	23 6			90	12
PRTPARM	1234567890	1	23 6			90	12
JUMP	1234567890	1	23 6			90	12
LABEL	1234567890	1	23 6			90	12
PARAM	1234567890	1	23 6			90	12
COND	1234567890	1	23 6			90	12
ALG	1234567890	1	23 67			90	12
COND	1234567890	1	23 6			90	12
PARAM	1234567890	1	23 6			90	12
PARAM	1234567890	1	23 6			90	12
COND	1234567890	1	23 6			90	12
GP3	1234567890	1	23 6			90	12
SSG1	1234567890	1	23 6			90	12

DMAP Inst.	Bit Position 1–10		20–30	40	50	60
ADD	12345678901		23 6			9012
LABEL	12345678901		23 6			9012
EQUIV	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
SSG2	12345678901		23 6			9012
SSG3	12345678901		23 6			9012
SAVE	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
COND	12345678901	7	23 6			9012
MATGPR	12345678901	7	23 6			9012
LABEL	12345678901	7	23 6			9012
SDR1	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
COND	12345678901		23 6			9012
EQUIV	12345678901		23 6			9012
LABEL	12345678901		23 6			9012
ADD	12345678901		23 6			9012
DSMG1	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
MPYAD	12345678901		23 6			9012
ADD	12345678901		23 6			9012
DSCHK	12345678901		23 6			9012
SAVE	12345678901		23 6			9012
COND	12345678901		23 6			9012
COND	12345678901		23 6			9012
EQUIV	12345678901		23 6			9012
EQUIV	12345678901		23 6			9012
EQUIV	12345678901		23 6			9012
REPT	12345678901		23 6			9012
TABPT	12345678901		23 6			9012
LABEL	12345678901		23 6			9012
ADD	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
EQUIV	12345678901		23 6			9012
CHKPNT	12345678901		23 6			9012
$SS	6					
EQUIV	12345678901		23 6			9012
REPT	12345678901		23 6			9012
TABPT	12345678901		23 6			9012
LABEL	12345678901		23 6			9012
PARAM	12345678901		23 6 8			9012
COND	12345678901		23 6 8			9012
ADD	12345678901		23 6 8			9012
OUTPUT1	12345678901		23 6 8			9012
OUTPUT1	12345678901		23 6 8			9012
LABEL	12345678901		23 6 8			9012

DMAP Inst.	Bit Position 1 – 10	20	30	40	50	60	
CHKPNT		9					
$SS	6						
ALG	1234567890	1	23 67			90	12
SDR 2		89					
OFP		9					
SAVE		9					
SDR 1	1234567890	1	23 6			90	12
GPFDR	1234567890	1	23 6			90	12
OFP	1234567890	1	23 6			90	12
COND		8					
$SS	7						
PLOT		8					
$SS	7						
SAVE		8					
$SS	7						
PRTMSG		8					
$SS	7						
LABEL		8					
$SS	7						
JUMP	1234567890	123456789	234			90	12
LABEL	1234567890	123456789	234			90	12
PRTPARM	1234567890	123456789	234			90	12
LABEL	1234567890	123456789	234			90	12
PRTPARM	1234567890	123456789	234			90	12
LABEL	1234567890	123456789	234			90	12
PRTPARM	1234567890	123456789	234			90	12
$SS	8						
LABEL	1234567890	123456789	234			90	12
$SS	8						
PRTPARM	1234567890	123456789	234			90	12
LABEL	1234567890	123456789	234			90	12
END	1234567890	123456789	234			90	12

7.22.4 Rigid Format Change Restart Table

DMAP Inst.	Bit Position 63 70 80
BEGIN	345 78901234567 345
GP1	
SAVE	
COND	
CHKPNT	
GP2	
CHKPNT	
PARAML	
PARAMR	
PURGE	
COND	
PLTSET	
SAVE	
PRTMSG	
PARAM	
PARAM	
COND	
PLOT	
SAVE	
PRTMSG	
LABEL	
CHKPNT	
GP3	
SAVE	
PARAM	345 78901234567 345
CHKPNT	
TA1	
SAVE	
COND	345 78901234567 345
PURGE	
CHKPNT	
PARAM	
EMG	
SAVE	
CHKPNT	
COND	
EMA	
CHKPNT	
LABEL	
COND	
EMA	
CHKPNT	
LABEL	
COND	
COND	
GPWG	
OFP	
LABEL	
EQUIV	
CHKPNT	
COND	

DMAP Inst.	Bit Position 63	70	80
SMA3			
CHKPNT			
LABEL			
PARAM			
GP4			
SAVE			
COND	345	901234567	345
PURGE			
CHKPNT			
COND	345	901234567	345
JUMP	345	901234567	345
LABEL	345	901234567	345
COND			
GPSP			
SAVE			
COND			
OFP			
LABEL			
EQUIV			
CHKPNT			
COND			
MCE1			
CHKPNT			
MCE2			
CHKPNT			
LABEL			
EQUIV			
CHKPNT			
COND			
SCE1			
CHKPNT			
LABEL			
EQUIV			
CHKPNT			
COND			
SMP1			
CHKPNT			
LABEL			
RBMG2			
CHKPNT			
SSG1			
CHKPNT			
PARAM			
COND			
ALG			
COND			
PARAM			
COND			
GP3			
CHKPNT			
SSG1			

DMAP Inst.	63	Bit Position 70	80
CHKPNT			
ADD			
LABEL			
EQUIV			
CHKPNT			
EQUIV			
CHKPNT			
COND			
SSG2			
CHKPNT			
LABEL			
SSG3	4		
SAVE	4		
CHKPNT	4		
COND	45	8901234567	345
MATGPR	45	8901234567	345
MATGPR	45	8901234567	345
LABEL	45	8901234567	345
SDR1			
CHKPNT			
SDR2			
PARAM			
OFP			
SAVE			
COND			
PLOT			
SAVE			
PRTMSG			
LABEL			
TA1			
DSMG1			
CHKPNT			
COND			
EQUIV			
LABEL			
PARAM			
PARAM			
PARAMR			
PARAML			
JUMP			
LABEL			
EQUIV			
CHKPNT			
PARAM			
EQUIV			
CHKPNT			
COND			
MCE2			
CHKPNT			
LABEL			
EQUIV			

DMAP	Bit Position		
Inst.	63	70	80
CHKPNT			
COND			
SCE1			
CHKPNT			
LABEL			
EQUIV			
CHKPNT			
COND			
SMP2			
CHKPNT			
LABEL			
ADD			
ADD			
ADD			
COND			
MPYAD			
MPYAD			
UMERGE			
EQUIV			
COND			
UMERGE			
LABEL			
ADD			
EQUIV			
LABEL			
ADD			
COPY			
RBMG2			
SAVE			
CHKPNT			
PRTPARM			
PRTPARM			
JUMP			
LABEL			
PARAM			
COND			
ALG			
COND			
PARAM			
PARAM			
COND			
GP3			
SSG1			
ADD			
LABEL			
EQUIV			
CHKPNT			
SSG2			
SSG3			
SAVE			
CHKPNT			

DMAP Inst.	Bit Position 63 70 80
COND	
MATGPR	
LABEL	
SDR1	345 78901234567 345
CHKPNT	345 78901234567 345
COND	
EQUIV	
LABEL	
ADD	
DSMG1	
CHKPNT	
MPYAD	
ADD	
DSCHK	
SAVE	
COND	
COND	
EQUIV	
EQUIV	
EQUIV	
REPT	
TABPT	
LABEL	
ADD	
CHKPNT	
EQUIV	
CHKPNT	
EQUIV	
REPT	
TABPT	
LABEL	
PARAM	
COND	
ADD	
OUTPUT1	
OUTPUT1	
LABEL	
CHKPNT	
ALG	
SDR2	
OFP	
SAVE	
SDR1	
GPFDR	
OFP	
COND	
PLOT	
SAVE	
PRTMSG	
LABEL	
JUMP	345 78901234567 345

DMAP Int.	63	Bit Position 70	80
LABEL	345	78901234567	345
PRTPARM	345	78901234567	345
LABEL	345	78901234567	345
PRTPARM	345	78901234567	345
LABEL	345	78901234567	345
PRTPARM	345	78901234567	345
LABEL	345	78901234567	345
PRTPARM	345	78901234567	345
LABEL	345	78901234567	345
END	345	78901234567	345

10.21.5 File Name Restart Table

DMAP Inst.	Bit Position 94	100	110	120	130	140	150
BEGIN							
GP1	4						
SAVE	4						
COND	4						
CHKPNT	4						
GP2	5						
CHKPNT	5						
PARAML				2			
PARAMR			7				
PURGE				2			
COND				2			
PLTSET				2			
SAVE				2			
PRTMSG				2			
PARAM				2			
PARAM				2			
COND							
PLOT							
SAVE							
PRTMSG							
LABEL							
CHKPNT				2			
GP3	6						
SAVE	6						
PARAM	6 9						
CHKPNT	6						
TA1	7						
SAVE	7						
COND	7 9						
PURGE	7	2					
CHKPNT	7						
PARAM	8						
EMG				3			
SAVE				3			
CHKPNT				3			
COND	8						
EMA	8						
CHKPNT	8						
LABEL	8						
COND	9						
EMA	9						
CHKPNT	9						
LABEL	9						
COND							
COND							
GPWG							
OFP							
LABEL	7 9						
EQUIV		0					
CHKPNT		0					
COND		0					

RIGID FORMAT RESTART TABLES

```
DMAP                    Bit Position
Inst.     94    100       110       120       130       140       150

SMA3            0
CHKPNT          0
LABEL           0
PARAM            1
GP4              1
SAVE             1
COND             1
PURGE            1 3 56  901   5 7
CHKPNT           1 3 56  901   5 7
COND
JUMP
LABEL
COND              2
GPSP              2
SAVE              2
COND              2
OFP               2
LABEL             2
EQUIV               4
CHKPNT              4
COND               34
MCE1               3
CHKPNT             3
MCE2                4
CHKPNT              4
LABEL              34
EQUIV                5
CHKPNT               5
COND                 5
SCE1                 5
CHKPNT               5
LABEL                5
EQUIV                 6
CHKPNT                6
COND                  6
SMP1                  6
CHKPNT                6
LABEL                 6
RBMG2                  7
CHKPNT                 7
SSG1                                    2
CHKPNT                                  2
PARAM                         4
COND                          4
ALG                           4
COND
PARAM                          5
COND                           5
GP3                            5
CHKPNT                         5
SSG1                            6
```

STATIC AEROELASTIC ANALYSIS

DMAP Inst.	94	100	110	120	130	140	150
CHKPNT				6			
ADD		8					
LABEL		8					
EQUIV		8					
CHKPNT		8					
EQUIV		9					
CHKPNT		9					
COND		9					
SSG2		9					
CHKPNT		9					
LABEL		9					
SSG3			0				
SAVE			0				
CHKPNT			0				
COND							
MATGPR							
MATGPR							
LABEL							
SDR1			1				
CHKPNT			1				
SDR2			2				
PARAM							
OFP							
SAVE							
COND							
PLOT							
SAVE							
PRTMSG							
LABEL							
TA1			3				
DSMG1			3				
CHKPNT			3				
COND							
EQUIV							
LABEL							
PARAM							
PARAM							
PARAMR							
PARAML							
JUMP							
LABEL							
EQUIV			4				
CHKPNT			4				
PARAM			4				
EQUIV			4				
CHKPNT			4				
COND			4				
MCE2			4				
CHKPNT			4				
LABEL			4				
EQUIV			5				

RIGID FORMAT RESTART TABLES

DMAP Inst.	94	100	110	120	130	140	150
CHKPNT			5				
COND			5				
SCE1			5				
CHKPNT			5				
LABEL			5				
EQUIV			6				
CHKPNT			6				
COND			6				
SMP2			6				
CHKPNT			6				
LABEL			6				
ADD			7				
ADD			7				
ADD			7				
COND							
MPYAD							
MPYAD							
UMERGE							
EQUIV							
COND							
UMERGE							
LABEL							
ADD							
EQUIV							
LABEL							
ADD							
COPY					3		
RBMG2			8				
SAVE			8				
CHKPNT			8				
PRTPARM			8				
PRTPARM			8				
JUMP							
LABEL							
PARAM							
COND				7			
ALG				7			
COND							
PARAM							
PARAM							
COND				89	0		
GP3				8			
SSG1				9			
ADD					0		
LABEL							
EQUIV							
CHKPNT					0		
SSG2							
SSG3			9				
SAVE							
CHKPNT							

DMAP			Bit Position				
Inst.	94	100	110	120	130	140	150
COND							
MATGPR							
LABEL					0		
SDR1					0		
CHKPNT							
COND							
EQUIV							
LABEL							
ADD							
DSMG1							
CHKPNT							
MPYAD							
ADD							
DSCHK							
SAVE							
COND							
COND							
EQUIV							
EQUIV							
EQUIV							
REPT							
TABPT							
LABEL							
ADD							
CHKPNT							
EQUIV							
CHKPNT							
EQUIV							
REPT							
TABPT							
LABEL							
PARAM							
COND							
ADD							
OUTPUT1							
OUTPUT1							
LABEL							
CHKPNT							
ALG					1		
SDR2				1			
OFP							
SAVE							
SDR1							
GPFDR							
OFP							
COND							
PLOT							
SAVE							
PRTMSG							
LABEL							
JUMP							

RIGID FORMAT RESTART TABLES

DMAP Inst.	94	100	110	120	130	140	150
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
END							

7.23 RESTART TABLES FOR COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

7.23.1 Bit Positions for Card Name Restart Table

Card Name	Bit Pos.
ADUM1	1
ADUM2	1
ADUM3	1
ADUM4	1
ADUM5	1
ADUM6	1
ADUM7	1
ADUM8	1
ADUM9	1
AXIC	1
AXIF	1
CELAS1	1
CELAS2	1
CELAS3	1
CELAS4	1
CMASS1	1
CMASS2	1
CMASS3	1
CMASS4	1
CORD1C	1
CORD1R	1
CORD1S	1
CORD2C	1
CORD2R	1
CORD2S	1
GRDSET	1
GRID	1
GRIDB	1
POINTAX	1
RINGAX	1
RINGFL	1
SECTAX	1
SEQGP	1
SPOINT	1
BAROR	2
CBAR	2
CCONEAX	2
CDUM1	2
CDUM2	2
CDUM3	2
CDUM4	2
CDUM5	2
CDUM6	2
CDUM7	2
CDUM8	2
CDUM9	2
CFLUID2	2
CFLUID3	2
CFLUID4	2
CHEXA1	2
CHEXA2	2
CIHEX1	2
CIHEX2	2
CIHEX3	2
CONROD	2
CQDMEM	2

Card Name	Bit Pos.
CQDPLT	2
CQUAD1	2
CQUAD2	2
CQUADTS	2
CROD	2
CSHEAR	2
CTETRA	2
CTORDRG	2
CTRAPAX	2
CTRAPRG	2
CTRBSC	2
CTRIA1	2
CTRIA2	2
CTRIAAX	2
CTRIARG	2
CTRIATS	2
CTRMEM	2
CTRPLT	2
CTUBE	2
CTWIST	2
CWEDGE	2
PBAR	3
PCONEAX	3
PDUM1	3
PDUM2	3
PDUM3	3
PDUM4	3
PDUM5	3
PDUM6	3
PDUM7	3
PDUM8	3
PDUM9	3
PIHEX	3
PQDMEM	3
PQDPLT	3
PQUAD1	3
PQUAD2	3
PQUADTS	3
PROD	3
PSHEAR	3
PTORDRG	3
PTRAPAX	3
PTRBSC	3
PTRIA1	3
PTRIA2	3
PTRIAAX	3
PTRIATS	3
PTRMEM	3
PTRPLT	3
PTUBE	3
PTWIST	3
GENEL	4
CONM1	5
CONM2	5
PELAS	6
PMASS	7
MAT1	8

Card Name	Bit Pos.
MAT2	8
MAT3	8
MATT1	8
MATT2	8
MATT3	8
TABLEM1	8
TABLEM2	8
TABLEM3	8
TABLEM4	8
TEMPMAT$	8
TEMPMX$	8
AXISYM	9
CRIGD1	9
CRIGD2	9
MPC	9
MPCADD	9
MPC$	9
MPCAX	9
SPC	10
SPC1	10
SPCADD	10
SPCAX	10
SPC$	10
ASET	11
ASET1	11
OMIT	11
OMIT1	11
OMITAX	11
SUPAX	12
SUPORT	12
TEMP	13
TEMPAX	13
TEMPD	13
TEMPP1	13
TEMPP2	13
TEMPP3	13
TEMPRB	13
GRDPNT	15
PLOTEL	16
PLOT$	18
POUT$	19
XYOUT$	20
AOUT$	21
COUPMASS	24
CPBAR	24
CPDPLT	24
CPQUAD1	24
CPQUAD2	24
CPROD	24
CPTRBSC	24
CPTRIA1	24
CPTRIA2	24
CPTRPLT	24
CPTUBE	24
WTMASS	24
NODJE	26
PAERO1	29

Card Name	Bit Pos.
SET1	32
SET2	32
SPLINE1	32
SPLINE2	32
MKAERO1	34
MKAERO2	34
AEFACT	35
FLFACT	36
FLUTTER	36
AERO	37
CAERO1	37
FMETHOD$	38
VREF	39
TF	40
CYJOIN	41
CTYPE	41
NSEGS	41
KINDEX	41
CYCSEQ	42
STREAML1	42
STREAML2	42
IREF	42
MINMACH	42
MAXMACH	42
MTYPE	42
KGGIN	43
SDAMP$	55
TABDMP1	55
EPOINT	56
SEQEP	56
B2PP$	57
DMIG	57
K2PP$	57
M2PP$	57
TF$	57
EIGR	58
METHOD$	59
EIGC	60
EIGP	60
CMETHOD$	61
HFREQ	62
LFREQ	62
LMODES	62

7.23 .2 Bit Positions for File Name Restart Table

File Name	Bit Pos.	File Name	Bit Pos.
BGPDT	94	KELM	122
CSTM	94	MDICT	122
EQEXIN	94	MELM	122
GPDT	94	MAA	123
GPL	94	ACPT	124
SIL	94	AERO	124
ECT	95	BGPA	124
GPTT	96	CSTMA	124
EST	97	ECTA	124
GEI	97	EQAERO	124
GPECT	97	FLIST	124
GPST	98	GPLA	124
KGGX	98	SILA	124
MGG	99	SILGA	124
KGG	100	SPLINE	124
RG	101	USETA	124
USET	101	ELSETS	125
OGPST	102	GPSETS	125
GM	103	PLTPAR	125
KNN	104	PLTSETX	125
MNN	104	GTKA	126
KFF	105	AJJL	127
KFS	105	D1JK	127
MFF	105	D2JK	127
KAA	106	SKJ	127
KLL	107	D1JE	128
KLR	107	D2JE	128
KRR	107	BXHH	129
MLL	107	KXHH	129
MLR	107	MXHH	129
MRR	107	FSAVE	129
LLL	108	CASEYY	130
DM	109	CLAMAL	130
MR	110	OVG	130
EED	111	PHIHL	130
EQDYN	111	CLAMAL1	131
GPLD	111	CPHIH1	131
SILD	111	CPHIA	132
TFPOOL	111	RP	132
USETD	111	CASEZZ	133
LAMA	112	OEIGS	134
MIX	112	MI	136
OEIGSX	112	QPACX	136
PHIA	112	OCPHIP	137
GO	113	OEFC1	137
B2PP	114	OESC1	137
K2PP	114	OQPC1	137
M2PP	114	PCPHIP	137
GMD	115	QHHL	138
GOD	115	QJHL	138
BHH	116	B2DD	139
KHH	116	K2DD	139
MHH	116	M2DD	139
PHIDH	116	CYCD	140
CLAMA	117	KKK	141
OCEIGS	117	MKK	141
PHIH	117	PHIK	142
CPHID	118	LAMK	142
CPHIP	120	PHIG	143
QPC	120	PVECT	144
KDICT	122	PHIAX	145

7.23 .3 Card Name Restart Table

DMAP Inst.	Bit Position 1	10	20	30	40	50	60
BEGIN	1234567890	123456 890	1234 6 9	2 4567890		567890	12
FILE	1234567890	1234 9	1234 6 9	2 4567890		567890	12
GP1	1						
SAVF	1						
COND	1						
CHKPNT	1						
$SS	6						
PURGE			6	7			
GP2	12 45	6					
CHKPNT	12 45	6					
$SS	6						
GP3	12	3					
CHKPNT	12	3					
$SS	6						
TA1	1234567	3					
SAVE	1234567	3					
COND	1234567	34					
PURGE	1234567						
CHKPNT	1234567	3					
$SS	6						
PARAM	123 6 8	3					
PARAM	123 5 78	34	4				
PARAM					3		
COND					3		
PARAM					3		
INPUTT1					3		
EQUIV					3		
CHKPNT					3		
$SS	6						
LABEL					3		
EMG	123 5678	34	4		3		
SAVE	123 5678	34	4		3		
CHKPNT	123 5678	34	4		3		
$SS	6						
COND	123 6 8	3			3		
EMA	123 6 8	3			3		
CHKPNT	123 6 8	3			3		
$SS	6						
LABEL	123 6 8	3			3		
COND	123 5 78	34	4				
EMA	123 5 78	34	4				
CHKPNT	123 5 78	34	4				
$SS	6						
COND	123 5 78	345	4				
GPWG	123 5 78	345	4				
OFP	123 5 78	345	4				
LABEL	123 5 78	345	4				
EQUIV	1234 6 8	3			3		
CHKPNT	1234 6 8	3			3		
$SS	6						
COND	1234 6 8	3			3		

COMPRESSION BLADE CYCLIC MODAL FLUTTER ANALYSES

```
DMAP                                   Bit Position
Inst.     1       10        20        30        40        50        60

SMA3      1234 6 8    3                              3
CHKPNT    1234 6 8    3                              3
$SS            6
LABEL     1234 6 8    3                              3
GP4       1                 9012
SAVE      1                 9012
PARAM     1                 9012                     3
COND      1                 9012                     3
PURGE     1                 9012                     3
GPCYC     1       901                              1
SAVE      1       901                              1
CHKPNT    1       901                              1
$SS            6
COND      1       901                              1
COND      1234 6 890  3                              3
GPSP      1234 6 890  3                              3
SAVE      1234 6 890  3                              3
COND      1234 6 890  3                              3
OFP       1234 6 890  3                              3
LABEL     1234 6 890  3                              3
EQUIV     123456789    4         4                   3
CHKPNT    123456789    4         4                   3
$SS            6
COND      123456789   34         4                   3
MCE1      1       9   3                              3
CHKPNT    1       9   3                              3
$SS            6
MCE2      123456789   34         4                   3
CHKPNT    123456789   34         4                   3
$SS            6
LABEL     123456789   34         4                   3
EQUIV     1234567890  34         4                   3
CHKPNT    1234567890  34         4                   3
$SS            6
COND      1234567890  34         4                   3
SCE1      1234567890  34         4                   3
CHKPNT    1234567890  34         4                   3
$SS            6
LABEL     1234567890  34         4                   3
EQUIV     12345678901 34         4                   3
CHKPNT    12345678901 34         4                   3
$SS            6
COND      12345678901 34         4                   3
SMP1      1234 6 8901 3                              3
CHKPNT    1234 6 8901 3                              3
$SS            6
SMP2      12345678901 34         4
CHKPNT    12345678901 34         4
$SS            6
LABEL     12345678901 34         4
OPD       1       9012                            0                6 8 0
```

RIGID FORMAT RESTART TABLES

DMAP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60	61–
SAVE	1 90	12		0		6 8 0	
COND	1 90	12		0		6 8 0	
EQUIV	1234567 90	12 4	234			6 8	
CYCT2	1234567890	1			1 3		
SAVE	1234567890	1			1 3		
CHKPNT	1234567890	1			1 3		
$SS	6						
COND	1234567890	1			1 3		
READ	1234567890	1234	4		1 3	89	
SAVE	1234567890	1234	4		1 3	89	
CHKPNT	1234567890	1234	4		1 3	89	
$SS	6						
PARAM	1234567890	1234	4		1 3	89	
OFP	1234567890	1234	4		1 3	89	
SAVE	1234567890	1234	4		1 3	89	
COND	1234567890	1234	4		1 3	89	
CYCT2	1234567890	1	4		1 3	89	
SAVE	1234567890	1	4		1 3	89	
CHKPNT	1234567890	1	4		1 3	89	
$SS	6						
COND	1234567890	1	4		1 3	89	
SDR1	1234567890	1	4		1 3	89	
SDR2		89					
OFP		9					
SAVE		9					
APDB	12 90	12		4567	123		
SAVE	12 90	12		4567	123		
CHKPNT	12 90	12		4567	123		
$SS	6						
PARTN	12 90	12			1 3	89	
SMPYAD	12 90	12			1 3	89	
MTRXIN	1		23	0		67	
SAVE	1		23	0		67	
PURGE	12 4		23	0		67	
EQUIV	12 4 9	1	23	0		67	
CHKPNT	12 4 9	1	23	0		67	
$SS	6						
GKAD	1234 6 890	1 34	23	0	123	67	
CHKPNT	1234 6 890	1 34	23	0	123	67	
$SS	6						
GKAM	1234567890	1234	234	0	123	56789	2
SAVE	1234567890	1234	234	0	123	56789	2
CHKPNT	1234567890	1234	234	0	123	56789	2
$SS	6						
PARAML		8					
$SS	7						
PURGE		8					
$SS	7						
COND		8					
$SS	7						
PLTSET		8					

```
                                 Bit Position
DAMP
Inst.    1        10        20        30        40        50        60
$SS            7
SAVE                    8
$SS            7
PRTMSG                  8
$SS            7
PARAM                   8
$SS            7
PARAM                   8
$SS            7
COND                    8
$SS            7
PLOT                    8
$SS            7
SAVE                    8
$SS            7
PRTMSG                  8
$SS            7
LABEL                   8
$SS            7
COND     1       9012                           0               6 8 0
PARAM    1                           9     5 7
AMG      1                           9    45 7    23
SAVE     1                           9    45 7    23
CHKPNT   1                           9    45 7    23
$SS           6
COND                          6          7
INPUTT2                       6          7
LABEL                         6          7
PARAM    1234567890123          4 6  9  2 45 7   123            6 89  2
AMP      1234567890123          4 6  9  2 45 7   123            6 89  2
SAVE     1234567890123          4 6  9  2 45 7   123            6 89  2
CHKPNT   1234567890123          4 6  9  2 45 7   123            6 89  2
$SS           6
PARAM                      0
PARAM                   8
PARAM                       1
PARAM    1234567890123          4 6  9  2 4567890              56789012
JUMP     1234567890123          4 6  9  2 4567890              56789012
LABEL    1234567890123          4 6  9  2 4567890              56789012
FAI      1234567890123          4 6  9  2 4567890123           56789012
SAVE     1234567890123          4 6  9  2 4567890123           56789012
CEAD     1234567890123          4 6  9  2 4567890123           56789012
SAVE     1234567890123          4 6  9  2 4567890123           56789012
COND     1234567890123          4 6  9  2 4567890123           56789012
COND                        1
VDR                         1
SAVE                        1
COND                        1
OFP                         1
SAVE                        1
LABEL                       1
```

RIGID FORMAT RESTART TABLES

DMAP Inst.	Bit Position 1–10	11–20	21–30	31–40	41–50	51–60
FA2	1234567890	123	4 6 9	2 4567890	123	56789012
SAVE	1234567890	123	4 6 9	2 4567890	123	56789012
CHKPNT	1234567890	123	4 6 9	2 4567890	123	56789012
$SS	6					
COND	1234567890	123	4 6 9	2 4567890	123	56789012
LABEL	1234567890	123	4 6 9	2 4567890	123	56789012
COND	1234567890	123	4 6 9	2 4567890	123	56789012
REPT	1234567890	123	4 6 9	2 4567890	123	56789012
JUMP	1234567890	123	4 6 9	2 4567890	123	56789012
LABEL	1234567890	123	4 6 9	2 4567890	123	56789012
CHKPNT	1234567890	123	4 6 9	2 4567890	123	56789012
$SS	6					
PARAML		0				
COND		0				
XYTRAN		0				
SAVE		0				
XYPLOT		0				
LABEL		0				
PARAM	1234567890	123	1 4 6 9	2 4567890	123	56789012
COND	1234567890	123	1 4 6 9	2 4567890	123	56789012
MODACC	1234567890	123	4 6 9	2 4567890	123	56789012
DDR1	1234567890	123	4 6 9	2 4 67890	123	56789012
CHKPNT	1234567890	123	4 6 9	2 4 67890	123	56789012
$SS	6					
EQUIV	1234567890	123	4 6 9	2 4567890	123	56789012
COND	1234567890	123	4 6 9	2 4567890	123	56789012
SDR1	1234567890	123	4 6 9	2 4567890	123	56789012
LABEL	1234567890	123	4 6 9	2 4567890	123	56789012
CHKPNT	1234567890	123	4 6 9	2 4567890	123	56789012
$SS	6					
EQUIV	1234567890	123	4 6 9	2 4567890	123	56789012
COND	1234567890	123	4 6 9	2 4567890	123	56789012
VEC	1234567890	123	4 6 9	2 4567890	123	56789012
PARTN	1234567890	123	4 6 9	2 4567890	123	56789012
LABEL	1234567890	123	4 6 9	2 4567890	123	56789012
SDR2	1234567890	123	4 6 9	2 4567890	123	56789012
CHKPNT	1234567890	123	4 6 9	2 4567890	123	56789012
$SS	6					
OFP		9				
COND		8				
$SS	7					
PLOT		8				
$SS	7					
PRTMSG		8				
$SS	7					
LABEL		8				
$SS	7					
JUMP	1234567890	123456 890	1234 6 9	2 4567890	123	56789012
LABEL	1234567890	123456 890	1234 6 9	2 4567890	123	56789012
PRTPARM	1234567890	123456 890	1234 6 9	2 4567890	123	56789012
LABEL	1234567890	123456 890	1234 6 9	2 4567890	123	56789012

COMPRESSOR BLADE CYCLIC MODAL FLUTTER ANALYSIS

DMAP Inst.	Bit Position (1, 10, 20, 30, 40, 50, 60)
PRTPARM	1234567890123456 8901234 6 9 2 4567890123 567890 12
LABEL	1234567890123456 8901234 6 9 2 4567890123 567890 12
PRTPARM	1234567890123456 8901234 6 9 2 4567890123 567890 12
LABEL	1234567890123456 8901234 6 9 2 4567890123 567890 12
PRTPARM	1234567890123456 8901234 6 9 2 4567890123 567890 12
LABEL	1234567890123456 8901234 6 9 2 4567890123 567890 12
PRTPARM	1234567890123456 8901234 6 9 2 4567890123 567890 12
LABEL	1234567890123456 8901234 6 9 2 4567890123 567890 12
PRTPARM	1234567890123456 8901234 6 9 2 4567890123 567890 12
LABEL	1234567890123456 8901234 6 9 2 4567890123 567890 12
END	1234567890123456 8901234 6 9 2 4567890123 567890 12

7.23 .4 Rigid Format Change Restart Table

DMAP Inst.	Bit Position 63 — 70	80
BEGIN	345678901234567	345
FILE	345678901234567	345
GP1		
SAVE		
COND	345678901234567	345
CHKPNT		
PURGE		
GP2		
CHKPNT		
GP3		
CHKPNT		
TA1		
SAVE		
COND	345678901234567	345
PURGE		
CHKPNT		
PARAM		
PARAM	3 678	
PARAM		
COND		
PARAM		
INPUTT1		
EQUIV		
CHKPNT		
LABEL		
EMG	3 678	
SAVE	3 678	
CHKPNT	3 678	
COND		
EMA		
CHKPNT		
LABEL		
COND	3 678	
EMA	3 678	
CHKPNT	3 678	
COND		
GPWG		
OFP		
LABEL		
EQUIV		
CHKPNT		
COND		
SMA3		
CHKPNT		
LABEL		
GP4		
SAVE		
PARAM		
COND		
PURGE		
GPCYC		

DMAP Inst.	Bit Position 63 70	80
SAVE		
CHKPNT		
COND		
COND		
GPSP		
SAVE		
COND		
OFP		
LABEL		
EQUIV		
CHKPNT		
COND		
MCE1		
CHKPNT		
MCE2		
CHKPNT		
LABEL		
EQUIV		
CHKPNT		
COND		
SCE1		
CHKPNT		
LABEL		
EQUIV		
CHKPNT		
COND		
SMP1		
CHKPNT		
SMP2		
CHKPNT		
LABEL		
DPD		
SAVE		
COND	345678901234567	345
EQUIV		
CYCT2		
SAVE		
CHKPNT		
COND		
READ		
SAVE		
CHKPNT		
PARAM		
OFP		
SAVE		
COND	345678901234567	345
CYCT2		
SAVE		
CHKPNT		
COND		
SDR1		

```
DMAP           Bit Position
Inst.     63        70         80

SDR 2
OFP
SAVE
APDB
SAVE
CHKPNT
PARTN
SMPYAD
MTRXIN
SAVE
PURGE
EQUIV
CHKPNT
GKAD
CHKPNT
GKAM      3        234
SAVE      3        234
CHKPNT    3        234
PARAML
PURGE
COND
PLTSET
SAVE
PRTMSG
PARAM
PARAM
COND
PLOT
SAVE
PRTMSG
LABEL
COND
PARAM     345678901234567     345
AMG
SAVE
CHKPNT
COND
INPUTT2
LABEL
PARAM
AMP
SAVE
CHKPNT
PARAM
PARAM
PARAM     345678901234567     345
PARAM     345678901234567     345
JUMP      345678901234567     345
LABEL     345678901234567     345
FA1
SAVE
```

DMAP Inst.	Bit Position 63 70	80
READ		
SAVE		
COND		
COND		
VDR		
SAVE		
COND		
OFP		
SAVE		
LABEL		
FA2		
SAVE		
CHKPNT		
COND	345678901234567	345
LABEL	345678901234567	345
COND	345678901234567	345
REPT	345678901234567	345
JUMP	345678901234567	345
LABEL	345678901234567	345
CHKPNT	345678901234567	345
PARAML		
COND		
XYTRAN		
SAVE		
XYPLOT		
LABEL		
PARAM		
COND		
MODACC		
DDR1		
CHKPNT		
EQUIV		
COND		
SDR1		
LABEL		
CHKPNT		
EQUIV		
COND		
VEC		
PARTN		
LABEL		
SDR2		
CHKPNT		
OFP		
COND		
PLOT		
PRTMSG		
LABEL		
JUMP	345678901234567	345
LABEL	345678901234567	345
PRTPARM	345678901234567	345

DMAP Inst.	Bit Position 63 70	80
LABEL	345678901234567	345
PRTPARM	345678901234567	345
LABEL	345678901234567	345
PRTPARM	345678901234567	345
LABEL	345678901234567	345
PRTPARM	345678901234567	345
LABEL	345678901234567	345
PRTPARM	345678901234567	345
LABEL	345678901234567	345
PRTPARM	345678901234567	345
LABEL	345678901234567	345
END	345678901234567	345

7.23 .5 File Name Restart Table

DMAP Inst.	94	100	110	120	130	140	150
			Bit Position				
BEGIN							
FILE							
GP1	4						
SAVE	4						
COND	4						
CHKPNT	4						
PURGE				8			
GP2	5						
CHKPNT	5						
GP3	6						
CHKPNT	6						
TA1	7						
SAVE	7						
COND	7						
PURGE	7	2					
CHKPNT	7	2					
PARAM	8						
PARAM	9						
PARAM	8						
COND	8						
PARAM	8						
INPUTT1	8						
EQUIV	8						
CHKPNT	8						
LABEL							
EMG				2			
SAVE				2			
CHKPNT				2			
COND	8						
EMA	8						
CHKPNT	8						
LABEL	8						
COND	9						
EMA	9						
CHKPNT	9						
COND							
GPWG							
OFP							
LABEL							
EQUIV		0					
CHKPNT		0					
COND		0					
SMA3		0					
CHKPNT		0					
LABEL		0					
GP4		1					
SAVE		1					
PARAM		1					
COND							
PURGE		3 5	35	0			
GPCYC						0	

RIGID FORMAT RESTART TABLES

DMAP Inst.	94	100	110	120	130	140	150
SAVE						0	
CHKPNT						0	
COND						0	
COND		2					
GPSP		2					
SAVE		2					
COND		2					
OFP		2					
LABEL		2					
EQUIV		4					
CHKPNT		4					
COND		34					
MCE1		3					
CHKPNT		3					
MCE2		4					
CHKPNT		4					
LABEL		34					
EQUIV		5					
CHKPNT		5					
COND		5					
SCE1		5					
CHKPNT		5					
LABEL		5					
EQUIV		6		3			
CHKPNT		6		3			
COND		6	3	3			
SMP1		6	3				
CHKPNT		6	3				
SMP2				3			
CHKPNT				3			
LABEL		6	3	3			
DPD			1				
SAVE			1				
COND			1				
EQUIV			5				
CYCT2						1	
SAVE						1	
CHKPNT						1	
COND						1	
READ					4	2	
SAVE					4	2	
CHKPNT					4	2	
PARAM					4	2	
OFP					4	2	
SAVE					4	2	
COND					4	2	
CYCT2			2				
SAVE			2				
CHKPNT			2				
COND			2				
SDR1						3	

DMAP Inst.	94	100	110 (Bit Position)	120	130	140	150
SDR2						3	
OFP						3	
SAVE						3	
APOB				4 6		4	
SAVE				4 6		4	
CHKPNT				4 6		4	
PARTN						5	
SMPYAD					6		
MTRXIN			4				
SAVE			4				
PURGE			4		9		
EQUIV			4		9		
CHKPNT			4		9		
GKAD			5		9		
CHKPNT			5		9		
GKAM			6				
SAVE			6				
CHKPNT			6				
PARAML				5			
PURGE				5			
COND				5			
PLTSET				5			
SAVE				5			
PRTMSG				5			
PARAM				5			
PARAM				5			
COND				5			
PLOT				5			
SAVE				5			
PRTMSG				5			
LABEL				5			
COND							
PARAM							
AMG				7			
SAVE				7			
CHKPNT				7			
COND				8			
INPUTT2				8			
LABEL				8			
PARAM					8		
AMP					8		
SAVE					8		
CHKPNT					8		
PARAM							
PARAM							
PARAM							
PARAM							
JUMP							
LABEL							
FA1				9			
SAVE				9			

RIGID FORMAT RESTART TABLES

DMAP Inst.	94	100	110	120	130	140	150
CEAD			7				
SAVE			7				
COND			7				
COND							
VDR							
SAVE							
COND							
OFP							
SAVE							
LABEL							
FA2					0		
SAVE					0		
CHKPNT					0		
COND							
LABEL							
COND							
REPT							
JUMP							
LABEL							
CHKPNT							
PARAML							
COND							
XYTRAN							
SAVE							
XYPLOT							
LABEL							
PARAM							
COND							
MODACC					1 3		
DDR1			8				
CHKPNT			8				
EQUIV				0			
COND				0			
SDR1				0			
LABEL				0			
CHKPNT				0			
EQUIV					2		
COND					2		
VEC					2		
PARTN					2		
LABEL					2		
SDR2					7		
CHKPNT					7		
OFP							
COND							
PLOT							
PRTMSG							
LABEL							
JUMP							
LABEL							
PRTPARM							

DMAP Inst.	94	100	110	120	130	140	150
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
PRTPARM							
LABEL							
END							

DEMONSTRATION MANUAL UPDATES (Level 17.7)

C-4

This section contains new and replacement pages for Level 17.7 of the NASTRAN Demonstration Manual, NASA SP-224(05).

The updates pertain to new demonstration problems. Pages to be replaced and inserted are:

Section	Pages
Table of Contents	iv
4	4
9.5	9.5-1 thru 9.5-6
16.1	16.1-1 thru 16.1-5

TABLE OF CONTENTS (Continued)

UMF pid	NASTRAN DEMONSTRATION PROBLEMS ON UMF TAPE
70220	Fifth Harmonic Complex Eigenvalue Analysis of a Gas-Filled Thing Elastic Cylinder
80110	Frequency Response of a 10xk0 Plate
80120	Frequency Response of a 20x20 Plate
80130	Frequency Response of a 10x10 Plate (via INPUT Module)
80140	Frequency Response of a 20x20 Plate (via INPUT Module)
90110	Transient Analysis with Direct Matrix Input
90210	Transient Analysis of a 1000-Cell String, Traveling Wave Problem
90220	Transient Analysis of a 1000-Cell String, Traveling Wave Problem (via INPUT module)
90310	Transient Analysis of a Fluid-Filled Elastic Cylinder
90410	Linear Transient Heat Transfer in a Plate
100110	Complex Eigenvalue Analysis of a Rocket Control System
100210	Aeroelastic Flutter Analysis of a 15° Swept Wing
110110	Frequency Response and Random Analysis of a Ten Cell Beam
RESTART	Frequency Response and Random Analysis of a Ten Cell Beam, Enforced Deformation and Gravity Load
110210	Frequency Response of a 500-Cell String
110220	Frequency Response of a 500-Cell String (via INPUT Module)
110310	Jet Transport Wing Dynamic Analysis, Frequency Response
110320	Jet Transport Wing Dynamic Analysis, Transient Response
120110	Transient Analysis of a Free One Hundred Cell Beam
130110	Normal Modes Analysis of a One Hundred Cell Beam with Differential Stiffness
140110	Static Analysis of a Circular Plate Using Dihedral Cyclic Symmetry
150110	Normal Modes Analysis of a Circular Plate Using Rotational Cyclic Symmetry

UMF pid	NASTRAN DEMONSTRATION PROBLEMS ON UMF TAPE
70220	Fifth Harmonic Complex Eigenvalue Analysis of a Gas-Filled Thin Elastic Cylinder
80110	Frequency Response of a 10x10 Plate
80120	Frequency Response of a 20x20 Plate
80130	Frequency Response of a 10x10 Plate (via INPUT Module)
80140	Frequency Response of a 20x20 Plate (via INPUT Module)
90110	Transient Analysis with Direct Matrix Input
90210	Transient Analysis of a 1000-Cell String, Traveling Wave Problem
90220	Transient Analysis of a 1000-Cell String, Traveling Wave Problem (via INPUT Module)
90310	Transient Analysis of a Fluid-Filled Elastic Cylinder
90410	Linear Transient Heat Transfer in a Plate
90510	Aeroelastic Flutter Analysis of an Axial Flow Compressor Stage
100110	Complex Eigenvalue Analysis of a Rocket Control System
100210	Aeroelastic Flutter Analysis of a 15° Swept Wing
110110	Frequency Response and Random Analysis of a Ten Cell Beam
RESTART	Frequency Response and Random Analysis of a Ten Cell Beam, Enforced Deformation and Gravity Load
110210	Frequency Response of a 500-Cell String
110220	Frequency Response of a 500-Cell String (via INPUT Module)
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130110	Normal Modes Analysis of a One Hundred Cell Beam with Differential Stiffness
140110	Static Analysis of a Circular Plate Using Dihedral Cyclic Symmetry
150110	Normal Modes Analysis of a Circular Plate Using Rotational Cyclic Symmetry
160110	Aeroelastic 'Design/Analysis' of an Axial Flow Compressor Stage

RIGID FØRMAT No. 9 (APP AERØ), Aeroelastic Analysis

Modal, Flutter and Subcritical Roots Analyses of an Axial Flow Compressor Stage (9-5-1)

A. Description

The problem illustrates the use of the aeroelastic cyclic modal and flutter analyses of the first stage rotor of an axial flow air compressor to,

i) determine the natural frequencies and mode shapes of the bladed disc sector, of Figure 1, which exhibits rotational cyclic symmetry. The total stiffness matrix, including the differential stiffness effects at the operating point under consideration, saved during the Static Aerothermoelastic "Analysis" (see Demonstration Manual example 16-1) is used for the cyclic modal analysis.

ii) examine if the operating point being considered is a flutter point by analyzing the V-g and V-f plots based on user-selected combinations of densities, inter-blade phase angles and reduced frequencies, and in the process

iii) identify the subcritical (stable) roots.

B. Input

Bulk data cards used include AERØ, FLFACT, FLUTTER, MKAERØ1, STREAML1, STREAML2 and PARAMeters IREF, KGGIN, LMØDES, MAXMACH, MINMACH, MTYPE and PRINT as described in the User's Manual Sections 1.15.2 and 1.15.5. Bulk data cards CYJØIN and PARAMeters CTYPE, KINDEX and NSEGS are discussed in Section 1.12 of the User's Manual.

C. Analyses and Results

The finite element model of the bladed disc sector analyzed is shown in Figure 1. The first five zeroth harmonic natural frequencies and mode shapes of the sector are noted in Table 1. The grid points on the hub in contact with the compressor shaft were permitted radial translational degree of freedom only.

As a typical example, the first of the three frames of V-g and V-f plots output requested in this demonstration problem is shown in Figure 2. The density and interblade phase angle are held constant at (0.059 x 1.507 E-6) slinch/in^3 and 180^o, respectively, for this frame. The three reduced frequencies are identified by the symbols *(k=0.3), O(k=0.7) and A(k=1.0). The flutter summary for the three (ρ, σ, k) groups is presented in Table 2.

A close examination of the damping curves shows that the damping is nearly zero in the fourth mode of frequency 1797 H_z.

The implied density, velocity and reduced frequency are, respectively (0.059 x 1.507 E-6) slinch/in^3, 1.055 E4 in/sec and 1.0 as compared with the actual values of these quantities as (0.059 x 1.507 E-6) slinch/in^3, 1.910 E4 in/sec and 1.0, respectively.

The ratio $V_{implied}/V_{actual}$ not being equal (or close) to 1.0 discounts the current operating point as being on a flutter boundary, at which all the three implied quantities must equal the actual quantities.

The demonstration example discussed has been presented principally for the purpose of illustrating the procedure for axial flow compressor flutter analysis. In order to locate the unstalled flutter boundaries over the entire region of operation of the compressor stage, similar analysis would be required for a series of operating points, harmonic numbers, interblade phase angles and reduced frequencies for both the stage rotor and the stator. Appropriate superposition of the rotor and stator results would then help identify the unstalled flutter boundaries on the compressor stage map.

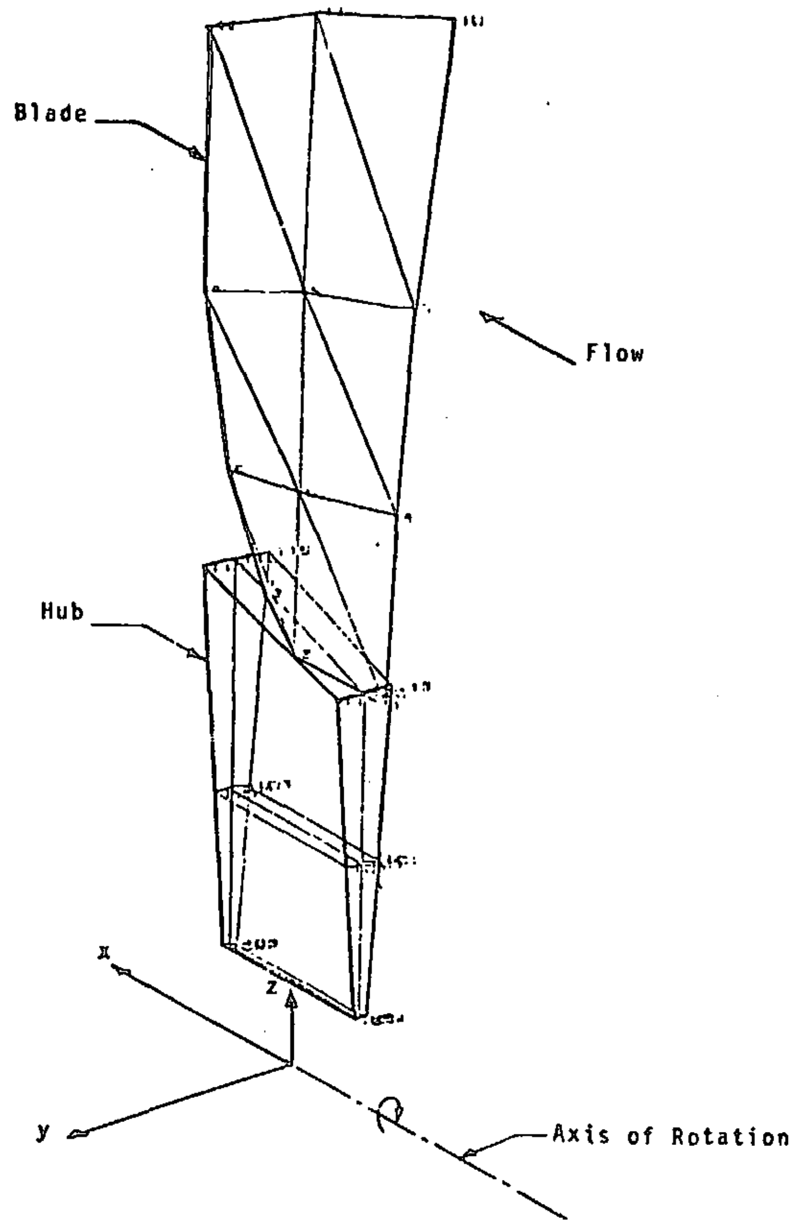

Figure 1. Finite Element Model of an Axial Flow Compressor Rotor Sector, and the Basic Coordinate System

Table 1. Bladed Disc Sector: Zeroth Harmonic Modes

Mode No.	1	2	3	4	5
Mode Frequency, Hz	471	790	977	1797	2154
Mode Shape	Circum-ferential Bending	\xial Bending	Torsion	Chordwise Bending (tip)	-

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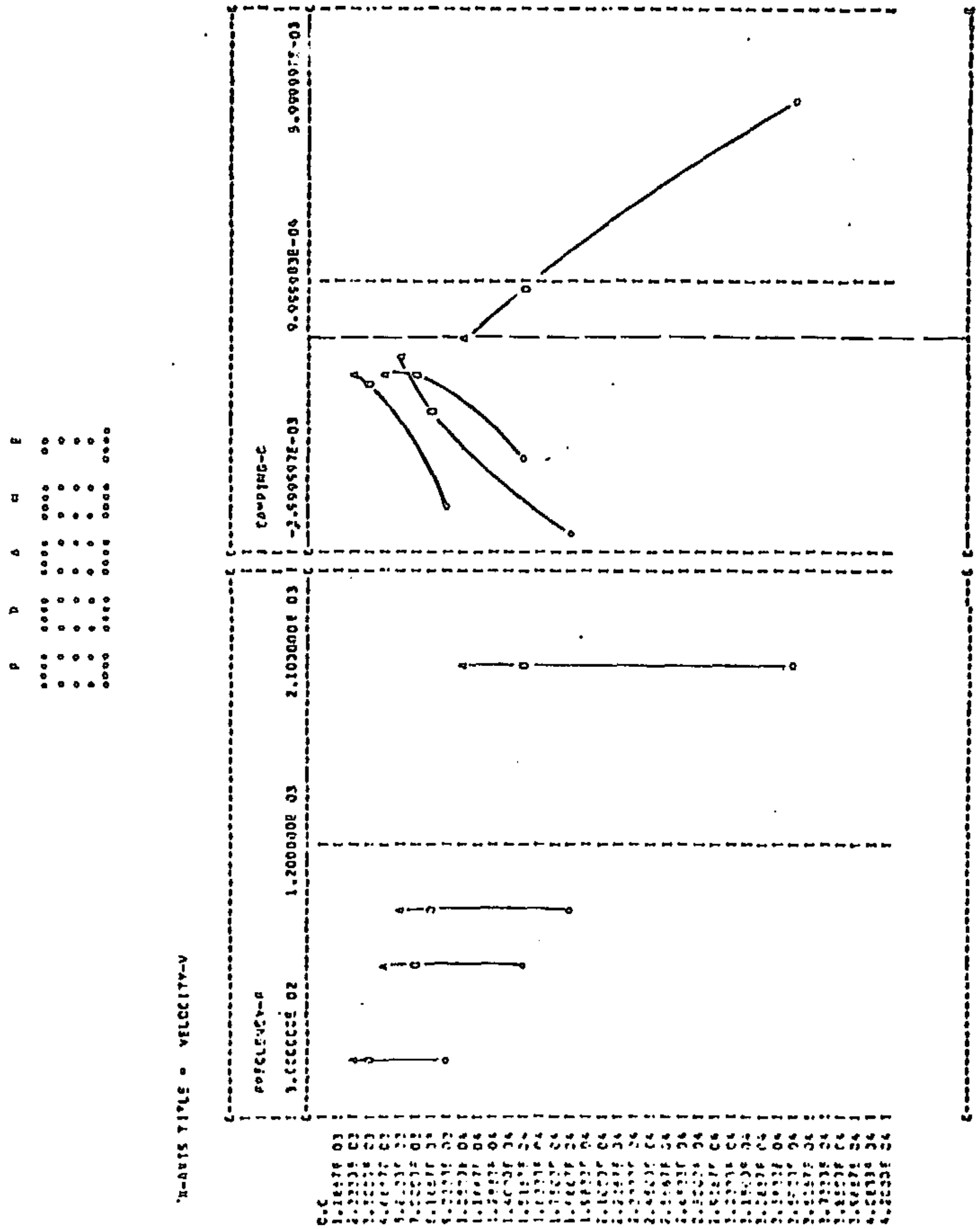

Figure 2. V-g, V-f Plots, Frame 1

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Table 2. Flutter Summary (k-Method)

ρσk Group	Reduced Frequency k	Velocity V, in/sec	Damping g	Frequency f, Hz
$\rho_1\sigma_1 k_1$	0.3	9.241 E3	-3.199 E-3	472
		1.549 E4	-2.291 E-3	791
		1.911 E4	-3.642 E-3	976
		3.530 E4	4.261 E-3	1803
$\rho_1\sigma_1 k_2$	0.7	3.956 E3	-9.376 E-4	471
		6.633 E3	-6.666 E-4	790
		8.199 E3	-1.379 E-3	977
		1.508 E4	8.001 E-4	1798
$\rho_1\sigma_1 k_3$	1.0	2.769 E3	-7.441 E-4	471
		4.643 E3	-6.892 E-4	790
		5.740 E3	-4.602 E-4	977
		1.055 E3	-8.848 E-5	1797

RIGID FORMAT No. 16, Static Aerothermoelastic 'Design/Analysis'

Aeroelastic 'Design/Analysis' of an Axial Flow Compressor Stage (16-1)

A. Description

This problem illustrates the use of the static aeroelastic analyses of the first stage rotor of an axial flow air compressor to determine,

i) the "as manufactured" blade shape required to produce the design point pressure ratio ("design" problem), and

ii) the operating point of the "flexible" designed blade ("analysis" problem). The total stiffness matrix, consisting of the elastic and geometric stiffness matrices, at any off-design operating point is saved for use in subsequent modal and flutter analyses. (See Demonstration Manual example 9-1).

The 43-blade rotor is designed to develop a total pressure ratio of 1.85 at a speed of 16043 rpm and an air flow rate of 73.15 lbm/sec. The finite element model of a representative sector of the rotor is shown in Figure 1.

B. Input

Bulk data cards used include DTI, STREAML1, PARAMeters APRESS, ATEMP, FXCØØR, FYCØØR, FZCØØR, IPRTCF, IPRTCI, IPRTCL, KTØUT, PGEØM, SIGN, STREAML and ZØRIGN as illustrated in the User's Manual Section 1.15.3.

C. Analyses and Results

The rigid blade of Figure 1 produces a total pressure ratio of 1.85 at 16043 rpm and 73.15 lbm/sec air flow rate (Table 1). Because of the elasticity of the material, and under the action of centrifugal and aerodynamic pressure and thermal loads, the blade deforms and produces a total pressure ratio greater than the design value. A "redesign" of the rigid blade, considering the elastic and geometric properties of the bladed disc sector, enables determination of the "as manufactured" blade shape that, when loaded and deformed, would produce the design pressure ratio. The 'rigid' performance of the "as manufactured" blade shape obtained at the end of the Design problem is also shown in Table 1.

This blade shape is then "Analyzed", in the current demonstration example, at the same (design) speed and flow rate to determine the 'flexible' operating pressure ratio. This value (1.84) can be further improved to approach the desired (1.85) pressure ratio by reducing the Parameters FXCØØR, FYCØØR and FZCØØR in the Design problem (see User's Manual Section 1.15.3).

The blade shape at various stages during the Design and Analysis problems, as reflected by the grid point coordinates, is also shown in Tables 1 and 2. The coordinates are expressed in the basic system of Figure 1.

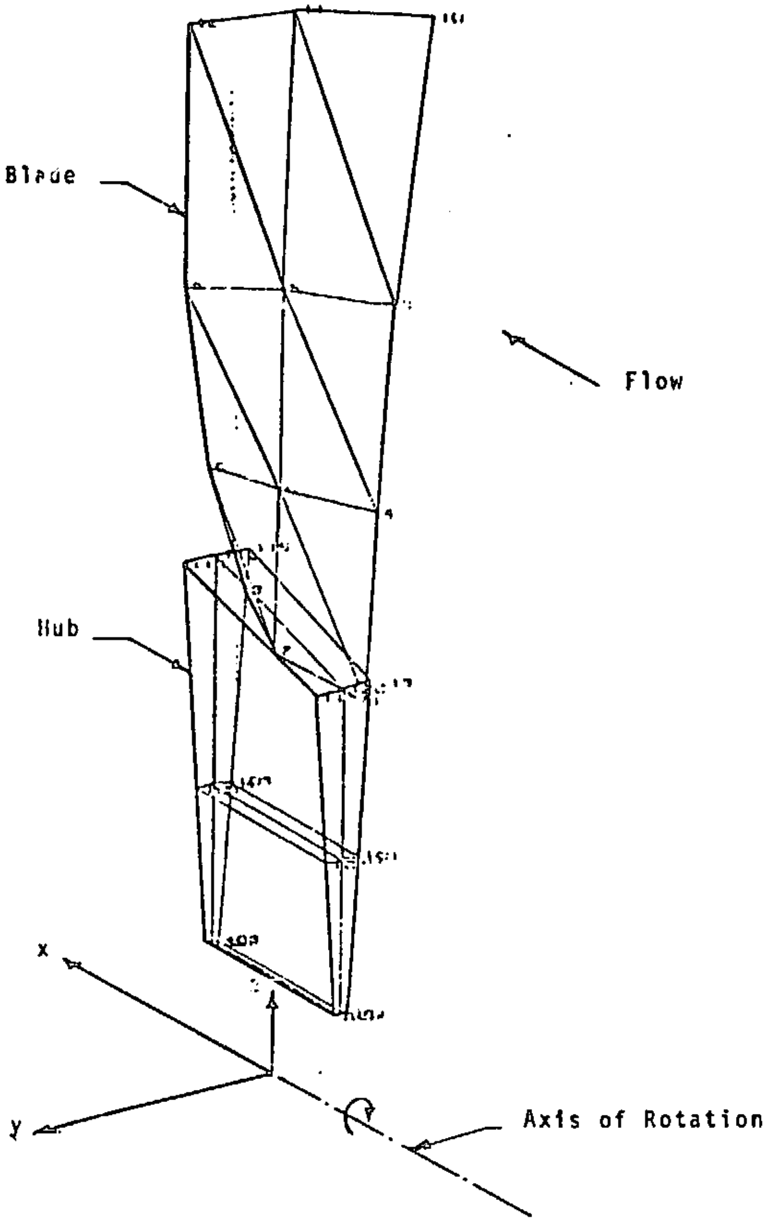

Figure 1. Finite Element Model of an Axial Flow Compressor Rotor Sector, and the Basic Coordinate System

Table 1. Design Problem

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	Initial, Designed Blade 'Rigid' Performance			"As Manufactured" Blade 'Rigid' Performance		
Total Pressure Ratio	1.85			1.80		
Rotational Speed, rpm	16043			16043		
Air Flow Rate, lbm/sec	73.15			73.15		
Grid Points	X,in.	Y,in.	Z,in.	X,in.	Y,in.	Z,in.
1	-0.8980	-0.2732	3.7902	-0.8981	-0.2755	3.7796
2	0.0	0.0532	3.9996	-0.0001	0.0540	3.9986
3	0.8980	-0.2499	4.1926	0.8979	-0.2464	4.1847
4	-0.7630	-0.5004	5.4772	-0.7653	-0.4830	5.4554
5	0.0	0.0209	5.5000	-0.0005	0.0209	5.4985
6	0.7800	0.2342	5.4950	0.7799	0.2307	5.4889
7	-0.6290	-0.7494	7.3620	-0.6386	-0.7217	7.3281
8	0.0	0.0131	7.4000	-0.0091	0.0155	7.3976
9	0.6290	0.6369	7.3725	0.6240	0.6123	7.3416
10	-0.4240	-0.9330	9.9564	-0.4058	-1.1351	9.8905
11	0.0	-0.0221	10.0000	-0.0106	-0.0236	9.9970
12	0.4240	0.7598	9.9711	0.4140	0.8134	9.9304

Table 2. Analysis Problem

	"As Manufactured" Blade 'Rigid' Performance			"As Manufactured" Blade 'Flexible' Performance		
Total Pressure Ratio	1.80			1.84		
Rotational Speed, rpm	16043			16043		
Air Flow Rate, lbm/sec	73.15			73.15		
Grid Points	X,in.	Y,in.	Z,in.	X,in.	Y,in.	Z,in.
1	-0.8981	-0.2755	3.7796	-0.8979	-0.2814	3.7712
2	-0.0001	0.0540	3.9986	0.0001	0.0516	4.0003
3	0.8979	-0.2464	4.1847	0.8981	-0.2461	4.1795
4	-0.7653	-0.4830	5.4554	-0.7726	-0.4744	5.4413
5	-0.0005	0.0209	5.4985	-0.0031	0.0228	5.5033
6	0.7799	0.2307	5.4889	0.7797	0.2247	5.4889
7	-0.6386	-0.7217	7.3281	-0.6646	-0.7082	7.3062
8	-0.0091	0.0155	7.3976	-0.0157	0.0164	7.4058
9	0.6240	0.6123	7.3416	0.6303	0.5962	7.3237
10	-0.4058	-1.1351	9.8905	-0.5237	-1.1552	9.8520
11	-0.0106	-0.0236	9.9970	-0.0320	-0.0656	10.0079
12	0.4140	0.8134	9.9304	0.4130	0.7329	9.9093

APPENDIX

RECODING OF SUBROUTINE UCAS

The two dimensional supersonic cascade unsteady aerodynamic routine UCAS (Ref. 1) delivered as part of the Bladed-Shrouded-Disc Aeroelastic Analysis Computer Program (Ref. 2) was recoded to improve the execution time. These improvements included the following:

1. Real variables originally defined as complex variables were changed to real to reduce complex arithmetic operations.
2. Computations within a Fortran loop which resulted in constant values and constant subroutines were removed outside the loop and stored for use within the loop.
3. It was noted that many complex exponent equations could be recursively formed by constant terms multiplications within loops. Extensive loop recoding was inserted to take advantage of this. All four subroutines in the module viz. SUBA, SUBBB, SUBC, and SUBD were modified to reflect this.
4. Alternative methods for reducing the number of iterations used in series convergence were considered and inserted into the program.

A listing of the revised code to generate the generalized modal aerodynamic matrices for chordwise aerodynamic modes is included.

Results for four cases using the original and the revised codes are presented in Table 1 at the end of the listing. The execution time has been reduced to about one-fourth the original time, maintaining an excellent agreement between the original and the revised code results.

REFERENCES

1. Goldstein, M. E., Braun, W., and Adamczyk, J. J., "Unsteady Flow in a Supersonic Cascade with Strong In-Passage Shocks", Journal of Fluid Mechanics, Vol. 83, Part 3, December 1977.
2. Smith, G. C. C., and Elchuri, V., "Aeroelastic and Dynamic Finite Element Analyses of a Bladed Shrouded Disk", Final Technical Report, NASA CR-159728, March 1980.

REVISED 'UCAS'

```
C
C     UCAS STAND-ALONE TEST (SUPER-SONIC).
C     REQUIRED INPUT DATA IS IN /TEST/.
C
      NAMELIST/TEST / IREF,MINMAC,MAXMAC,NLINES,NSTNS,REFSTG,REFCRD,
     1                REFMAC,REFDEN,REFVEL,REFFLO,SLN,NSTNSX,STAGER,
     2                CHORD,RADIUS,BSPACE,MACH,DEN,VEL,FLOWA,AMACH,
     3                REDF,BLSPC,AMACHR,TSONIC,REFC,SIGMA,RFREQ
      REAL MINMAC,MAXMAC,MACH
      INTEGER SYSBUF,SLN,AMACHR
      LOGICAL TSONIC
      COMMON /AMGMN/ MCB(7),NROW,DUM(2),REFC,SIGMA,RFREQ
      COMMON /BAMG1L/ IREF,MINMAC,MAXMAC,NLINES,NSTNS,REFSTG,REFCRD,
     1                REFMAC,REFDEN,REFVEL,REFFLO,SLN,NSTNSX,STAGER,
     2                CHORD,RADIUS,BSPACE,MACH,DEN,VEL,FLOWA,AMACH,
     3                REDF,BLSPC,AMACHR,TSONIC
      COMMON /SYSTEM/ SYSBUF,IOUT
      DIMENSION IY(8)
      COMPLEX Q(3,3)
      IOUT=6
   10 READ(5,TEST,END=999)
      DEGRA=0.0174 53292 51994
      AMACH=MACH*COS(DEGRA*(FLOWA-STAGER))
      REDF=RFREQ*(CHORD/REFCRD)*(REFVEL/VEL)*(MACH/AMACH)
      BLSPC=BSPACE/CHORD
      WRITE(6,1000) SLN,SIGMA,RFREQ
      WRITE(6,TEST)
      CALL GETTIM(IY)
      CPU1=IY(2)
      CALL AMGB1C(Q)
      CALL GETTIM(IY)
      CPU2=IY(2)
      WRITE(6,1001)Q
      CPU=(CPU2-CPU1)/1000.0
      WRITE(6,1002)CPU
      GO TO 10
  999 STOP
 1000 FORMAT('1SLN = ',I2,', SIGMA = ',F7.2,', RFREQ = ',E13.6 //)
 1001 FORMAT('0Q--MATRIX FOLLOWS '/(1X,1P6E20.7))
 1002 FORMAT('0CPU TIME ON IBM 370/3031 = ',F7.2,' SECONDS.')
      END
```

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```
C***********************************************************************
C                                                                      *
C     PLACE UCAS SOURCE CODE HERE.                                     *
C     ROUTINES - AMGB1C,SUBA,SUBBB,SUBC,SUBD                           *
C                ALAMDA,AKP2,AKAPPA,DLKAPM,ASYCON,AKAPM,DRKAPM         *
C                                                                      *
C     NASTRAN ROUTINES INVERS AND MESAGE ARE ALSO USED.                *
C     COMMON /SYSTEM/ SYSBUF,IOUT   (IS ALSO NECESSARY. SET IOUT=6)    *
C                                                                      *
C***********************************************************************
      SUBROUTINE AMGB1C(Q)
      COMMON /SYSTEM/SYSBUF,IBBOUT
      COMMON /AMGMN/MCB(7),NROW,DLM(2),REFC,SIGM ,RFREQ
      COMMON /BAMG1L/IREF,MINMAC,MAXMAC,NLINES,NSTNS,REFSTG,REFCRD,
     1               REFMAC,REFDEN,REFVEL,REFFLO,SLN,NSTNSX,STG,
     2               CHORD,RADIUS,BSPACE,MACH,DEN,VEL,FLOWA,AMACHD,
     3              REDFD,BLSPC,AMACHR,TSONIC
C     SUPER SONIC
C
C     UNSTEADY FLOW ANAYSIS OF A SUPERSONIC CASCADE
C
C
C     LIFT AND MOMENT COEFICIENT
C
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMMON/BLK3/ SBKDE1,SBKDE2,F4,F4S,AM4,F5S,F6S,AM4TST,SUM3,SUM4,
     1 AM5TT,AM6,SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T,
     2 A,B,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N,
     3 C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,
     4 FT3T,F2P,AM2P,SUM1T,SUM2T,C1P,C1N,     BKDEL1,     BKDEL2,
     5 BLKAP1,ARG,ARG2,FT3TST,BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4,
     6 CLIFT,CMOMT,PRES1,PRES2,PRES3,PRES4,QRES4,FQA,FQB,FQ7
      COMMON/BLK4/I,R,Y,A1,B1,C4,C5,GL,I6,I7,JL,NL,RI,RT,R5,SN,SP,XL,
     1    Y1,AMU,          GAM,IDX,INX,NL2,RL1,RL2,RQ1,RQ2,XL1,ALP1,ALP2,
     2 GAMN,GAMP,INER,IOUT,REDF,STAG,STEP,AMACH,BETNN,BETNP,
     3 BKAP1,XLSV1,XLSV2,XLSV3,XLSV4,ALPAMP,AMOAXS,
     4 DISAMP,GUSAMP,PITAXS,PITCCR
      COMPLEX SBKDE1,SBKDE2
      COMPLEX F4,F4S,       AM4,F5S,F6S,AM4TST,SUM3,SUM4,AM5TT,AM6
      COMPLEX SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T
      COMPLEX AI,A,B,BSYCON,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N -
      COMPLEX C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,   -
     1FT3T,F2P,AM2P,SUM1T,SUM2T
      COMPLEX C1P,C1N,BKDEL1,BKDEL2,BLKAP1,ARG,ARG2,FT3TST
      COMPLEX BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4
      COMPLEX CLIFT,CMOMT
      COMPLEX PRES1,PRES2,PRES3,PRES4,QRES4
      COMPLEX FQA,FQB
      COMPLEX FQ7
      COMPLEX PRESU,PRESL,Q,AVGDP
      DIMENSION GYE(29,29),GEE(29,20),PRESU(29),PRESL(29),XUP(29)
      DIMENSION XLOW(29)
```

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```
      DIMENSION AYE(10,29)
      DIMENSION W(8)
      DIMENSION INDEX(29,3)
      DIMENSION Q(NSTNS,NSTNS)
      DIMENSION PRES1(21),PRES2(21),PRES3(21),PRES4(21),QRES4(21)
      DIMENSION SBKDE1(201),SBKDE2(201)
      DIMENSION SUMSV1(201),SUMSV2(201),SVKL1(201),SVKL2(201)
      DIMENSION XLSV1(21),XLSV2(21),XLSV3(21),XLSV4(21)
      EQUIVALENCE (AYE(1,1),GYE(1,1))
      DATA W/1.27324,0.0,.424413,0.,.254648,0.,.1818913,0.0/
      REDF = REDFD
      AMACH = AMACHD
      AI=CMPLX(0.0,1.0)
      PI=3.1415927
      PITCOR = BLSPC
      STAG = 90.0 - STG
      SIGMA= SIGM * PI/180.0
      BETA=SQRT(AMACH**2-1.0)
      SCRK=REDF*AMACH/(BETA**2)
      DEL=SCRK*AMACH
      AMU=REDF/(BETA**2)
      SP=PITCOR*COS(STAG*PI/180.0)*2.0
      SN=PITCOR*SIN(STAG*PI/180.0)*2.0
      SPS=SP
      SNS=SN*BETA
      DSTR=SQRT(SPS**2-SNS**2)
      SPS1 = ABS( SPS - SNS)
      IF(SPS1 .LT. .00001) GO TO 9991
C     ZERO OUT GEE
      NSTNS2 = 2*NSTNS
      DO 50 I=1,29
      DO 50 J=1,NSTNS2
   50 GEE(I,J) = 0.0
      PITAXS   = 0.0
      AMDAXS   = 0.
      CALL ASYCON
      CALL AKP2
      RL1=9
      S1=SPS-SNS
      AA=S1/RL1
      XLSV1(1)=0.0
      DO 4541 JL=1,9
 4541 XLSV1(JL+1)=JL*AA
      AA=SPS-SNS
      RL2=19
      S1=2.0+SNS-SPS
      TEMP=S1/RL2
      XL=AA
      DO 4571 JL=1,20
      XLSV2(JL)=XL
      XLSV3(JL)=XL+SNS-SPS
 4571 XL=XL+TEMP
      XL=SNS+2.0-SPS
      TEMP=(SPS-SNS)/RL1
      DO 458 JL=1,10
      XLSV4(JL)=XL
  458 XL=XL+TEMP
C       ACCUMULATE PRESSURE VECTORS INTO G-MATRIX
```

```
      DO 100  NM=1,NSTNS
      NTIMES = 1
      IF(NM .GT.2) NTIMES =2
      DO 100  NMM =1,NTIMES
C          DEFINE -----------------------------
C                   ALPAMP - PITCHING AMP
C                   DISAMP - PLUNGING AMP
C                   GUSAMP - GUST AMP
C                   GL -GUST WAVE NUMBER
      ALPAMP = 0.C
      IF(NM .EQ. 2) ALPAMP=1.0
      DISAMP = 0.0
      IF(NM .EQ. 1) DISAMP=1.0
      GUSAMP=0.C
      GL =0.0
      IF(NM.GT. 2 .AND. NMM .EQ.1) GUSAMP= REDF/2.0 -(NM-2)*PI/4.0
      IF(NM.GT. 2 .AND. NMM .EQ.1) GL = (NM-2)*PI/2.0
      IF(NM.GT. 2 .AND. NMM .EQ.2) GUSAMP= -(REDF/2.0+((NM-2)*PI/4.0))
      IF(NM.GT. 2 .AND. NMM .EQ.2) GL = -(NM-2)*PI/2.0
C
      A=(1.0+AI*REDF*PITAXS)*ALPAMP-AI*REDF*DISAMP
      B=-AI*REDF*ALPAMP
      IF( GL .EQ. 0.0)  GO TO 2047
      A=GUSAMP
      B=0.0
 2047 CONTINUE
      CALL  SUBA
C
C        FIND  DELTA P(LOWER-UPPER)
      DO 60 NX=1,10
      PRESU(NX) = PRES1(NX)
      XUP(NX)    = XLSV1(NX)
      IF(NX .EQ. 10)GO TO 55
      NXX = NX + 20
      PRESL(NXX) = PRES4(NX+1)
      XLOW( NXX) = XLSV4(NX+1)
      GO TO 610
   55 PRESU(NX) = (PRES1(10) + PRES2(1))/2.0
      XUP(10) = (XLSV1(10) + XLSV2(1))/2.0
 610  CONTINUE
   60 CONTINUE
      DO 70 NX=1,20
      NXX = NX + 10
      IF(NX .EQ. 20)GO TO 65
      PRESU(NXX) = PRES2(NX+1)
      XUP   (NXX) = XLSV2(NX+1)
      PRESL(NX)   = PRES3(NX)
      XLOW( NX)   = XLSV3(NX)
      GO TO 710
   65 PRESL(20)   = (PRES3(20) + PRES4(1))/2.0
      XLOW(20)= (XLSV3(20) + XLSV4(1))/2.0
  710 CONTINUE
   70 CONTINUE
      NM2 = NM + NSTNS
      DO 100 NMMM=1,29
      IF(NMMM .EQ.1) GO TO 80
      AVGDP =(PRESL(NMMM)*XLOW(NMMM) - PRESU(NMMM)*XUP(NMMM))
     1        /((XLOW(NMMM) + XUP(NMMM))/2.0)
```

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```
      GO TO 85
   80 AVGDP =(PRESL(1) - PRESU(1))
   85 GEE(NMMM,NM) = REAL(AVGDP) + GEE(NMMM,NM)
      GEE(NMMM,NM2)= AIMAG(AVGDP)+ GEE(NMMM,NM2)
  100 CONTINUE
C      NOW DEFINE LARGE G MATRIX
      DO 110 I=1,29
      GYE(1,I) = 0.0
  110 GYE(I,1) = 1.0
C                   FIND AVERAGE LOCATIONS PUT IN XLOW
      DO 120 I=2,29
  120 XLOW(I) =(XLOW(I) + XLP(I))/2.0
      DO 160  J=3,29
      CONST =  (J-2)*PI/2.0
      DO 160  I=2,29
      GYE(I,J) =  SIN( CONST * XLOW(I))
  160 CONTINUE
      DO 165  I=2,29
  165 GYE(I,2) = XLOW(I)
C       SOLVE FOR G-INVERSE G IN GEE MATRIV
C      ISING =1 NON-SINGULLAR (GYE)
C      ISING =2  SIGULAR      (GYE)
C      INDEX IS WORK STORAGE FOR ROUTINE INVERS
      CALL  INVERS(29,GYE,29,GEE,NSTNS2,DETERM,ISING,INDEX)
      IF (ISING .EQ. 2) GO TO 9992
C     NOW DEFINE  I-MATRIX (NSTNS X 29)
      AYE(1,1) = 2.0
      CON = 1.0
      AYE(1,2) =2.0
      NIN =27
      DO   288  J=1,NIN
      AYE(1,J+2) = CON*4.0 / J / PI
  288 CON = 1.0 -CON
      AYE(2,1) = 2.C
      AYE(2,2)  = 2.66666667
      CON = 1.0
      DO 289  J=1,NIN
      AYE(2, J+2) =  CON  *4 /J/PI
  289 CON =    -CON
      DO 290 I=3,NSTNS
      DO 290   J=  2,28
      CON = 0.0
      IF((I-1) .EQ. J) CON=1.0
 290  AYE(I,J+1) = CON
      DO 291 J= 3,NSTNS
  291 AYE(J,1) = W(J-2)
      DO   292   J=3,29
  292 AYE(J,2) =  AYE(2,J)
C         NOW  MULTIPLY  I * G-INVERSE * G(DELTA P'S)
      DO   360  J=1,NSTNS
      DO   360  K=1,NSTNS
      NF   =     K+ NSTNS
      SUMI   =0.0
      SUMR  = 0.C
      DO 350  I=1,29
      SUMR  =  AYE(J,I) * GEE(I,K) + SUMR
      SUMI  =  AYE(J,I) * GEE(I,NF) + SUMI
  350 CONTINUE
```

```
 360 Q(J,K) = - CMPLX(SUMR,SUMI) * 0.5
     RETURN
9991 WRITE(IBBOUT,3000)
3000 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE AMGBIC/
    1      39X,45HAXIAL MACH NUMB. IS EQUAL TO OR GREATER THAN ONE.)
     GO TO 9999
9992 WRITE(IBBOUT,3001)
3001 FORMAT(84H0*** USER FATAL MESSAGE - AMG MODULE - LARGE G-MATRIX IS
    1 SINGULAR IN ROUTINE AMGBIC. )
9999 CALL MESAGE(-61,0,0)
     RETURN
     END
```

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```
      SUBROUTINE SUBA
C
C     UNSTEADY FLOW ANAYSIS OF A SLPERSONIC CASCADE
C
C
C     LIFT AND MOMENT COEFICIENT
C
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMMON/BLK3/ SBKDE1,SBKDE2,F4,F4S,AM4,F5S,F6S,AM4TST,SUM3,SUM4,
     1 AM5TT,AM6,SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T,
     2 A,B,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N,
     3 C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,
     4 FT3T,F2P,AM2P,SUM1T,SUM2T,C1P,C1N,       BKDEL1,      BKDEL2,
     5 BLKAP1,ARG,ARG2,FT3TST,BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4,
     6 CLIFT,CMOMT,PRES1,PRES2,PRES3,PRES4,QRES4,FQA,FQB,FQ7
      COMMON/BLK4/I,R,Y,A1,B1,C4,C5,GL,I6,I7,JL,NL,RI,RT,R5,SN,SP,XL,
     1    Y1,AMU,         GAP,IDX,INX,NL2,RL1,RL2,RQ1,RQ2,XL1,ALP1,ALP2,
     2 GAMN,GAMP,INER,IOUT,REDF,STAG,STEP,AMACH,BETNN,BETNP,
     3 BKAP1,XLSV1,XLSV2,XLSV3,XLSV4,ALPAMP,AMOAXS,
     4 DISAMP,GUSAMP,PITAXS,PITCCR
      COMPLEX SBKDE1,SBKDE2
      COMPLEX F4,F4S,        AM4,F5S,F6S,AM4TST,SUM3,SUM4,AM5TT,AM6
      COMPLEX SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T
      COMPLEX AI,A,B,BSYCON,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N -
      COMPLEX C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,  -
     1FT3T,F2P,AM2P,SUM1T,SUM2T
      COMPLEX C1P,C1N,BKDEL1,BKDEL2,BLKAP1,ARG,ARG2,FT3TST             -
      COMPLEX BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4
      COMPLEX CLIFT,CMOMT
      COMPLEX PRES1,PRES2,PRES3,PRES4,QRES4
      COMPLEX FQA,FQB,T1,T2,T3,T4
      COMPLEX FQ7,CEXP3,CEXP4,CEXP5,CONST,C1A,C2A
      DIMENSION PRES1(21),PRES2(21),PRES3(21),PRES4(21),QRES4(21)
      DIMENSION SBKDE1(201),SBKDE2(201)
      DIMENSION SUMSV1(201),SUMSV2(201),SVKL1(201),SVKL2(201)
      DIMENSION XLSV1(21),XLSV2(21),XLSV3(21),XLSV4(21),IY(8)
      S1=SPS-SNS
      S2=SPS*DEL-SIGMA
      S3=SPS/(DSTR**2)
      S4=SNS/DSTR
      S0=2.0-SPS+SNS
      T1=CEXP(-AI*SIGMA)
      T2=CEXP(AI*SIGMA)
      A1=2.0*PI/(S1)
      B1=(S2)/(S1)
      GAM=S2
      C1P=GAM/DSTR-SCRK
      C1N=GAM/DSTR+SCRK
      ALP=GAM*S3+S4*CSQRT(C1P)*CSQRT(C1N)
      BC=-B1/ALP*BSYCON/SIN(PI*B1/A1)
      T3=ALP-DEL
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```
      F1=(ALP-AMU)/(T3)*AI*SNS/(BETA*(GAM-ALP*SPS))
      ARG2=DEL
      CALL AKAPM(ARG2,BKDEL1)
      ARG=DEL-GL
      CALL AKAPM(ARG,BKDEL2)
      CALL DLKAPM(ARG2,BLKAP1)
      INX=0
      CALL DRKAPM(ALP,INX,BLKAPM)
      F1=F1*BKDEL1/BLKAPM*(-(T3)/(T3+GL)*A*AI*BKDEL2/BKDEL1            -
     1+B*BLKAP1+B/(T3))
      F1S=F1
      NL=10
      RL1=NL-1
      CEXP3=CEXP(-AI*T3/RL1*S1)
      PRES1(1)=F1S
      NNL1=NL-1
      DO 453 JL=1,NNL1
      PRES1(JL+1)=PRES1(JL)*CEXP3
  453 CONTINUE
      F1=F1*AI/(T3)*(CEXP(-AI*(T3)*(S1))-1.0)
      AM1=F1/(AI*(T3))-F1S/(AI*(T3))*(S1)*CEXP(-AI*(                   -
     1T3)*(S1))
      AMTEST=0.C
      FQB=BKDEL1/(BETA*BC)*CEXP(AI*(S2)/2.0)                           -
     1*(-A *AI*BKDEL2/BKDEL1+B*BLKAP1)
      DO 20 I=1,200
      R=I
      GAMP=2.0*PI*R+S2
      GAMN=-2.0*PI*R+S2
      C1P=(GAMP/DSTR)-SCRK
      C2P=(GAMP/DSTR)+SCRK
      ALP=GAMP*S3+S4*CSQRT(C1P)*CSQRT(C2P)
      T3=ALP-DEL
      IDX=I
      CALL DRKAPM(ALP,IDX,BLKAPM)
      C1=(ALP-AMU)/(T3)*AI*SNS/(BETA*(GAMP-ALP*SPS))*BKDEL1/           -
     1(          BLKAPM)*(-(T3)/(T3+GL)*A*AI*BKDEL2/BKDEL1+            -
     2B*BLKAP1+B/(T3))
      C1N=(GAMN/DSTR)-SCRK
      C2N=(GAMN/DSTR)+SCRK
      ALN=GAMN*S3+S4*CSQRT(C1N)*CSQRT(C2N)
      T4=ALN-DEL
      IDX=-I
      CALL DRKAPM(ALN,IDX,BLKAPM)
      C2=(ALN-AMU)/(T4)*AI*SNS/(BETA*(GAMN-ALN*SPS))*BKDEL1/           -
     1(          BLKAPM)*(-(T4)/(T4+GL)*A*AI*BKDEL2/BKDEL1+            -
     2B*BLKAP1+B/(T4))
      F1=F1+C1*AI/(T3)*(CEXP(-AI*(T3)*(S1))-1.0)+C2                    -
     1*AI/(T4)*(CEXP(-AI*(T4)*(S1))-1.0)
      AM1=AM1+C1/(AI*(T3))*(-(S1)*CEXP(-AI*(T3)                        -
     1*(S1))+AI/(T3)*(CEXP(-AI*(T3)*(S1))-1.0))                        -
     2+C2/(AI*(T4))*(-(S1)*CEXP(-AI*(T4)*(S1))+                        -
     3AI/(T4)*(CEXP(-AI*(T4)*(S1))-1.0))
      C2A=C2
      C1A=C1
      AA=S1/RL1
      CEXP3=CEXP(-AI*T3*AA)
      CEXP4=CEXP(-AI*T4*AA)
```

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      TEMP=2.0*PI*R
      CEXP5=CEXP(AI*(SIGMA-SNS*DEL)/S1*AA)
      CONST=4.0*FQB/TEMP
      PRES1(1)=PRES1(1)+C1+C2
      DO 454 JL=1,NNL1
      CONST=CONST*CEXP5
      C1A=C1A*CEXP3
      C2A=C2A*CEXP4
      PRES1(JL+1)=PRES1(JL+1)+C1A+C2A
      PRES1(JL+1)=PRES1(JL+1)+CONST*SIN(TEMP*JL/RL1)
  454 CONTINUE
      IF (CABS((AM1-AMTEST)/AM1) .LT. 0.0005) GO TO 45
      AMTEST=AM1
   20 CONTINUE
      GO TO 9992
 9992 WRITE(IBBOUT,3005)
 3005 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBA  /
     1       39X,26HAM1 LOOP DID NOT CONVERGE. )
      CALL MESAGE(-61,0,C)
   45 CONTINUE
      AA=S1/RL1
      CEXP3=CEXP(AI*(SIGMA-SNS*DEL)/RL1)
      CONST=FQB
      TEMP=2.0*AA/(SPS-SNS)
      PRES1(1)=PRES1(1)-FQB
      DO 4541 JL=1,NNL1
      CONST=CONST*CEXP3
      PRES1(JL+1)=PRES1(JL+1)-CONST*(1.0-JL*TEMP)
 4541 CONTINUE
      Y=0.0
      Y1=SNS
      ARG=DEL-GL
      CALL ALAMDA(ARG,Y,BLAM1)
      CALL ALAMDA(ARG,Y1,BLAM )
      CALL AKAPPA(ARG,BKAP1)
      FT2=A*AI*(DEL-GL-AMU)*BLAM1/BKAP1
      FT2T=A*AI*(DEL-GL-AMU)*BLAM2/BKAP1
      ARG=DEL
      CALL ALAMDA(ARG,Y,BLAM1)
      CALL ALAMDA(ARG,Y1,BLAM2)
      CALL AKAPPA(ARG,BKAP1)
      GAM=SQRT(DEL**2-SCRK**2)
      S5=SIN(SNS*GAM)
      S6=COS(SNS*GAM)
      C1=-1.0/(BETA*GAM*S5)
      C1T=C1*(AI*SPS*T2*S6-SNS*DEL/GAM*T2                               -
     1 *S5)-BLAM2/BKAP1*DEL/GAM*(S5                                     -
     2+GAM*SNS*S6)/(GAM*S5)
      C1=C1*(ARG/GAM*SNS*S5+AI*SPS*T2)-BLAM1/                           -
     1BKAP1*DEL/(GAM*S5)*(S5/GAM+SNS*S6)
      FT3=-B*(BLAM1/BKAP1+(DEL-AMU)*C1)
      FT3T=-B*(BLAM2/BKAP1+(DEL-AMU)*C1T)
      IF(GL .EQ. 0.0)  GO TO 50
      F2=FT2*(CEXP(2.0*AI*GL)-CEXP(AI*GL*(S1)))/(AI*GL)                 -
     1+FT3*(S0)+B*AI*(DEL-AMU)*BLAM1/BKAP1*(4.0-(S1)**2)                -
     2/2.0
      AM2=FT2*(2.0*CEXP(2.0*AI*GL)/(AI*GL)-(S1)/(AI*GL)*CEXP(GL*        -
     1AI*(S1))+(CEXP(2.0*AI*GL)-CEXP(AI*(S1)*GL))/GL**2)                -
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     2+FT3*(4.0-(S1)**2)/2.C+B*AI*(DEL-AMU)*BLAM1/BKAP1*           -
     3(8.0-(S1)**3)/3.C
      F2P=FT2T*T1*CEXP(AI*GL*SNS)/(AI*GL)*(CEXP(2.0*AI*            -
     1GL)-CEXP(AI*GL*(S1)))+FT3T*T1*(SO)                           -
     2+B*AI*(DEL-AMU)*T1*BLAM2/BKAP1*((SO)**2/                     -
     32.0+SPS*(SO))
      AM2P=FT2T*T1*(CEXP(AI*GL*SPS)/(AI*GL)*(SO)                   -
     1*CEXP(AI*GL*(SO))+CEXP(AI*GL*SPS)/(GL**2)*(CEXP              -
     2(AI*GL*(SO))-1.0))+FT3T*T1*(SO)**2                           -
     3/2.0+B*AI*(DEL-AMU)*T1*BLAM2/BKAP1*((SO)**3                  -
     4/3.0+SPS*(SO)**2/2.0)
      GO TO 55
   50 CONTINUE
      F2=FT2*(SO)+FT3*(SO)+B*AI*(DEL-AMU)*BLAM1/                   -
     1BKAP1*(4.C-(S1)**2)/2.0
      AM2=FT2*(4.0-(S1)**2)/2.0+FT3*(4.0-(S1)**2)/2.0              -
     1+B*AI*(DEL-AMU)*BLAM1/BKAP1*(8.0-(S1)**3)/3.0
      F2P=FT2T*T1*(SO)+FT3T*T1*(SO                                 -
     1)+B*AI*(DEL-AMU)*T1*BLAM2/BKAP1*((SO                         -
     2)**2/2.0+SPS*(SO))
      AM2P=FT2T*T1*(SO)**2/2.0+FT3T*T1                             -
     1*(SO)**2/2.C+B*AI*(DEL-AMU)*T1*BLAM2                         -
     2/BKAP1*((SO)**3/3.C+SPS*(SO)**2/2.0)
   55 CONTINUE
      NL2=20
      RL2=NL2-1
      AA=SPS-SNS
      CONST=B*AI*(DEL-AMU)*BLAM1/BKAP1
      TEMP=SO/RL2
      C1A=AI*GL
      CEXP3=CEXP(C1A*AA)
      CEXP4=CEXP(C1A*TEMP)
      DO 455 JL=1,NL2
      XL=AA+TEMP*(JL-1)
      PRES2(JL)=FT2*CEXP3+FT3+CONST*XL
      CEXP3=CEXP3*CEXP4
  455 CONTINUE
      CALL SUBBB
 5000 RETURN
      END                                                          -
```

```
      SUBROUTINE SUBBB
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMMON/BLK3/ SBKDE1,SBKDE2,F4,F4S,AM4,F5S,F6S,AM4TST,SUM3,SUM4,
     1 AM5TT,AM6,SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T,
     2 A,B,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N,
     3 C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,
     4 FT3T,F2P,AM2P,SUM1T,SUM2T,C1P,C1N,       BKDEL1,      BKDEL2,
     5 BLKAP1,ARG,ARG2,FT3TST,BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4,
     6 CLIFT,CMOMT,PRES1,PRES2,PRES3,PRES4,QRES4,FQA,FQB,FQ7
      COMMON/BLK4/I,R,Y,A1,B1,C4,C5,GL,I6,I7,JL,NL,RI,RT,R5,SN,SP,XL,
     1    Y1,AMU,           GAM,IDX,INX,NL2,RL1,RL2,RQ1,RQ2,XL1,ALP1,ALP2,
     2 GAMN,GAMP,INER,IOUT,REDF,STAG,STEP,AMACH,BETNN,BETNP,
     3 BKAP1,XLSV1,XLSV2,XLSV3,XLSV4,ALPAMP,AMOAXS,
     4 DISAMP,GUSAMP,PITAXS,PITCCR
      COMPLEX SBKDE1,SBKDE2
      COMPLEX F4,F4S,       AM4,F5S,F6S,AM4TST,SUM3,SUM4,AM5TT,AM6
      COMPLEX SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T
      COMPLEX AI,A,B,BSYCON,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N   -
      COMPLEX C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,    -
     1FT3T,F2P,AM2P,SUM1T,SUM2T
      COMPLEX C1P,C1N,BKDEL1,BKDEL2,BLKAP1,ARG,ARG2,FT3TST                -
      COMPLEX BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4
      COMPLEX CLIFT,CMOMT
      COMPLEX PRES1,PRES2,PRES3,PRES4,QRES4,CEXP4C
      COMPLEX FQA,FQB,T1,T2,T3,T4,CEXP2A,CEXP2B,CEXP2C,CEXP4A,CEXP4B
      COMPLEX FQ7,C1A,C3A,C4A,CONST,CEXP3,CEXP4,CEXP3A,CEXP3B,CEXP3C
      DIMENSION PRES1(21),PRES2(21),PRES3(21),PRES4(21),QRES4(21)
      DIMENSION SBKDE1(201),SBKDE2(201)
      DIMENSION SUMSV1(201),SUMSV2(201),SVKL1(201),SVKL2(201)
      DIMENSION XLSV1(21),XLSV2(21),XLSV3(21),XLSV4(21),IY(8)
      S1=2.0*SNS-SPS
      T1=CEXP(-AI*SIGMA)
      T2=CEXP(AI*SIGMA)
      TEMP=S1/RL2
      C1A=AI*GL
      CONST=B*AI*(DEL-AMU)*BLAM2/BKAP1
      CEXP3=CEXP(C1A*SPS)
      CEXP4=CEXP(C1A*TEMP)
      XL=SPS
      DO 456 JL=1,NL2
      PRES3(JL)=(FT2T*CEXP3+FT3T+CONST*XL)*T1
      CEXP3=CEXP3*CEXP4
      XL=XL+TEMP
  456 CONTINUE
      FT3TST=0.0
      FT2=0.0
      FT3=0.0
      FT2T=0.0
      FT3T=0.0
      FQA=BKDEL1/(BC*BETA)*(A*AI*BKDEL2/BKDEL1-B*BLKAP1)                 -
     1*CEXP(-AI*(DEL*SPS-SIGMA)/2.0)
```

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```
      DO 60 I=1,5C
      RT=0.0
      R=I-1
      RI=(-1.0)**(I-1)
      ALP=SQRT((R*PI/SNS)**2+SCRK**2)
      ALN=-ALP
      CALL AKAPM(ALP,BKDEL3)
      T3=ALP-DEL
      SVKL1(I)=BKDEL3
      IF(I.EQ.1) RT=1.0
      SUM1=(ALP-AMU)/(T3)*(RI-CEXP     (AI*(T3)*SPS)*T2                -
     1)/(BETA*(1.C+RT))*RI/(SNS*ALP)*BKDEL1/BKDEL3*(A*AI*BKDEL2/       -
     2BKDEL1*(T3)/(T3+GL)-B*BLKAP1-B/(T3))
      SUM1T=(ALP-AMU)/(T3)*(1.0-CEXP(AI*(T3)*SPS)*T2                   -
     1*?I)/(BETA*(1.0+RT))*RI/(SNS*ALP)*BKDEL1/BKDEL3*(A*AI*           -
     2BKDEL2/BKDEL1*(T3)/(T3+GL)-B*BLKAP1-B/(T3))
      SUMSV1(I)=(ALP-AMU)/(T3)*(1.0-CCOS((T3)*SPS+SIGMA                -
     1+R*PI))/(BETA*(1.C+RT)*SNS*ALP)*BKDEL1/BKDEL3*CEXP(-2.0*AI*(ALP  -
     2-DEL))*(A*BKDEL2/BKDEL1*(T3)/(T3+GL)+B*AI*BLKAP1                 -
     3+B*AI/(T3))
      FT2=SUM1*AI/(T3)*(CEXP(-2.0*AI*(T3))-CEXP(-AI*(SPS-SNS)          -
     1*(T3)))+FT2
      FT3=SUM1*(2.0*AI*CEXP(-2.0*AI*(T3))/(T3)-AI*(SPS-SNS)/           -
     1(T3)*CEXP(-AI*(T3)*(SPS-SNS))+CEXP(-2.0*AI*(T3))/                -
     2((T3)**2)-CEXP(-AI*(T3)*(SPS-SNS))/((T3)**2))+FT3
      FT2T=SUM1T*T1*CEXP(-AI*(T3)*SPS)*AI/(T3)                         -
     1*(CEXP(-AI*(T3)*(S1))-1.0)+FT2T
      FT3T=SUM1T*T1*CEXP(-AI*(T3)*SPS)*((S1)                           -
     1*AI/(T3)*CEXP(-AI*(T3)*(S1))+1.0/((T3)                           -
     2**2)*(CEXP(-AI*(T3)*(S1))-1.0))+FT3T
      CALL AKAPM(ALN,BKDEL3)
      T4=ALN-DEL
      SVKL2(I)=BKDEL3
      SUM2=(ALN-AMU)/(T4)*(RI-CEXP(AI*(T4)*SPS)*T2                     -
     1)/(BETA*(1.C+RT))*RI/(SNS*ALN)*BKDEL1/BKDEL3*(A*AI*BKDEL2/       -
     2BKDEL1*(T4)/(T4+GL)-B*BLKAP1-B/(T4))
      SUM2T=(ALN-AMU)/(T4)*(1.0-CEXP(AI*(T4)*SPS)*T2                   -
     1*RI)/(BETA*(1.0+RT))*RI/(SNS*ALN)*BKDEL1/BKDEL3*(A*AI*           -
     2BKDEL2/BKDEL1*(T4)/(T4+GL)-B*BLKAP1-B/(T4))
      SUMSV2(I)=(ALN-AMU)/(T4)*(1.0-CCOS((T4)*SPS+SIGMA                -
     1+R*PI))/(BETA*(1.C+RT)*SNS*ALN)*BKDEL1/BKDEL3*CEXP(-2.0*AI*(T4   -
     2))*(A*BKDEL2/BKDEL1*(T4)/(T4+GL)+B*AI*BLKAP1                     -
     3+B*AI/(T4))
      FT2=FT2+SUM2*AI/(T4)*(CEXP(-2.0*AI*(T4))-CEXP(-AI*(SPS           -
     1-SNS)*(T4)))
      FT2T=SUM2T*T1*CEXP(-AI*(T4)*SPS)*AI/(T4)                         -
     1*(CEXP(-AI*(T4)*(S1))-1.0)+FT2T
      FT3=FT3+SUM2*(2.0*AI*CEXP(-2.0*AI*(T4))/(T4)-AI*(SPS             -
     1-SNS)/(T4)*CEXP(-AI*(T4)*(SPS-SNS))+CEXP(-2.0*AI*                -
     2(T4))/((T4)**2)-CEXP(-AI*(T4)*(SPS-SNS))/                        -
     3((T4)**2))
      FT3T=FT3T+SUM2T*T1*CEXP(-AI*(T4)*SPS)*((S1                       -
     1)*AI/(T4)*CEXP(-AI*(T4)*(S1))+1.0/                               -
     2((T4)**2)*(CEXP(-AI*(T4)*(S1))-1.0))
      I7=I
      AA=SPS-SNS
      TEMP=S1/RL2
      TEMP2=R*PI/SNS
```

```
      CONST=4.0/PI*FQA
      TEMP3=R+RT
      C3A=-AI*T3
      C4A=-AI*T4
      C1A=AI*DEL
      CEXP3A=CEXP(C3A*AA)
      CEXP3B=CEXP(C3A*SPS)
      CEXP3C=CEXP(C3A*TEMP)
      CEXP4A=CEXP(C4A*AA)
      CEXP4B=CEXP(C4A*SPS)
      CEXP4C=CEXP(C4A*TEMP)
      CEXP2A=CEXP(C1A*AA)
      CEXP2B=CEXP(C1A*SPS)
      CEXP2C=CEXP(C1A*TEMP)
      XL1=AA
      DO 457 JL=1,NL2
      PRES2(JL)=SUM1*CEXP3A+SUM2*CEXP4A+PRES2(JL)
      PRES2(JL)=PRES2(JL)+CONST*CEXP2A*RI/TEMP3*SIN(TEMP2*(XL1-SPS))
      XL2=XL1+SNS
      PRES3(JL)=(SUM1T*CEXP3B+SUM2T*CEXP4B)*T1+PRES3(JL)
      PRES3(JL)=PRES3(JL)+CONST*CEXP2B/TEMP3*SIN(TEMP2*(XL2-SPS))*T1
      XL1=XL1+TEMP
      CEXP3A=CEXP3A*CEXP3C
      CEXP4A=CEXP4A*CEXP4C
      CEXP2A=CEXP2A*CEXP2C
      CEXP3B=CEXP3B*CEXP3C
      CEXP4B=CEXP4B*CEXP4C
      CEXP2B=CEXP2B*CEXP2C
  457 CONTINUE
      IF (CABS((FT3-FT3TST)/FT3).LT. 0.0006) GO TO 65
      FT3TST=FT3
   60 CONTINUE
      GO TO 9994
   65 CONTINUE
      FT3TST=FT3
      F2=F2+FT2
      AM2=AM2+FT3
      F2P=F2P+FT2T
      AM2P=AM2P+FT3T
      AA=SPS-SNS
      AA1=SPS+SNS
      AA2=SPS+2.0*SNS
      TEMP=S1/RL2
      XL=AA
      C1A=AI*DEL
      CEXP3=CEXP(C1A*AA)
      CEXP3C=CEXP(C1A*TEMP)
      CEXP4=CEXP(C1A*SPS)
      CONST=2.0*FQA
      CEXP2A=T1*CONST
      DO 4571 JL=1,NL2
      STEP=0.0
      IF(XL.GE.AA1)STEP=1.0
      PRES2(JL)=PRES2(JL)+CONST*CEXP3*((XL-SPS)/SNS-2.0*STEP)
      XL2=XL+SNS
      STEP=0.0
      IF(XL2.GE.AA2)STEP=1.C
      PRES3(JL)=PRES3(JL)-CEXP2A*CEXP4*(1.0-(XL2-SPS)/SNS+2.0*STEP)
```

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```
      CEXP3=CEXP3*CEXP3C
      CEXP4=CEXP4*CEXP3C
      XL=XL+TEMP
 4571 CONTINUE
      GAM=SPS*DEL-SIGMA
      C1P=(GAM/DSTR)-SCRK
      C2P=(GAM/DSTR)+SCRK
      ALP=GAM*SPS/(DSTR**2)-SNS/DSTR*CSQRT(C1P)*CSQRT(C2P)
      T3=ALP-DEL
      F4=CEXP(AI*(ALP*SPS-GAM))*(ALP*SPS-GAM)/((ALP*DSTR**2-GAM*SPS)     -
     1*(T3))
      CALL AKAPM(ALP,BKDEL3)
      SBKDE1(1)=BKDEL3
      SBKDE2(1)=0.C
      CALL AKAPPA(DEL,BKAP1)
      CARG=DEL-GL
      CALL AKAPPA(CARG,CKAP1)
      F4=F4*BKDEL3/(BKDEL1*BKAP1)*(A*(BKDEL1/BKDEL2*(T3)/(T3             -
     1+GL)*(DEL-GL-AMU)*CEXP(2.0*AI*GL)*BKAP1/CKAP1)+B*AI*(1.0-2.0       -
     2*AI*(DEL-AMU)-(DEL-AMU)*RES)-B*AI*(DEL-AMU)*(BLKAP1-1.0/(T3))      -
     3)
      F5S=B*AI/(BKDEL1*BKAP1)*(1.C-2.0*AI*(DEL-AMU)-(DEL-AMU)*RES-       -
     1(DEL-AMU)*BLKAP1)
      F6S=A/(BKDEL1*BKAP1)*(BKDEL1/BKDEL2*(DEL-GL-AMU)*CEXP(2.0*AI*GL)   -
     1*BKAP1/CKAP1)
      F4S=F4
      FQ7=BC*(F6S+F5S)
      TEMP=(SPS-SNS)/RL1
      TEMP2=2.0-SPS
      CONST=-T1*F4S
      C1A=-AI*T3
      CEXP3A=CEXP(C1A*SNS)
      CEXP3B=CEXP(C1A*TEMP)
      DO 458 JL=1,NL
      PRES4(JL)=CONST*CEXP3A
      CEXP3A=CEXP3A*CEXP3B
  458 CONTINUE
      C1=CEXP(-AI*(T3)*SPS)
      C2=CEXP(-AI*(T3)*SNS)
      F4=F4*AI*T1/(T3)*(C1-C2)
      AM4=F4S*T1*(AI*SPS*C1/(T3)-AI*SNS*C2/(T3)                          -
     1+(C1-C2)/((T3)**2))+F4S*AI*(2.0-SPS)*T1/                           -
     2(T3)*(C1-C2)
      CALL SUBC
      RETURN
 9994 WRITE(IBBOUT,3015)
 3015 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBC   /
     1       39X,26HAM4 LOOP DID NCT CONVERGE. )
      CALL MESAGE(-61,0,C)
      RETURN
      END
```

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```
      SUBROUTINE SUBC
      COMMON /SYSTEM/SYSBUF,IBBCUT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMMON/BLK3/ SBKDE1,SBKDE2,F4,F4S,AM4,F5S,F6S,AM4TST,SUM3,SUM4,
     1 AM5TT,AM6,SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T,
     2 A,B,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N,
     3 C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,
     4 FT3T,F2P,AM2P,SUM1T,SUM2T,C1P,C1N,       BKDEL1,       BKDEL2,
     5 BLKAP1,ARG,ARG2,FT3TST,BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4,
     6 CLIFT,CMOMT,PRES1,PRES2,PRES3,PRES4,QRES4,FQA,FQB,FQ7
      COMMON/BLK4/I,R,Y,A1,B1,C4,C5,GL,I6,I7,JL,NL,RI,RT,R5,SN,SP,XL,
     1    Y1,AMU,           GAM,IDX,INX,NL2,RL1,RL2,RQ1,RQ2,XL1,ALP1,ALP2,
     2 GAMN,GAMP,INER,IOUT,REDF,STAG,STEP,AMACH,BETNN,BETNP,
     3 BKAP1,XLSV1,XLSV2,XLSV3,XLSV4,ALPAMP,AMOAXS,
     4 DISAMP,GUSAMP,PITAXS,PITCCR
      COMPLEX SBKDE1,SBKDE2
      COMPLEX F4,F4S,         AM4,F5S,F6S,AM4TST,SUM3,SUM4,AM5TT,AM6
      COMPLEX SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T
      COMPLEX AI,A,B,BSYCON,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N -
      COMPLEX C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,   -
     1FT3T,F2P,AM2P,SUM1T,SUM2T
      COMPLEX C1P,C1N,BKDEL1,BKDEL2,BLKAP1,ARG,ARG2,                    -
     1FT3TST,C1A,C2A,C3A,CEXP1,CEXP2,CEXP3,CEXP1A,CEXP2A,CEXP3A,CONST
      COMPLEX BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4
      COMPLEX CLIFT,CMOMT,C4A,CEXP4,CEXP5,CEXP4A,CEXP5A
      COMPLEX PRES1,PRES2,PRES3,PRES4,QRES4
      COMPLEX FQA,FQB,T1,T2,T3
      COMPLEX FQ7
      DIMENSION PRES1(21),PRES2(21),PRES3(21),PRES4(21),QRES4(21)
      DIMENSION SBKDE1(201),SBKDE2(201)
      DIMENSION SUMSV1(201),SUMSV2(201),SVKL1(201),SVKL2(201)
      DIMENSION XLSV1(21),XLSV2(21),XLSV3(21),XLSV4(21),IY(8)
      AM4TST=0.0
      S1=SPS*DEL-SIGMA
      S2=SPS/(DSTR**2)
      S3=SNS/DSTR
      S4=SPS+SNS
      T3=CEXP(-AI*SIGMA)
      DO 70 I=1,200
      R=I
      GAMP=2.0*PI*R+S1
      GAMN=-2.0*PI*R+S1
      C1P=(GAMP/DSTR)-SCRK
      C2P=(GAMP/DSTR)+SCRK
      ALP=GAMP*S2-S3*CSQRT(C1P)*CSQRT(C2P)
      T1=ALP-DEL
      CALL AKAPM(ALP,BKDEL3)
      SBKDE1(I+1)=BKDEL3
      SUM1=CEXP(AI*(ALP*SPS-GAMP))*(ALP*SPS-GAMP)*BKDEL3/((ALP*DSTR**2  -
     1-GAMP*SPS)*T1)*(F6S*T1/(T1+GL)+F5S                                 -
     2+B*AI/(BKDEL1*BKAP1)*(DEL-AMU)/(ALP-DEL))
      C1N=(GAMN/DSTR)-SCRK
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      C2N=(GAMN/DSTR)+SCRK
      ALN=GAMN*S2-S3*CSQRT(C1N)*CSQRT(C2N)
      T2=ALN-DEL
      CALL AKAPM(ALN,BKDEL3)
      SBKDE2(I+1)=BKDEL3
      SUM2=CEXP(AI*(ALN*SPS-GAMN))*(ALN*SPS-GAMN)*BKDEL3/((ALN*DSTR**2       -
     1-GAMN*SPS)*T2)*(F6S*(T2)/(T2+GL)+F5S                                   -
     2+B*AI/(BKDEL1*BKAP1)*(DEL-APL)/(T2))
      C1P=CEXP(-AI*(T1)*SPS)
      C2P=CEXP(-AI*(T1)*SNS)
      C1N=CEXP(-AI*(T2)*SPS)
      C2N=CEXP(-AI*(T2)*SNS)
      F4=F4+SUM1*T3*AI/(T1)*(C1P-C2P)+SUM2*T3                               -
     1*AI/(T2)*(C1N-C2N)
      AM4=AM4+SUM1*T3*(AI*SPS*C1P/(T1)-AI*SNS*C2P/                          -
     1(T1)+1.0/((T1)**2)*(C1P-C2P)+AI*(2.0-SPS)/(T1)*                       -
     2(C1P-C2P))+SUM2*T3*(AI*SPS*C1N/(T2)-AI*SNS*C2N/                        -
     3(T2)+1.0/((T2)**2)*(C1N-C2N)+AI*(2.0-SPS)/(T2)*                       -
     4(C1N-C2N))
      I6=I+1
      TEMP=(SPS-SNS)/RL1
      C1A=-AI*T1
      C2A=-AI*T2
      C3A=AI*DEL
      CEXP1=CEXP(C1A*SNS)
      CEXP2=CEXP(C2A*SNS)
      CEXP3=CEXP(C3A*SNS)
      CEXP1A=CEXP(C1A*TEMP)
      CEXP2A=CEXP(C2A*TEMP)
      CEXP3A=CEXP(C3A*TEMP)
      CONST=FQ7/(2.0*PI)
      TEMP2=2.0*PI*R/S4
      C4A=-AI*S1
      CEXP4=CEXP(C4A*(2.0*SNS/S4+0.5))
      CEXP5=CEXP(C4A*0.5)
      CEXP4A=CEXP(C4A*TEMP/S4)
      CEXP5A=CEXP(C4A*TEMP/(SPS+SNS))
      XL=SNS
      DO 459 JL=1,NL
      PRES4(JL)=PRES4(JL)-T3*(SUM1*CEXP1+SUM2*CEXP2
     1 +CONST*CEXP3*(CEXP4*SIN(TEMP2*(SNS+XL))/R
     2 -CEXP5*SIN(TEMP2*(SPS+XL))/R))
      XL=XL+TEMP
      CEXP1=CEXP1*CEXP1A
      CEXP2=CEXP2*CEXP2A
      CEXP3=CEXP3*CEXP3A
      CEXP4=CEXP4*CEXP4A
      CEXP5=CEXP5*CEXP5A
  459 CONTINUE
      IF (CABS((AM4-AM4TST)/AM4) .LT. 0.0006) GO TO 75
      AM4TST=AM4
   70 CONTINUE
      GO TO 9994
   75 CONTINUE
      TEMP=(SPS-SNS)/RL1
      TEMP1=2.0*SNS/S4+0.5
      TEMP2=0.5-(SPS+SNS)/S4
      C1A=AI*DEL
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      C2A=-AI*S1
      C3A=-C2A
      CEXP1=CEXP(C1A*SNS)
      CEXP2=CEXP(C2A*TEMP1)
      CEXP3=CEXP(C3A*TEMP2)
      CEXP1A=CEXP(C1A*TEMP)
      CEXP2A=CEXP(C2A*TEMP/S4)
      CONST=T3*FQ7/2.0
      XL=SNS
      DO 4596 JL=1,NL
      PRES4(JL)=PRES4(JL)-CONST*CEXP1*(CEXP2*
     1  ((SNS+XL)/S4-0.5)-CEXP3*((SPS+XL)/S4-1.5))
      XL=XL+TEMP
      CEXP1=CEXP1*CEXP1A
      CEXP2=CEXP2*CEXP2A
      CEXP3=CEXP3*CEXP2A
 4596 CONTINUE
      CALL SUBD
      RETURN
 9994 WRITE(IBBOUT,3015)
 3015 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBC  /
     1       39X,26HAM4 LOOP DID NCT CONVERGE. )
      CALL MESAGE(-61,0,0)
      RETURN
      END
```

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```
      SUBROUTINE SUBD
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMMON/BLK3/ SBKDE1,SBKDE2,F4,F4S,AM4,F5S,F6S,AM4TST,SUM3,SUM4,
     1  AM5TT,AM6,SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T,
     2  A,B,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N,
     3  C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,
     4  FT3T,F2P,AM2P,SUM1T,SUM2T,C1P,C1N,       BKDEL1,      BKDEL2,
     5  BLKAP1,ARG,ARG2,FT3TST,BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4,
     6  CLIFT,CMOMT,PRES1,PRES2,PRES3,PRES4,QRES4,FQA,FQB,FQ7
      COMMON/BLK4/I,R,Y,A1,B1,C4,C5,GL,I6,I7,JL,NL,RI,RT,R5,SN,SP,XL,
     1    Y1,AMU,         GAM,IDX,INX,NL2,RL1,RL2,RQ1,RQ2,XL1,ALP1,ALP2,
     2  GAMN,GAMP,INER,IOUT,REDF,STAG,STEP,AMACH,BETNN,BETNP,
     3  BKAP1,XLSV1,XLSV2,XLSV3,XLSV4,ALPAMP,AMOAXS,
     4  DISAMP,GUSAMP,PITAXS,PITCCR
      COMPLEX SBKDE1,SBKDE2
      COMPLEX F4,F4S,       AM4,F5S,F6S,AM4TST,SUM3,SUM4,AM5TT,AM6
      COMPLEX SUMSV1,SUMSV2,SVKL1,SVKL2,F5,F5T,AM5,AM5T
      COMPLEX AI,A,B,BSYCON,ALP,F1,AM1,ALN,BLKAPM,BKDEL3,F1S,C1,C2P,C2N  -
      COMPLEX C2,AMTEST,FT2,BLAM1,FT3,AM2,SUM1,SUM2,F2,BLAM2,FT2T,C1T,   -
     1FT3T,F2P,AM2P,SUM1T,SUM2T
      COMPLEX C1P,C1N,BKDEL1,BKDEL2,BLKAP1,ARG,ARG2,FT3TST              -
      COMPLEX BC,BC2,BC3,BC4,BC5,CA1,CA2,CA3,CA4
      COMPLEX CLIFT,CMOMT
      COMPLEX PRES1,PRES2,PRES3,PRES4,QRES4
      COMPLEX FQA,FQB,SS,T1,T2,T3,T4,CONST,CONST2,CONST3,CONST4
      COMPLEX FQ7,CONST5,CONST6,C1A,C2A,CEXP1,CEXP2,CEXP1A,CEXP2A
      DIMENSION PRES1(21),PRES2(21),PRES3(21),PRES4(21),QRES4(21)
      DIMENSION SBKDE1(201),SBKDE2(201)
      DIMENSION SUMSV1(201),SUMSV2(201),SVKL1(201),SVKL2(201)
      DIMENSION XLSV1(21),XLSV2(21),XLSV3(21),XLSV4(21),IY(8)
      AM6=0.0
      F5=0.0
      AM5=0.0
      S1=SPS+SNS
      S2=SIGMA-SPS*DEL
      S3=SPS/(DSTR**2)
      S4=SNS/DSTR
      S5=DEL*SNS+SIGMA
      SS=CEXP(-AI*SIGMA)
      DO 80 IOUT=1,200
      IF(IOUT .GT. I7)  GO TO 9997
      R5=IOUT-1
      RQ1=SQRT((R5*PI/SNS)**2+SCRK**2)
      RQ2=-RQ1
      C4=(RQ1*S1+S2)/(2.0*PI)
      C5=(RQ2*S1+S2)/(2.0*PI)
      BC2=BC/(2.0*SVKL1(IOUT))*CEXP(-AI*(-S2)*(SPS+3.0*SNS)/             -
     1(2.0*S1))/(2.0*PI*AI)
      BC3=BC2*SVKL1(IOUT)/SVKL2(ICLT)
      BC4=BC/(2.0*SVKL1(IOUT))*CEXP(AI*(-S2)*(SNS-SPS)/                  -
     1 (2.0*S1))/(2.0*PI*AI)
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      BC5=BC4*SVKL1(IOUT)/SVKL2(ICUT)
      F5T=0.0
      AM5T=0.0
      AM5TT=0.0
      DO 461 JL=1,NL
      QRES4(JL)=C.0
  461 CONTINUE
      DO 85 INER=1,200
      R=INER-1
      GAMP=2.0*PI*R-S2
      GAMN=-2.0*PI*R-S2
      C1P=(GAMP/DSTR)-SCRK
      C2P=(GAMP/DSTR)+SCRK
      ALP=GAMP*S3-S4*CSQRT(C1P)*CSQRT(C2P)
      BKDEL3=SBKDE1(INER)
      IF(INER .LE. I6)  GO TO 200
      CALL AKAPM(ALP,BKDEL3)
      SBKDE1(INER)=BKDEL3
  200 CONTINUE
      T1=ALP*SPS-GAMP
      T2=ALP*DSTR**2-GAMP*SPS
      SUM1=SUMSV1(IOUT)*CEXP(AI*T1)*BKDEL3*T1/(                       -
     1T2* SVKL1(IOUT)*(ALP-RQ1))
      SUM3=SUMSV2(IOUT)*CEXP(AI*T1)*BKDEL3*T1/(                       -
     1T2*SVKL2(IOUT)*(ALP-RQ2))
      IF(INER .EQ. 1) GO TO 90
      C1N=(GAMN/DSTR)-SCRK
      C2N=(GAMN/DSTR)+SCRK
      ALN=GAMN*S3-S4*CSQRT(C1N)*CSQRT(C2N)
      BKDEL3=SBKDE2(INER)
      IF(INER  .LE.  I6)  GC TO 210
      CALL AKAPM(ALN,BKDEL3)
      SBKDE2(INER)=BKDEL3
  210 CONTINUE
      T1=ALN*SPS-GAMN
      T2=ALN*DSTR**2-GAMN*SPS
      SUM2=SUMSV1(IOUT)*CEXP(AI*T1)*BKDEL3*T1/(                       -
     2T2*SVKL1(IOUT)*(ALN-RQ1))
      SUM4=SUMSV2(IOUT)*CEXP(AI*T1)*BKDEL3*T1/(                       -
     2T2*SVKL2(IOUT)*(ALN-RQ2))
   90 CONTINUE
      IF(INER .EQ. 1)  SUM2=0.0
      IF(INER .EQ. 1)  SUM4=0.0
      C1P=CEXP(-AI*(ALP-DEL)*SPS)
      C2P=CEXP(-AI*(ALP-DEL)*SNS)
      C1N=CEXP(-AI*(ALN-DEL)*SPS)
      C2N=CEXP(-AI*(ALN-DEL)*SNS)
      F5T=F5T+(SUM1+SUM3)*AI*SS/(ALP-DEL)*(C1P-C2P)+                  -
     1(SUM2+SUM4)*SS*AI/(ALN-DEL)*(C1N-C2N)
      AM5T=AM5T+(SUM1+SUM3)*SS*(AI*SPS*C1P/(ALP-DEL)-AI               -
     1*SNS*C2P/(ALP-DEL)+1.C/((ALP-DEL)**2)*(C1P-C2P)+AI*(2.0-SPS)/(  -
     2ALP-DEL)*(C1P-C2P))+(SUM2+SUM4)*SS*(AI*SPS*C1N/(ALN-            -
     3DEL)-AI*SNS*C2N/(ALN-DEL)+1.0/((ALN-DEL)**2)*(C1N-C2N)+AI*(2.0- -
     4SPS)/(ALN-DEL)*(C1N-C2N))
      TEMP=(SPS-SNS)/RL1
      CONST=(SUM1+SUM3)*SS
      CONST2=(SUM2+SUM4)*SS
      C1A=-AI*(ALP-DEL)
```

```
      C2A=-AI*(ALN-DEL)
      CEXP1=CEXP(C1A*SNS)
      CEXP2=CEXP(C2A*SNS)
      CEXP1A=CEXP(C1A*TEMP)
      CEXP2A=CEXP(C2A*TEMP)
      DO 462 JL=1,NL
      QRES4(JL)=QRES4(JL)-(CONST*CEXP1+CONST2*CEXP2)
      CEXP1=CEXP1*CEXP1A
      CEXP2=CEXP2*CEXP2A
  462 CONTINUE
      BETNP=(2.0*R*PI-S5)/S1
      BETNN=(-2.0*R*PI-S5)/S1
      C1P=CEXP(-2.0*PI*R*AI*SNS/S1)
      C2P=CEXP(-2.0*PI*R*AI*SPS/S1)
      C1N=CEXP(2.0*PI*R*AI*SNS/S1)
      C2N=CEXP(2.0*PI*R*AI*SPS/S1)
      T1=CEXP(-AI*BETNP*SPS)
      T2=CEXP(-AI*BETNP*SNS)
      T3=CEXP(-AI*BETNN*SPS)
      T4=CEXP(-AI*BETNN*SNS)
      CA1=AI*SS/BETNP*(T1-T2)                                           -
      CA2=AI*SS/BETNN*(T3-T4)                                           -
      CA3=SS*(AI*SPS/BETNP*T1-AI*SNS                                    -
     1*T2/BETNP+(T1-T2                                                  -
     2 )/BETNP**2+(2.0-SPS)*AI/BETNP*(T1-                               -
     3T2))
      CA4=SS*(AI*SPS*T3/BETNN-AI*SNS*                                   -
     1T4/BETNN+(T3-T4                                                   -
     2)/BETNN**2+(2.0-SPS)*AI/BETNN*(T3-                                -
     3T4))
      IF(INER .GT. 1) GO TO 300
      F5T=F5T-SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)/(R-C4)*CA1-SUMSV2(IOUT)   -
     1*(BC3*C1P-BC5*C2P)/(R-C5)*CA1
      AM5T=AM5T-SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)/(R-C4)*CA3-SUMSV2(IOUT) -
     1*(BC3*C1P-BC5*C2P)/(R-C5)*CA3
      TEMP=(SPS-SNS)/RL1
      CONST=SS*SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)/(R-C4)
      CONST2=SS*SUMSV2(IOUT)*(BC3*C1P-BC5*C2P)/(R-C5)
      C1A=-AI*BETNP
      CEXP1=CEXP(C1A*SNS)
      CEXP1A=CEXP(C1A*TEMP)
      DO 4622 JL=1,NL
      QRES4(JL)=QRES4(JL)+CONST*CEXP1+CONST2*CEXP1
      CEXP1=CEXP1*CEXP1A
 4622 CONTINUE
      GO TO 310
  300 CONTINUE
      F5T=F5T-SUMSV1(IOUT)*((BC2*C1P-BC4*C2P)/(R-C4)*CA1-(BC2*C1N-BC4  -
     1*C2N)/(R+C4)*CA2)-SUMSV2(IOUT)*((BC3*C1P-BC5*C2P)/(R-C5)*CA1     -
     2-(BC3*C1N-BC5*C2N)/(R+C5)*CA2)
      AM5T=AM5T-SUMSV1(IOUT)*((BC2*C1P-BC4*C2P)/(R-C4)*CA3-(BC2*C1N-   -
     1BC4*C2N)/(R+C4)*CA4)-SUMSV2(IOUT)*((BC3*C1P-BC5*C2P)/(R-C5)*CA3  -
     2 -(BC3*C1N-BC5*C2N)/(R+C5)*CA4)
      TEMP=(SPS-SNS)/RL1
      CONST=(BC2*C1P-BC4*C2P)/(R-C4)
      CONST2=(BC2*C1N-BC4*C2N)/(R+C4)
      CONST3=(BC3*C1P-BC5*C2P)/(R-C5)
      CONST4=(BC3*C1N-BC5*C2N)/(R+C5)
```

ORIGINAL PAGE IS
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```
      CONST5=SS*SUMSV1(IOUT)
      CONST6=SS*SUMSV2(IOUT)
      C1A=-AI*BETNP
      C2A=-AI*BETNN
      CEXP1=CEXP(C1A*SNS)
      CEXP2=CEXP(C2A*SNS)
      CEXP1A=CEXP(C1A*TEMP)
      CEXP2A=CEXP(C2A*TEMP)
      DO 4623 JL=1,NL
      QRES4(JL)=QRES4(JL)+CCNST5*(CONST*CEXP1-CONST2*CEXP2)
     1                      +CCNST6*(CONST3*CEXP1-CONST4*CEXP2)
      CEXP1=CEXP1*CEXP1A
      CEXP2=CEXP2*CEXP2A
 4623 CONTINUE
  310 CONTINUE
      IF (CABS((AM5TT-AM5T)/AM5T) .LT. 0.001) GO TO 95
      AM5TT=AM5T
   85 CONTINUE
      GO TO 9995
   95 CONTINUE
      IF(INER  .LE.  I6)  GO TO 220
      I6=INER
  220 CONTINUE
      F5=F5+F5T
      AM5=AM5+AM5T
      DO 463 JL=1,NL
      PRES4(JL)=PRES4(JL)+QRES4(JL)
  463 CONTINUE
      ALP1=(2.0*PI*C4-DEL*SNS-SIGMA)/S1
      ALP2=(2.0*PI*C5-DEL*SNS-SIGMA)/S1
      T1=1.0-CEXP(-2.0*PI*AI*C4)
      T2=1.0-CEXP(-2.0*PI*AI*C5)
      C1P=CEXP(-2.0*PI*AI*C4*SNS/S1)/(T1)
      C2P=CEXP(2.0*PI*AI*C4*SNS/S1)/(T1)
      C1N=CEXP(-2.0*PI*AI*C5*SNS/S1)/(T2)
      C2N=CEXP(2.0*PI*AI*C5*SNS/S1)/(T2)
      T1=CEXP(-AI*SPS*ALP1)
      T2=CEXP(-AI*SNS*ALP1)
      T3=CEXP(-AI*SPS*ALP2)
      T4=CEXP(-AI*SNS*ALP2)
      CA1=AI*SS/ALP1*(T1-T2)                                          -
      CA2=AI*SS/ALP2*(T3-T4)                                          -
      CA3=SS*(AI*SPS*T1/ALP1-AI*SNS                                   -
     1*T2/ALP1+(T1-T2)                                                -
     2/ALP1**2+(2.0-SPS)*AI/ALP1*(T1-T2))                             -
      CA4=SS*(AI*SPS*T3/ALP2-AI*SNS                                   -
     1 *T4/ALP2+(T3-T4)                                               -
     2/ALP2**2+(2.0-SPS)*AI/ALP2*(T3-T4))                             -
      F5=F5-2.0*PI*AI*SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)*CA1-2.0*PI*AI    -
     1*SUMSV2(IOUT)*(BC3*C1N-BC5*C2N)*CA2
      AM5=AM5-2.0*PI*AI*SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)*CA3-2.0*PI*AI  -
     2 *SUMSV2(IOUT)*(BC3*C1N-BC5*C2N)*CA4
      TEMP=(SPS-SNS)/RL1
      CONST=SS*2.0*PI*AI
      CONST2=CONST*SUMSV1(IOUT)*(BC2*C1P-BC4*C2P)
      CONST3=CONST*SUMSV2(IOUT)*(BC3*C1N-BC5*C2N)
      C1A=-AI*ALP1
      C2A=-AI*ALP2
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      CEXP1=CEXP(C1A*SNS)
      CEXP2=CEXP(C2A*SNS)
      CEXP1A=CEXP(C1A*TEMP)
      CEXP2A=CEXP(C2A*TEMP)
      DO 4632 JL=1,NL
      PRES4(JL)=PRES4(JL)+CCNST2*CEXP1+CONST3*CEXP2
      CEXP1=CEXP1*CEXP1A
      CEXP2=CEXP2*CEXP2A
 4632 CONTINUE
      IF (CABS((AM5-AM6)/AM5) .LT. 0.0009) GO TO 100
      AM6=AM5
   80 CONTINUE
      GO TO 9996
  100 CONTINUE
      CLIFT=F1+F2-F2P+F4+F5
      CMOMT=AM1+AM2-AM2P+AM4+AM5-AMCAXS*CLIFT
      GO TO 5000
 9995 WRITE(IBBOUT,3020)
 3020 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBD  /
     1       39X,27HAM5T LOOP DID NCT CONVERGE. )
      CALL MESAGE(-61,0,C)
 9996 WRITE(IBBOUT,3025)
 3025 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBD  /
     1       39X,26HAM5 LOOP DID NCT CONVERGE.  )
      CALL MESAGE(-61,0,0)
 9997 WRITE(IBBOUT,3030)
 3030 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE SUBD  /
     1       39X,30HOUTER LOOP OF AM5 EXCEEDED 17. )
      CALL MESAGE(-61,0,C)
 5000 CONTINUE
      RETURN
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE ALAMDA(ARG,Y,BLAMDA)
C
C     SUBROUTINE FOR COMPUTING LAMDA
C
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMPLEX BLAMDA,AI,C1
      SCRK1= ABS(SCRK)
      ARG1=  ABS(ARG)
      S1=(ARG-DEL)*SPS+SIGMA
      IF( SCRK1.GT.ARG1) GO TO 10
      GAM=SQRT(ARG**2-SCRK**2)
      C1=COS(GAM*(SNS-Y))-CEXP(AI*S1)*COS(GAM*Y)
      C2=COS(SNS*GAM)-COS(S1)
      BLAMDA=C1/C2
      RETURN
   10 CONTINUE
      GAM=SQRT(SCRK**2-ARG**2)
      C1=COSH(GAM*(SNS-Y))-CEXP(AI*S1)*COSH(GAM*Y)
      C2=COSH(SNS*GAM)-COS(S1)
      BLAMDA=C1/C2
      RETURN
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE AKP2
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMPLEX AI
      GAM=SQRT(DEL**2-SCRK**2)
      S1=SNS*GAM
      C1=(SIGMA-S1)/2.0
      C2=(SIGMA+S1)/2.0
      DGDA=DEL/GAM
      D1=SPS/2.0
      D2=SNS/2.C*DGDA
      DC1DA=D1-D2
      DC2DA=D1+D2
      RES=1.0/GAM*DGDA+SNS*COS(S1)/SIN(S1)*DGDA
     1-COS(C1)/SIN(C1)*DC1DA-COS(C2)/SIN(C2)*DC2DA
      RETURN
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE AKAPPA(ARG,BKAPPA)
C
C     SUBROUTINE FOR COMPUTING KAPPA
C
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMPLEX AI
      SCRK1 =  ABS (SCRK)
      ARG1  =  ABS (ARG)
      IF ( SCRK1 .GT. ARG1)  GO TO 10
      GAM=SQRT(ARG**2-SCRK**2)
      S1=SNS*GAM
      C1=BETA*GAM*SIN(S1)
      C2=COS(S1)-COS((ARG-DEL)*SPS+SIGMA)
      BKAPPA=C1/C2
      RETURN
   10 CONTINUE
      GAM=SQRT(SCRK**2-ARG**2)
      S1=SNS*GAM
      C1=-BETA*GAM*SINH(S1)
      C2=COSH(S1)-COS((ARG-DEL)*SPS+SIGMA)
      BKAPPA=C1/C2
      RETURN
      END
```

```
      SUBROUTINE DLKAPM(ARG,BLKAPP)
C
C     SUBROUTINE FOR COMPUTING LOGARITHMIC DERIVATIVE OF KAPPA MINUS
C
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMPLEX BLKAPM,AI,C1,D1,D2,C1TEST,ARG,E1
      COMPLEX ALPO,ALP,ALN
      C1=-AI/2.0*(SPS-SNS)
      PI2=2.0*PI
      S1=SPS/(DSTR**2)
      S2=SNS/DSTR
      GAMO=SPS*DEL-SIGMA
      C2Q=GAMO/DSTR-SCRK
      C3Q=GAMO/DSTR+SCRK
      NN=0
      CSEC=C2Q*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMO*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2Q.LT.0.0.AND.C3Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALPO=T1+T2
      IF(NN.EQ.1)ALPO=CMPLX(T1,T2)
      C1=C1+1.0/(ARG-ALPO)
      A1=PI2/(SPS-SNS)
      A2=-A1
      B1=GAMO/(SPS-SNS)
      C1TEST=0.0
      DO 20 I=1,200
      R=I
      GAMP=PI2*R+GAMO
      GAMN=-PI2*R+GAMO
      C2P=GAMP/DSTR-SCRK
      C2Q=GAMP/DSTR+SCRK
      C2N=GAMN/DSTR-SCRK
      C3Q=GAMN/DSTR+SCRK
      NN=0
      CSEC=C2P*C2Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMP*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2P.LT.0.0.AND.C2Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALP=T1+T2
      IF(NN.EQ.1)ALP=CMPLX(T1,T2)
      NN=0
      CSEC=C2N*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMN*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2N.LT.0.0.AND.C3Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALN=T1+T2
      IF(NN.EQ.1)ALN=CMPLX(T1,T2)
      E1=A1*R+B1-ARG
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      D1=(ALP-A1*R-B1)/E1
      D2=D1/E1
      C1=C1+1.0/(1.0+D1)*D2
      E1=A2*R+B1-ARG
      D1=(ALN-A2*R-B1)/E1
      D2=D1/E1
      C1=C1+1.0/(1.0+D1)*D2
      IF (CABS((C1-C1TEST)/C1) .LT. 0.0006) GO TO 50
      C1TEST=C1
   20 CONTINUE
      GO TO 9999
   50 CONTINUE
      E1=ARG-B1
      B=PI/A1
      C1=C1-1.0/E1+B
     1*CCOS(B*E1)/(CSIN(B*E1))
      BLKAPM=C1
      RETURN
 9999 WRITE(IBBOUT,1000)
      CALL MESAGE(-61,0,C)
 1000 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE DLKAPM)
      RETURN
      END
```

```
      SUBROUTINE ASYCON
C
C     SUBROUTINE FOR COMPUTING CCNSTANT TERM IN KAPPA MINUS
C
      COMMON/BLK2/ BSYCCN
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMPLEX BSYCON,AI,C1,C1TEST,ALP,ALN,ARAT1,ARAT2
      C1=1.0
      PI2=2.0*PI
      A1=PI2/(SPS-SNS)
      GAMO=SPS*DEL-SIGMA
      A2=-A1
      B1=GAMO/(SPS-SNS)
      S1=SPS/(DSTR**2)
      S2=SNS/DSTR
      C1TEST=0.0
      DO 10 I=1,2C0
      R=I
      GAMP=PI2*R+GAMO
      GAMN=-PI2*R+GAMO
      C2P=GAMP/DSTR-SCRK
      C2Q=GAMP/DSTR+SCRK
      C2N=GAMN/DSTR-SCRK
      C3Q=GAMN/DSTR+SCRK
      NN=0
      CSEC=C2P*C2Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMP*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2P.LT.0.C.AND.C2Q.LT.0.C) T2=-T2
      IF(NN.EQ.C)ALP=T1+T2
      IF(NN.EQ.1)ALP=CMPLX(T1,T2)
      NN=0
      CSEC=C2N*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMN*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2N.LT.0.0.AND.C3Q.LT.0.C) T2=-T2
      IF(NN.EQ.0)ALN=T1+T2
      IF(NN.EQ.1)ALN=CMPLX(T1,T2)
      ARAT1=(A1*R+B1)/ALP
      ARAT2=(A2*R+B1)/ALN
      C1=C1*ARAT1*ARAT2
      IF(CABS((C1-C1TEST)/C1) .LT. 0.0001)   GO TO 60
      C1TEST=C1
   10 CONTINUE
      GO TO 9999
   60 CONTINUE
      BSYCON=C1
      RETURN
 9999 WRITE(IBBOUT,1C00)
      CALL MESAGE(-61,0,C)
```

```
1000 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE ASYCON)
     RETURN
     END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE AKAPM(ARG,BKPM)
C
C     SUBROUTINE FOR COMPUTING KAPPA MINUS
C
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMPLEX BKPM,C1,AI,C1TEST,BSYCON,ARG
      COMPLEX AT2,AT3,ALPO,ALP,ALN
      C1=CEXP(-AI*ARG/2.0*(SPS-SNS))
      GAMO=SPS*DEL-SIGMA
      PI2=2.0*PI
      S1=SPS/(DSTR**2)
      S2=SNS/DSTR
      C2Q=GAMO/DSTR-SCRK
      C3Q=GAMO/DSTR+SCRK
      NN=0
      CSEC=C2Q*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMO*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2Q.LT.0.0.AND.C3Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALPO=T1+T2
      IF(NN.EQ.1)ALPO=CMPLX(T1,T2)
      C1=C1*(1.0-ARG/ALPO)
      A1=PI2/(SPS-SNS)
      A2=-A1
      B1=GAMO/(SPS-SNS)
      C1TEST=0.0
      DO 20 I=1,200
      R=I
      GAMP=PI2*R+GAMO
      GAMN=-PI2*R+GAMO
      C2P=GAMP/DSTR-SCRK
      C2Q=GAMP/DSTR+SCRK
      C2N=GAMN/DSTR-SCRK
      C3Q=GAMN/DSTR+SCRK
      NN=0
      CSEC=C2P*C2Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMP*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2P.LT.0.0.AND.C2Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALP=T1+T2
      IF(NN.EQ.1)ALP=CMPLX(T1,T2)
      NN=0
      CSEC=C2N*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMN*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2N.LT.0.0.AND.C3Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALN=T1+T2
      IF(NN.EQ.1)ALN=CMPLX(T1,T2)
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      AT2=(ALP-A1*R-B1)/(A1*R+B1-ARG)
      AT3=(ALN-A2*R-B1)/(A2*R+B1-ARG)
      C1=C1*(1.0+AT2)*(1.C+AT3)
      IF (CABS((C1-C1TEST)/C1) .LT. 0.0009) GO TO 50
      C1TEST=C1
   20 CONTINUE
      GO TO 9999
   50 CONTINUE
      C1=C1*B1/(ARG-B1)*CSIN(PI/A1*(ARG-B1))/(SIN(PI*B1/A1))
      C1=C1*BSYCON
      BKPM=C1
      RETURN
 9999 WRITE(IBBOUT,1000)
      CALL MESAGE(-61,0,0)
 1000 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE AKAPM )
      RETURN
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE DRKAPM(ARG,INDX,RESLT)
C
C     THIS SUBROUTINE COMPUTES THE DERVIATIVE OF KAPPA MINUS
C
      COMMON /SYSTEM/SYSBUF,IBBCLT
      COMMON/BLK1/SCRK,SPS,SNS,DSTR,AI,PI,DEL,SIGMA,BETA,RES
      COMMON/BLK2/BSYCON
      COMPLEX AI,ARG,RESLT,BSYCON,C1,C2,C2TEST,AT2,AT3,ALPO,ALP,ALN        -
      PI2=2.0*PI
      A1=PI2/(SPS-SNS)
      A2=-A1
      GAMO=SPS*DEL-SIGMA
      B1=GAMO/(SPS-SNS)
      C1=CEXP(-AI*ARG/2.0*(SPS-SNS))
      C2Q=GAMO/DSTR-SCRK
      C3Q=GAMO/DSTR+SCRK
      S1=SPS/(DSTR**2)
      S2=SNS/DSTR
      NN=0
      CSEC=C2Q*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMO*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2Q.LT.0.0.AND.C3Q.LT.0.C) T2=-T2
      IF(NN.EQ.0)ALPO=T1+T2
      IF(NN.EQ.1)ALPO=CMPLX(T1,T2)
      RINDX=INDX
      IF( INDX .EQ. 0)  GO TO 10
      C2=C1*B1/ALPO*CSIN(PI/A1*(ARG-B1))/(A1*RINDX+B1-ARG)*                -
     1(1.0+(ALPO-B1)/(B1-ARG))/(SIN(PI*B1/A1))*BSYCON
      GO TO 20
   10 CONTINUE
      C2=C1*B1/ALPO*CSIN(PI/A1*(ARG-B1))/((B1-ALPO)*SIN(PI*B1/A1))        -
     1*BSYCON
   20 CONTINUE
      C2TEST=0.0
      DO 30 I=1,200
      R=I
      IF( INDX.LT. 0    .AND. ABS(RINDX) .EQ. R)  GO TO 30
      IF( INDX .GT. 0   .AND.    RINDX .EQ. R)  GO TO 30
      GAMP=PI2*R+GAMO
      GAMN=-PI2*R+GAMO
      C2P=GAMP/DSTR-SCRK
      C2Q=GAMP/DSTR+SCRK
      C2N=GAMN/DSTR-SCRK
      C3Q=GAMN/DSTR+SCRK
      NN=0
      CSEC=C2P*C2Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMP*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2P.LT.0.0.AND.C2Q.LT.C.C) T2=-T2
      IF(NN.EQ.C)ALP=T1+T2
```

```
      IF(NN.EQ.1)ALP=CMPLX(T1,T2)
      NN=0
      CSEC=C2N*C3Q
      IF(CSEC.LT.0.0)NN=1
      T1=GAMN*S1
      T2=S2*SQRT(ABS(CSEC))
      IF(C2N.LT.0.0.AND.C3Q.LT.0.0) T2=-T2
      IF(NN.EQ.0)ALN=T1+T2
      IF(NN.EQ.1)ALN=CMPLX(T1,T2)
      AT2=(ALP-A1*R-B1)/(A1*R+B1-ARG)
      AT3=(ALN-A2*R-B1)/(A2*R+B1-ARG)
      C2=C2*(1.0+AT2)*(1.0+AT3)
      IF (CABS((C2-C2TEST)/C2) .LT. 0.0009) GO TO 40
      C2TEST=C2
   30 CONTINUE
      GO TO 9999
   40 CONTINUE
      RESLT=C2
      RETURN
 9999 CONTINUE
      WRITE(IBBOUT,2040)
      CALL MESAGE(-61,0,0)
 2040 FORMAT(55H0*** USER FATAL MESSAGE - AMG MODULE -SUBROUTINE DRKAPM)
      RETURN
      END
```

```
      SUBROUTINE INVERS(NDIM,A,N,B,M,DETERM,ISING,INDEX)
C
C     ***** INVERSE OR LINEAR EQUATIONS SOLVER ****
C     ***********************************************************************
C
C     NDIM IS THE ACTUAL SIZE OF A IN CALLING PROGRAM.
C              EG.  A(NDIM,NDIM)
C     A IS SQUARE MATRIX TO BE INVERTED.
C     N IS SIZE OF UPPER LEFT PORTION BEING INVERTED.          MINIMUM
C     B IS COLUMN OF CONSTANTS (OPTIONAL INPUT). SUPPLY SPACE B(NDIM,1)
C     M IS THE NUMBER OF COLUMNS OF CONSTANTS
C     DETERM RETURNS THE VALUE OF DETERMINANT IF NON-SINGULAR
C     ISING RETURNS,2 IF MATRIX A(N,N) IS SINGULAR
C                  ,1 IF MATRIX A(N,N) IS NON-SINGULAR
C     INVERSE RETURNS IN A
C     SOLUTION VECTORS RETURN IN B
C     INDEX IS WORKING STORAGE (N,3)
C     ***********************************************************************
      DIMENSION  A(NDIM,1),  B(NDIM,1), INDEX(N,3)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX, T, SWAP)
C
C     INITIALIZE
C
      DETERM = 1.0E0
      DO 10 J=1,N
   10 INDEX(J,3) = 0
      DO 130 I=1,N
C
C     SEARCH FOR PIVOT
C
      AMAX = 0.0E0
      DO 40 J=1,N
      IF(INDEX(J,3) .EQ. 1) GO TO 40
      DO 30 K=1,N
      IF(INDEX(K,3) - 1) 20,30,190
   20 IF( ABS( A(J,K) ) .LE. AMAX) GO TO 30
      IROW = J
      ICOLUM = K
      AMAX = ABS( A(J,K) )
   30 CONTINUE
   40 CONTINUE
      INDEX(ICOLUM,3) = INDEX(ICOLUM,3) + 1
      INDEX(I,1) = IROW
      INDEX(I,2) = ICOLUM
C
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
      IF (IROW .EQ. ICOLUM) GO TO 70
      DETERM = -DETERM
      DO 50 L=1,N
      SWAP = A(IROW,L)
      A(IROW,L) = A(ICOLUM,L)
   50 A(ICOLUM,L) = SWAP
```

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```
      IF(M .LE. 0) GO TO 70
      DO 60 L=1,M
      SWAP = B(IROW,L)
      B(IROW,L) = B(ICOLUM,L)
   60 B(ICOLUM,L) = SWAP
C
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT
C
   70 PIVOT = A(ICOLUM,ICOLUM)
      DETERM = DETERM * PIVOT
      A(ICOLUM,ICOLUM) = 1.0E0
      DO 80 L=1,N
   80 A(ICOLUM,L) = A(ICOLUM,L) / PIVOT
      IF(M .LE. 0) GO TO 100
      DO 90 L=1,M
   90 B(ICOLUM,L) = B(ICOLUM,L) / PIVOT
C
C     REDUCE NON PIVOT ROWS
C
  100 DO 130 L1=1,N
      IF(L1 .EQ. ICOLUM) GO TO 130
      T = A(L1,ICOLUM)
      A(L1,ICOLUM) = 0.0E0
      DO 110 L=1,N
  110 A(L1,L) = A(L1,L) - A(ICOLUM,L) * T
      IF(M .LE. 0) GO TO 130
      DO 120 L=1,M
  120 B(L1,L)=B(L1,L) - B(ICOLUM,L) * T
  130 CONTINUE
C
C     INTERCHANGE COLUMNS
C
      DO 150 I=1,N
      L = N + 1 - I
      IF(INDEX(L,1) .EQ. INDEX(L,2)) GO TO 150
      JROW = INDEX(L,1)
      JCOLUM = INDEX(L,2)
      DO 140 K=1,N
      SWAP = A(K,JROW)
      A(K,JROW) = A(K,JCOLUM)
      A(K,JCOLUM) = SWAP
  140 CONTINUE
  150 CONTINUE
      DO 170 K=1,N
      IF(INDEX(K,3) .EQ. 1) GO TO 160
      ISING = 2
      GO TO 180
  160 CONTINUE
  170 CONTINUE
      ISING = 1
  180 RETURN
  190 ISING = 2
      RETURN
      END
```

```
      SUBROUTINE MESAGE(NO,PARM,NAME)
C*******
C     MESAGE IS USED TO QUELE NCN-FATAL MESSAGES DURING THE EXECUTION
C     OF A MODULE AND GIVE A CORE DUMP, PRINT THE MESSAGES, AND CALL
C     PEXIT FOR FATAL MESSAGES
C*******
      INTEGER PARM,NAME(2)
      CALL EXIT
      STOP
      END
```

CASE 1

$M = 1.149,\ k = 0.384,\ \lambda = 44.7°,\ s/c = 0.633,\ \sigma = 180°$

Original Code

```
Q--MATRIX FOLLOWS
   8.5682106E-01   -1.4077015E+00   6.7009401E-01   -1.3614397E+00   5.3634501E-01   -8.3955431E-01
   4.5665112E+00    1.2750947E+00   4.4559908E+00    6.3499403E-01   2.8131104E+00    8.0391312E-01
  -3.4068050E+00    7.3223548E-02  -2.7439871E+00    8.3338976E-01  -1.9028158E+00    3.3147687E-01
CPU TIME ON IBM 370/3031 =   55.73 SECONDS.
```

Revised Code

```
Q--MATRIX FOLLOWS
   8.4951735E-01   -1.4041214E+00   6.6280460E-01   -1.3556175E+00   5.3059006E-01   -8.3692026E-01
   4.5573463E+00    1.2555581E+0C   4.4405394E+00    6.1205339E-01   2.8063698E+00    7.8564692E-01
  -3.3993435E+00    8.3261311E-02  -2.7342386E+00    8.4393167E-01  -1.8973961E+00    3.3962262E-01
CPU TIME ON IBM 370/3031 =   11.44 SECONDS.
```

CASE 2

$M = 1.149,\ k = 0.896,\ \lambda = 44.7°,\ s/c = 0.633,\ \sigma = 180°$

Original Code

```
Q--MATRIX FOLLOWS
   2.1633062E+00   -3.0848389E+00   2.3042755E+00   -3.3407059E+00   1.2806244E+00   -1.9720144E+00
   4.6619616E+00    1.2544241E+00   4.9538498E+00    1.1370173E+00   3.0111361E+00    6.9599724E-01
  -4.7993441E+00   -2.9282513E+CC  -4.8682671E+00   -3.9111328E+00  -2.9995308E+00   -1.4711590E+00
CPU TIME ON IBM 370/3031 =   80.00 SECONDS.
```

Revised Code

```
Q--MATRIX FOLLOWS
   2.1563778E+00   -3.0855061E+00   2.2965918E+00   -3.3421240E+00   1.2749214E+00   -1.9753036E+00
   4.6691284E+00    1.2410307E+0C   4.9568596E+00    1.1228180E+00   3.0161667E+00    6.8528414E-01
  -4.8084507E+00   -2.9031C48E+0C  -4.8709688E+00   -3.8851547E+00  -3.0057068E+00   -1.4512701E+00
CPU TIME ON IBM 370/3031 =   21.11 SECONDS.
```

TABLE 1. Real and Imaginary Elements of the Generalized Modal Aerodynamic Matrices (Q) for 3 Chordwise Aerodynamic Modes

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CASE 3

$M = 1.502$, $k = 0.300$, $\lambda = 62.03°$, $s/c = 0.776$, $\sigma = -90°$

Original Code

```
Q--MATRIX FOLLOWS
   -1.7240173E-01   -5.7555485E-01   -5.1772743E-02   -4.8066342E-01   -1.1560851E-01   -3.7468612E-01
    1.8682089E+00   -1.1136847E+00    1.7137804E+00   -7.8412008E-01    1.1922522E+00   -7.4794483E-01
   -1.6930246E-01    9.9687767E-01    6.6171122E-01    1.1019030E+00   -4.5508087E-02    5.1341581E-01
CPU TIME ON IBM 370/3031 =   45.15 SECONDS.
```

Revised Code

```
Q--MATRIX FOLLOWS
   -1.7289913E-01   -5.7528162E-01   -5.2272797E-02   -4.8052174E-01   -1.1599171E-01   -3.7452883E-01
    1.8683834E+00   -1.1133976E+00    1.7141838E+00   -7.8374815E-01    1.1925201E+00   -7.4772501E-01
   -1.6419333E-01    9.9079227E-01    6.6701174E-01    1.0957689E+00   -4.1819721E-02    5.0852489E-01
CPU TIME ON IBM 370/3031 =   8.42 SECONDS.
```

CASE 4

$M = 1.502$, $k = 1.000$, $\lambda = 62.03°$, $s/c = 0.776$, $\sigma = 90°$

Original Code

```
Q--MATRIX FOLLOWS
    6.3198280E-01   -1.1564703E+00    5.5702972E-01   -1.5027952E+00    3.8543093E-01   -6.7132902E-01
    1.8102617E+00   -5.5115163E-02    2.2852879E+00   -7.6359129E-01    1.0673132E+00   -3.2578036E-04
   -8.5292264E-01   -6.2339449E-01   -2.8504801E-01   -3.1878477E-01   -5.4620981E-01   -3.6355180E-01
CPU TIME ON IBM 370/3031 =   64.33 SECONDS.
```

Revised Code

```
Q--MATRIX FOLLOWS
    6.3278437E-01   -1.1557157E+00    5.5876732E-01   -1.5063906E+00    3.8595814E-01   -6.7309809E-01
    1.8164253E+00   -5.4449648E-02    2.2916298E+00   -7.6139498E-01    1.0707445E+00   -2.2899732E-04
   -8.7068701E-01   -6.1977291E-01   -3.0391908E-01   -3.1861329E-01   -5.5741930E-01   -3.6080706E-01
CPU TIME ON IBM 370/3031 =   14.77 SECONDS.
```

TABLE 1. Concluded