NASA CR-120993
ASRL TR 154-7

COMPUTER PROGRAM-JET 3-TO CALCULATE THE LARGE ELASTIC-PLASTIC DYNAMICALLY-INDUCED DEFORMATIONS OF FREE AND RESTRAINED, PARTIAL AND/OR COMPLETE STRUCTURAL RINGS

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August 1972

Prepared for

AEROSPACE SAFETY RESEARCH AND DATA INSTITUTE
LEWIS RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CLEVELAND, OHIO 44135

NASA Grant NGR 22-009-339

1. Report No. NASA CR-120993	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle COMPUTER PROGRAM - JET 3 - TO CALCULATE THE LARGE ELASTIC-PLASTIC DYNAMICALLY-INDUCED DEFORMATIONS OF FREE AND RESTRAINED, PARTIAL AND/OR COMPLETE STRUCTURAL RINGS		5. Report Date August 1972
		6. Performing Organization Code
7. Author(s) Richard W-H Wu and Emmett A. Witmer		8. Performing Organization Report No. ASRL TR 154-7
		10. Work Unit No.
9. Performing Organization Name and Address Aeroelastic and Structures Research Laboratory Department of Aeronautics and Astronautics Massachusetts Institute of Technology Cambridge, Massachusetts 02139		11. Contract or Grant No. NGR 22-009-339
		13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes
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16. Abstract

A user-oriented FORTRAN IV computer program, called JET 3, is presented. The JET 3 program, which employs the spatial finite-element and timewise finite-difference method, can be used to predict the large two-dimensional elastic-plastic transient Kirchhoff-type deformations of a complete or partial structural ring, with various support conditions and restraints, subjected to a variety of initial velocity distributions and externally-applied transient forcing functions. The geometric shapes of the structural ring can be circular or arbitrarily curved and with variable thickness. Strain-hardening and strain-rate effects of the material are taken into account.

17. Key Words (Suggested by Author(s))		18. Distribution Statement
Computer Program	Large Deflections	Unclassified, Unlimited
Finite-Element Method	Elastic-Plastic Behavior	
Structural Mechanics	Turbojet Rotor Containment	
Stress Analysis	Aircraft Safety	
Transient Structural Response	Aircraft Hazards	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	260	$3.00

* For sale by the National Technical Information Service, Springfield, Virginia 22151

NASA-C-168 (Rev. 6-71)

FOREWORD

This report has been prepared by the Aeroelastic and Structures Research Laboratory (ASRL), Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts under Grant No. NGR 22-009-339 from the Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio 44135. Mr. Patrick T. Chiarito of the Lewis Research Center served as technical monitor and Mr. Richard H. Kemp served as technical advisor.

The cooperation and helpful suggestions of Mr. Chiarito and Mr. Kemp throughout this research program are deeply appreciated.

The authors especially wish to acknowledge the careful reviewing of this report and the many constructive suggestions contributed by Dr. John W. Leech and Mr. Raffi P. Yeghiayan of the MIT-ASRL.

The use of SI units (NASA Policy Directive NPD 2220.4, September 14, 1970) was waived for the present document in accordance with provisions of paragraph 5d of that Directive by the authority of the Director of the Lewis Research Center.

CONTENTS

CONTENTS CONCLUDED

LIST OF ILLUSTRATIONS

SECTION 1

INTRODUCTION

JET 3 is the third in a series of computer programs which are intended to be made available to the aircraft industry for use in analyzing structural response problems such as containment/deflection rings intended to defeat the impact of aircraft engine rotor fragments. Each of these programs requires that any externally-applied forces which act on the structure being analyzed be prescribed.

The computer program JET 3, written in FORTRAN IV, permits one to predict the large, two-dimensional, elastic-plastic, transient Kirchhoff-type responses of a complete or partial single-layer, variable thickness structural ring, with various support conditions and restraints; the ring may be subjected to arbitrary but prescribed distributions of initial impulse loading and/or externally-applied time-dependent forces. The geometrical shapes of the structural ring can be simple,circular or arbitrarily curved and with variable thickness along the circumferential direction. Strain-hardening and strain-rate sensitive material behavior are taken into account.

The JET 3 program embodies the spatial finite-element and temporal finite-difference analysis features. It should be noted that in the two previous series of computer programs, JET 1 (Ref. 1) and JET 2 (Ref. 2), the finite-difference method is employed for both spatially- and time-varying quantities. The relative ease and versatility with which the spatial finite-element method can be applied to a structure with complicated boundary conditions, geometric shape, and material properties in comparison with the finite-difference method is often regarded as an important attribute of the finite-element method. Accordingly, the spatial finite-element method of analysis is implemented in the present program. The pertinent analytical development and the solution method upon which the JET 3 program is based are presented in Ref. 3. The reader is invited to consult Ref. 3 for a very detailed description of this information.

Section 2 of this report is devoted to describing concisely the general organization and capabilities of JET 3, including (1) structural geometry, prescribed displacement conditions, and restraints accommodated, (2) the initial impulse and forcing function provisions, and (3) the solution procedure. Next, in Section 3, the main program and subprograms in JET 3 are described, including a partial list and explanation of the variable names used in the program. The input procedure and output information are presented in Section 4. A complete FORTRAN IV listing of the JET 3 program is given in Section 5. Example problems, including input data and the resulting solution data from JET 3 are given in Section 6. Finally, Appendix A describes the equations on which the computer program is based.

SECTION 2

GENERAL DESCRIPTION OF THE JET 3 PROGRAM

The JET 3 computer program can analyze:

(a) a structural ring, complete or partial, whose geometrical shape can be circular or arbitrarily curved and with variable thickness.

(b) a structural ring, with various support conditions, subjected to arbitrarily distributed elastic restraints.

(c) a structural ring subjected to arbitrary initial velocity distributions.

(d) a structural ring subjected to transient mechanical loads which vary arbitrarily in both space and time.

The distribution of the initial velocity, and the spatial, as well as temporal variations of the transient mechanical load, can be prescribed arbitrarily. However, mainly because of computer storage considerations, only a few examples of such variations have been built into the present version of JET 3. These will be described in the following subsections after a brief description is given of the geometry, prescribed displacement conditions, and elastic restraints that are available in the program. The user should provide the necessary subroutines and modifications to handle other types of forcing functions and/or initial velocity distributions, which are more closely attuned to his needs.

2.1 Geometry, Prescribed Displacement Conditions, and Elastic Restraints

In the present analysis, the transient structural responses of the ring are assumed to consist of planar (two-dimensional) deformations. Also, the Bernoulli-Euler (or Kirchhoff) hypothesis is employed; that is, transverse shear deformation is excluded. In the structural finite-element context, such problems are termed "one dimensional".

The geometrical shapes of the ring that can be treated are divided for convenience into the following four groups (as shown in Fig. 1):

(1) Circular partial ring with uniform thickness

(2) Circular complete ring with uniform thickness

(3) Arbitrarily curved partial ring with variable thickness

(4) Arbitrarily curved complete ring with variable thickness

For each of these four configurations, the cross sections of the ring are assumed to be rectangular in shape.

In the spatial finite-element analysis, the ring is represented by an assemblage of discrete (or finite) elements compatibly joined at the nodal stations. The geometry and nomenclature of a typical simple circular ring element and an arbitrarily curved ring element are shown in Figs. 2a and 2b, respectively. The behavior of each finite-element is characterized by a knowledge of the four generalized displacements: v, w, $\psi = (\partial w/\partial \eta) - (v/R)$, and $\chi = (\partial v/\partial \eta) + (w/R)$ at each of its nodal stations, where v and w are the midplane displacements in the circumferential and normal direction, respectively; R is the radius of curvature, and η is the length coordinate measured along the centroidal axis (meridian) of the ring. The displacement behavior within each finite-element is represented by a cubic polynomial in η for the circumferential displacement v and a cubic polynomial in η for the normal displacement w, anchored to the four generalized nodal displacements at each node (see Appendix A and/or Ref. 3 for further details). For application to arbitrarily curved, variable thickness, ring structures, the finite elements are described by reading in at each nodal station the two coordinates Y and Z, the slope, and the thickness of the discretized structure, where X, Y, Z represent global reference Cartesian coordinates. Within each element, the slope is approximated by a quadratic function in η and the thickness is approximated as being piecewise linear between nodes. For application to a circular, uniform thickness, ring structure, and in view of the computer storage and operation considerations, the structure is modeled by uniform-mesh, uniform-thickness, circular ring elements. The local reference coordinate system of each element is arranged to take advantage of the symmetry of the element geometry. In the present report, separate groups of programs will be used to handle uniform thickness circular ring structures and the more general variable-thickness, arbitrarily-curved ring structure, respectively.

As for the support conditions of the structure, the JET 3 program includes three types of prescribed nodal displacement conditions (see Fig. 3a):

(1) Symmetry $(v = \psi = 0)$

(2) Ideally-Clamped $(v = w = \psi = 0)$

(3) Smoothly-Hinged $(v = w = 0)$

and two types of elastic restraints (see Fig. 3b):

(a) Point elastically restrained (elastic restoring spring) at given locations

(b) Distributed elastically restrained (elastic foundation) over a given number of elements.

A global effective stiffness matrix supplied by the elastic foundation and/or the restoring springs will be evaluated in the program from the virtual-work statement, for the case in which the structure is subjected to one or both of these two types of elastic restraints.

2.2 Initial Velocity Provisions and/or Externally-Applied Forces

2.2.1 Initial Velocity Provisions

The initial velocity distribution is specified by reading in the initial nodal velocities. Three ways are available to describe these distributions (see Fig. 4):

(1) Arbitrary distribution by prescribing nodal initial velocities, $\dot{v}$, $\dot{w}$, and $\dot{\psi}$ at certain nodes of the structure.

(2) One or more local uniform initial normal velocity values, $\dot{w}$, distributed over certain elements of the structure, and/or

(3) One or more local sine-shaped distributions of initial

velocity in the normal direction, distributed over certain elements of the structure.

2.2.2 Transient Externally-Applied Loads

The transient externally-applied loads, $F(\eta,t)$, are assumed to be expressible as

$$F(\eta,t) = g(\eta)\, f(t) \tag{2.1}$$

where $g(\eta)$ is the prescribed spatial distribution function and $f(t)$ denotes the amplitude time history. These quantities are described in the program as follows (see Fig. 5):

(a) The function $f(t)$ can be arbitrary and is represented by a series of coordinates in time which specify values of characteristic two-component (normal and circumferential) forces on the force versus time curves. The program then linearly interpolates between time points to obtain values of forces at intermediate times by:

$$f(t) = f_m + \frac{f_{m+1} - f_m}{T_{m+1} - T_m}\,(t - T_m) \tag{2.1a}$$

where f_m and f_{m+1} are the amplitudes of the forces at some user-specified times T_m and T_{m+1}. The quantity $f(t)$ is found by this interpolation in the time interval (T_m to T_{m+1}) linearly in terms of f_m and f_{m+1}.

(b) The spatial distribution of the forces acting on the ring is described through the following three forms:

(1) One or more concentrated loads prescribed at certain locations

(2) One or more local uniform load distributions specified over given numbers of elements

(3) One or more local half sinusoidal-shaped load distributions specified over given numbers of elements (this distribution is approximated

as being piecewise linear within each element)

Corresponding to this general distribution of externally-applied loads, a set of virtual-work equivalent (or consistent) nodal loads is evaluated in the program.

2.3 Solution Procedure

The spatial finite-element approach is utilized in conjunction with the Principle of Virtual Work and D'Alembert's Principle to obtain the equations of motion of the structural ring which is permitted to undergo large-deflection elastic-plastic transient deformations. In the interest of conciseness and convenience in this report, the user is invited to consult Ref. 3 and/or Appendix A for a detailed derivation and discussion of the equations of motion. For present purposes, it suffices to note that the governing equations of motion for the complete assembled discretized structural ring may be written in the following conventional form:

$$[M^*]\{\ddot{q}^*\} + [K^*]\{q^*\} = \{F^*\} - [K_s^*]\{q^*\} + \{\overset{*}{F}{}_q^{NL}\} + \{\overset{*}{F}{}_p^{L}\} + \{\overset{*}{F}{}_p^{NL}\} \qquad (2.2)$$

where

$\{q^*\}$ and $\{\ddot{q}^*\}$	are the global generalized displacement and acceleration
$[M^*]$	is the mass matrix of the complete structure
$[K^*]$	is the usual stiffness matrix of the complete structure
$[K^*_s]$	represents the effective stiffness matrix supplied by the elastic foundation and/or the restraining spring
$\{F^*\}$	denotes the prescribed externally-applied generalized loading acting on the structure
$\{\overset{*}{F}{}_q^{NL}\}$	represents a "generalized loads" vector arising from large deflections and is a function of quadratic and cubic displacement terms -- a nonlinear force contribution.

$\{F_p^{*L}\}$ is the generalized loads vector arising from the presence of plastic strains, and is associated with the linear terms of the strain-displacement relations.

$\{F_p^{*NL}\}$ is a generalized loads vector of origin similar to $\{F_p^{*L}\}$ but is associated with the nonlinear terms of the strain-displacement relations.

Alternatively, by carrying out the reduction process differently, a much simpler, unconventional form (called "improved formulation" in Ref. 3) of the equations of motion may be obtained and appears as:

$$[M^*]\{\ddot{q}^*\} + \{P^*\} + [H^*]\{q^*\} = \{F^*\} - [K_s^*]\{q^*\} \qquad (2.3)$$

where the quantities $[M^*]$, $\{\ddot{q}^*\}$, $\{q^*\}$, $\{F^*\}$ and $[K^*_s]$ retain the meaning given following Eq. 2.2. However, $\{P^*\}$ represents not only $[K^*]$ $\{q^*\}$ of Eq. 2.2 but also some plastic behavior contributions. The term $[H^*]\{q^*\}$ represents "generalized loads" arising from both large deflections and plastic strains.

The resulting equations of motion, Eq. 2.2 or Eq. 2.3, are solved by applying an appropriate timewise finite-difference operator whereby one obtains a recurrence equation which provides a solution step-by-step in finite-time increments.

A wide variety of timewise finite-difference operators has been developed; a brief discussion of the advantages and disadvantages of some of these operators may be found in Section 3 of Ref. 3. However, based on the present information, it is still not conclusive as to whether any one timewise operator is superior to the others for analyzing nonlinear transient response problems of the present type.

Two options are provided in this report: (1) the explicit 3-point central difference operator is employed to solve the equations of motion expressed in the unconventional form, Eq. 2.3, (2) the implicit Houbolt operator (4-point backward difference) is chosen to solve the equations of motion expressed in the conventional form, Eq. 2.2.

Based on computing experience, the first option is much more simple and requires a minimum of storage and operations within each time step of calculation for advancing the solution ahead in time. However, it should be noted that in order for the 3-point central-difference operator to provide a reliable prediction, the time-step size, Δt, employed must be small enough. The following procedures are built into the computer program utilizing this central-difference operator so that the time-step size, Δt, can be either specified by the user or the program will compute the largest natural frequency, ω_{max} of the system and will then choose a value of $\Delta t = 0.8\ (2/\omega_{max})$ where $\Delta t_{c\ell} \leq 2/\omega_{max}$ is the stability criterion of a corresponding linear dynamic system; the factor 0.8 is introduced in order to take the large deflection effects into account. The ω_{max}, which represents the largest natural frequency contained in the (linear) mathematical model of the structure, is obtained by an iteration process applied to

$$\omega^2 [M^*]\{q^*\} = [K^*]\{q^*\} \tag{2.4}$$

The second option is provided in this report, because of the fact that a "larger Δt" which will provide an acceptably accurate solution is permitted by the Houbolt operator, compared with the stringently small Δt permitted by the 3-point central-difference operator to avoid numerical instability. This may result in the saving of computing time for a given period of actual structural response to be computed. However, it has been demonstrated (Refs. 3 and 4) that the Houbolt operator which is unconditionally stable for linear structural response problems exhibits a degradation of predicted response for large-deflection nonlinear response problems unless a suitably small Δt is used. Thus, the selection of a suitable Δt to insure a reliable solution should be guided by numerical experimentation. Also, the Houbolt method is implicit in nature; that is, the generalized nodal forces (which may be due to large-deflection and elastic-plastic effects) at each time step depend on the displacement (or stress and strain) at that time instant, but this information remains to be determined; thus, extrapolation (or iteration) is needed at each time step of calculation. Linear extrapolation by using the generalized nodal forces at two previous time steps is employed in the present analysis.

In the following, the general solution process is described briefly (see the information flow chart of Figs. 6a and 6b for, respectively, option 1, the central difference operator and option 2, Houbolt's operator).

First, information is provided to define the geometry of the ring including its prescribed displacement conditions and elastic restraints. In addition, the material property constants, as well as the prescribed initial velocity and/or the prescribed applied transient external loading are defined. Also defined is the structural discretization information and numerical integration data. It should be mentioned that Gaussian quadrature is employed in the present analysis to evaluate the element-property matrices -- this requires that the stresses and strains be evaluated at a selected finite number of Gaussian stations over the "spanwise" and depthwise region of each finite element. Next, the mass matrix and the stiffness matrix for the entire structure are evaluated by assembling the element mass and stiffness matrices. Then the proper prescribed displacement conditions are imposed and a reduced mass matrix and stiffness matrix are obtained by deleting the corresponding rows and columns associated with those generalized displacements which are prescribed to be zero. Also constructed are the discrete-element property matrices that do not change with time (and remain constant throughout the program), such as the strain-nodal generalized displacement transformation matrices, the equivalent nodal load vector and actual externally-applied load transformation matrices, etc.

Starting from a set of given initial conditions at time t_o on the generalized nodal displacements, nodal velocities, and externally-applied forces, the generalized nodal displacements and displacement increments are computed for the first time increment Δt. Next, the strain increment developed from t_o to t_1 at every Gaussian station (or point) required over and depthwise through each finite element are calculated. From a knowledge of the prescribed initial stresses (if any) and the strain increments, one can determine the stress increments, the stresses and/or the plastic strains and the plastic strain increments through the use of the pertinent elastic-plastic stress-strain relations including the plastic yield condition and flow rule. Next, one can calculate the equivalent generalized load vectors due to large deflections and plastic strains. Also, the prescribed generalized load vector due to externally-applied loads at the present time step is calculated. Then, the proper recurrence equations, which is the finite-difference representation of the equations of motion, are solved to obtain the nodal generalized displacements and displacement increments of the next time increment. The process then proceeds cyclically for as many time steps as desired. Finally, it should be noted that the Choleski scheme is employed to solve the system of ordinary algebraic equations.

For present purposes, the above general description is considered to be adequate; one may consult Ref. 3 and Appendix A for a more detailed discussion of the solution and evaluation process.

SECTION 3

DESCRIPTION OF PROGRAMS AND SUBPROGRAMS

3.1 Program Contents

In order to provide the necessary capability and versatility and at the same time to keep the program concise, JET 3 is composed of the following four separate groups of programs:

(1) JET 3A: This group of program handles uniform-thickness, circular,complete, and/or partial rings and employs the timewise 3-point central-difference operator.

(2) JET 3B: This group of program handles uniform-thickness, circular, complete, and/or partial rings and employs Houbolt's timewise finite-difference operator.

(3) JET 3C: This group of program handles variable-thickness, arbitrarily-curved, complete, and/or partial rings; the timewise 3-point central-difference operator is employed.

(4) JET 3D: This group of program handles variable-thickness, arbitrarily-curved,complete, and/or partial rings; Houbolt's timewise finite-difference operator is employed.

Each of the four groups of program consists of a main program and several subroutines. Also, depending upon whether the structural configuration to be analyzed is a complete or a partial ring, the main program and some of the subroutines are modified accordingly.

The main program and the name of each subroutine are listed in the following with a brief description of its functions. It should be noted that the subroutine name and its function which are presented in Subsection 3.1 are those which are common to all four groups of programs.

MAIN — Reads the ring geometry, material property data, the structural discretization information, and/or the prescribed displacement conditions and elastic restraints. It computes the quantities that are constant throughout the program and initializes most of the variables used in the subroutines. It controls the logical flow of information supplied by the various subroutines and the overall time cycle.

ASSEM — This subroutine updates the structural mass (and/or stiffness) matrix as the element mass (and/or stiffness) matrices are generated. The components of the assembled structural mass matrix [M*], which is a symmetric matrix, are stored in a linear-array form; only the lower triangular part of [M*] need be and is stored (row-wise) starting with the first nonzero element in the row and ending with the diagonal term. Similar handling of the assembled stiffness matrices ([K*] and $[K_s^*]$) of the structure is employed.

ASSEF — This subroutine assembles the generalized nodal load vectors (due to externally-applied forces and/or large-deflection elastic-plastic effects) of each individual element into a generalized nodal load vector for the structure as a whole.

IDENT — The IDENT subroutine is used to print out at the beginning of the run, the values of certain input parameters, and is used to identify the type of run that is being made.

IMPULS — The information for the initial generalized nodal velocities is read in. This subroutine also sets the initial generalized nodal displacements, the initial stresses, and/or the initial plastic strains to be equal to zero.

PRINT — The PRINT subroutine evaluates the strains on the inner and the outer surfaces at the midspan point of each element, and computes the relevant energies. An inspection process to find the maximum strain and to test for "material failure" is done in this subroutine. PRINT also controls the program output and format.

ELMPP — This subroutine evaluates the element mass matrix [m], and/or element stiffness matrix [k], for each discrete element, and then performs discrete element assembly to form [M*] and/or [K*] for the complete structure with respect to global coordinates. Next, the appropriate prescribed displacement conditions (if any) are imposed on [M*] and/or [K*] to form restrained matrices. Also evaluated are the transformation matrices between the strain at each spanwise checking (Gaussian) station and the generalized nodal displacements of the element.

ERC — Imposes the proper prescribed displacement conditions to the [M*] and/or [K*] matrices by restraining the corresponding rows and columns of the matrices.

FAC — FAC factors a symmetric matrix, [B] into a lower triangular matrix [L] and an upper triangular matrix [L] according to the Choleski scheme; $[B] = [L][L]^T$.

FICØL — Finds the corresponding location of an element in the linear-array expression to a location in a two-dimensional array expression of the [M*] and/or [K*] matrices.

LØADEQ — Computes the transformation matrices between the element generalized (virtual-work equivalent) nodal load vectors and the externally-applied mechanical load which may be concentrated, uniformly distributed, and/or linearly distributed within the element.

LØADFT — This subroutine reads the data pertaining to the subsequent time-dependent externally-applied loads and uses these data to compute the element generalized load vectors and, subsequently, an assembled generalized load vector for the whole structure is formed at each time step of calculation.

MINV — Performs the matrix inversion; a standard Gaussian-Jordan inversion method is used.

ØMULT — Computes various linear arrays (in which a two-dimensional matrix is stored) and vector products. A vector results.

QREM — Evaluates the effective stiffness matrix $[K_s^*]$, supplied by the elastic foundations and/or the restoring springs, and then imposes the prescribed displacement conditions on $[K_s^*]$ accordingly.

SØLV — Performs two back substitutions involving the factorized form of a matrix by the Choleski method to obtain the solution of a matrix equation.

STRESS — This subroutine evaluates the generalized load vectors, $(\{P^*\} + [H^*]\{q\}$ of Eq. 2.3, and/or $\{F_q^{*NL}\} + \{F_p^{*L}\} + \{F_p^{*NL}\}$ of Eq. 2.2) arising from the presence of large-deflections and elastic plastic strains. First, the stresses and/or plastic strains are determined at each quadrature station, which involves the use of the strain-displacement relation and the stress-strain relation. The strain-hardening and strain-sensitivity effects are taken into consideration. Next, the appropriate Gaussian integration scheme is used to form the element generalized nodal load for each discrete element, and finally, an assembled generalized nodal load vector is calculated.

TSTEP — This subroutine is contained only in the JET 3A and the JET 3C computer programs wherein the timewise 3-point central-difference operator is employed. It is called when the time-step size, Δt, is not specified by the user. It finds the highest natural frequency, ω_{max}, in the mathematical model of a corresponding linear dynamic system $[M^*]\{\ddot{q}\} + [K^*]\{q^*\} = 0$ by using an iteration process, and then a value of $\Delta t = 0.8(2/\omega_{max})$ is chosen for use in the program.

3.2 Partial List of Variable Names

3.2.1 Variables Having the Same Definition in JET 3A, JET 3B, JET 3C, and JET 3D

A(I,J)	[A], an 8x8 matrix, of Eq. A.10 or Eq. A.41 defines the transformation between the element generalized nodal displacements {q} and the parameters {β} in the assumed displacement field of each element. It is destroyed in computation and is replaced by its inverse $[A^{-1}]$.
AMASS(I)	The lower triangular part of the symmetric structural mass matrix [M*] (stored in a linear-array form of size ISIZE). Later on, it is destroyed in calculation and is replaced by a lower triangular matrix of a factorized matrix according to the Choleski method.
AMP1FV AMP1FW	Initial nominal amplitudes (at time TBEGIN) of the externally-applied forces in the circumferential and the normal direction, respectively.
AMP2FV AMP2FW	Nominal force amplitudes, in the circumferential and the normal direction, respectively, of each succeeding point on the force versus time curve to be prescribed.
AMPFV AMPFW	The linearly-interpolated values of the nominal force amplitudes in the circumferential and the normal direction, respectively, at the current time instant.
ANGV	Initial angular velocity, $\dot{\psi} = (\partial\dot{w}/\partial\eta - \dot{v}/R)$, at time zero.
ANGV1 ANGV2	Initial angular velocities at the two edge nodes of the local uniform initial normal velocity distributed over certain elements of the structure.
APD	Work done on the structure by externally-applied forces during the current time step.
APDEN	Total work done on the structure by externally-applied forces up to the present time step.
B	Width of the ring

BE1(J,I,K)	The transformation matrix which relates the strain at Jth spanwise Gaussian station to the parameter {β} in the assumed displacement field of each element. Equals $[B_I][U]$, I = 1, 2, 3 (see Eq. A.14a or Eq. A.42c).
BEPS(I)	$[D_I]\{\Delta q\}$, I = 1, 2, 3 (see Eq. A.15a).
BEPX	Strain increment during the current time step at the selected Gaussian station (over spanwise and depthwise region of each element).
BIG	The largest computed strain up to the present cycle. It should be noted that strains are computed only at every printout cycle.
BINP(I,J) } BIMP(I,J) }	The longitudinal force and the bending moment, respectively, over the cross section at the Jth spanwise Gaussian station of the Ith element (see Eq. A.33).
BINPP(J) } BIMPP(J) }	The integration of the plastic strain over the cross section at the Jth spanwise Gaussian station of each element (see Eq. A.36).
BMASS(I)	The lower triangular part of the symmetric structural mass matrix, [M*], (stored in a linear-array form of size ISIZE).
BØNE	The highest natural frequency of a corresponding linear dynamic system.
BTIME	The time at which the largest computed strain occurs.
C5	Equals 1./P if the material is strain rate dependent (Eq. A.37).
C6	Equals 1./(DSxDELTAT); see Eq. A.37.
CEPS(J,I)	Equals $[D_I]\{q\}$, I = 1, 2, 3 (see Eq. A.15) at the Jth spanwise Gaussian station of each element.
CINE(I)	A work vector used in the calculation of kinetic energy of the structure.
CINET	Kinetic energy of the structure at the current time instant.
CINETØ	Initial kinetic energy imparted to the structure.
CINETT	Total work done by all external agencies (externally-applied forces and initial imparted kinetic energy) up to the current time step.

CØPY(J) } CØPZ(I)	Current Y coordinate and Z coordinate, respectively, of the Ith node.
CRITS	Critical value of tensile strain at which the material will "fail" (or fracture will appear).
DDELD(I)	Vector of dimension NI, contains the initial generalized nodal acceleration $\{\ddot{q}^*\}_o$ as defined by Eq. A.65.
DELD(I)	Vector contains the generalized nodal displacement increment during the current time step.
DELTAT	Time-step size used in the program, Δt.
DENS	Densityof the material ($lb\text{-}sec^2/in^4$).
DESNP	Plastic strain increment during the current time step at each mechanical sublayer at any selected Gaussian station (over the spanwise and the depthwise region of each element).
DET	Resultant determinant of matrix [A]
DIS(I)	Vector contains the generalized nodal displacement at the next time instant ($\{q^*\}_{m+1}$ as defined in Eq.A.53a or Eq. A.57)
DISM1(I) } DISM2(I)	Vectors contain the generalized nodal displacements at one previous time instant and at the two previous time instants, respectively (defined by $\{q^*\}_{m-1}$ and $\{q^*\}_{m-2}$, respectively, of Eq. A.57).
DISP(I)	Vector contains the generalized nodal displacement at the current time instant.
DS	Material constant used in the strain-rate sensitivity formula (see Eq. A.37).
ELAST	Total elastic energy present in the structure at the present time instant.
ELF(I)	Element generalized nodal load vector due to externally-applied forces (see Eq. A.20 or Eq. A.45).
ELFP(I)	Element generalized nodal load vector due to large deflections and elastic-plastic strains; it equals $\{p\} + [h]\{q\}$ for JET 3A and JET 3C, and equals $-(\{f_q^{NL}\} + \{f_p^L\} + \{f_p^{NL}\})$ for JET 3B and JET 3D.
ELK(I,J)	Element stiffness matrix of dimension 8x8 (Eq. A.26a or Eq. A.47d).
ELMAS(I,J)	Element mass matrix of dimension 8x8 (Eq. A.18c or Eq. A.44).

ELRP(I,J) — Element effective stiffness matrix of dimension 8x8 supplied by elastic restraints (Eq. A.29a or Eq. A.48).

EPS(L) — Input quantities of abscissa of the uniaxial stress-strain curve for the Lth mechanical sublayer material model.

EPSI(I), EPSØ(I) — Axial strain on the inner surface and on the outer surface, respectively, at the midspan point of element I.

EPSLN — Convergence criteria for the determination of the highest natural frequency of a corresponding linear dynamic system by employing an iteration process (used in subroutine TSTEP)

ES(I) — The slope of the Ith segment in the piecewise linear approximation of the material uniaxial stress-strain curve.

FAILI(I), FAILØ(I) — Print out an "*" at the printout cycle during which the axial strains first exceed the critical value on the inner surface, and/or outer surface, respectively.

FARE, FCUR — Midplane axial strain and curvature increment, respectively, at the selected spanwise Gaussian station of each element.

FLN(I) — Vector contains the generalized nodal load due to large deflections and plastic strain at one previous time instant.

FLR(I) — Vector contains the generalized nodal load equivalent to the externally-applied forces.

FLVA(I) — Assembled generalized load vector due to large deflections and elastic-plastic strains. It equals $\{P^*\} + [H^*]\{q^*\}$ in JET 3A and JET 3C, and equals $-(\{F_q^{*NL}\} + \{F_p^{*L}\} + \{F_p^{*NL}\})$ in JET 3B and JET 3D.

FMECH(I) — Assembled generalized load vector due to externally-applied forces.

FMV, FMW — Linear interpolated values of the nominal amplitude of the externally-applied forces in the circumferential and the normal direction, respectively.

FQREF(I) — Assembled generalized load vector supplied by elastic restraints equals $[K_s^*]\{q^*\}$ of Eq. 2.2 or Eq. 2.3.

FREQ — The highest natural frequency of a corresponding linear dynamic system.

HNL(I) — Work vector of dimension 8, required for the evaluation of element generalized nodal load vector due to large deflections and elastic-plastic strains.

IBIG	The element number whose midspan computed strain exhibits the largest value during the present computer run.
ICØL(I)	Vector, of length NI, contains the column number of the first nonzero entry in the Ith row of the structural mass and/or stiffness matrix.
IDET	Work parameter used in subroutine FAC
IE1, IE2	The first element and the number of elements, respectively, over which the local uniform initial normal velocity is to be prescribed.
IK	Number of discrete elements into which the whole structure is discretized for analysis.
INUM(I)	Vector of dimension NI contains the corresponding position in the linear-array of the first nonzero entry in the Ith row of the structural mass or stiffness matrix.
IØTA	Number of local uniform initial normal velocity distributions.
IØTB	Number of nodes at which the initial generalized nodal velocity components are to be prescribed.
IØTC	Number of local sine-shaped initial normal velocity distributions.
IS1, IS2	The first element and the number of elements, respectively, over which the local sine-shaped initial normal velocity is to be specified.
ISIZE	Number of locations required for the storage of the structural mass or stiffness matrix in linear-array form.
ISURF	Equals 1 means largest computed strain occurs on the inner surface; equals 2 means on the outer surface.
IT	Current time-step (cycle) number
ITT	Work parameter equals IT + 1.
JELEM(I)	The element number at which the Ith concentrated load is to be specified.
KRØW(I)	The row number of the Ith irregular row in the structural mass or stiffness matrix.
LMI(I)	Work vector of length 8 used by subroutine MINV.
MM	Time step (cycle) at which run is to stop.
M1	Cycle at which regular printing starts
M2	Printout will occur every M2 cycles.

MCRIT	A dummy variable which controls the print of "*" at the printout cycle when the strain(s) first exceeds the critical value.
MMI(I)	Work vector of length 8 used by subroutine MINV.
MREAD, MWRITE, MPUNCH	Number for the data input tape unit, printed output tape unit, and the punched output tape unit, respectively. These names must be assigned numbers in MAIN corresponding to the user's computing facility requirements.
NBC(I)	The prescribed-displacement condition identification number.
NBCØND	The number of nodes at which the prescribed displacement conditions are to be specified.
NDEX(I)	The corresponding position in the linear-array of the first nonzero entry in the Ith irregular row.
NELF2(I)	The number of elements over which the Ith local uniformly distributed externally-applied load is to be specified.
NELF3(I)	The number of elements over which the Ith local sine-shaped distributed externally-applied load is to be specified.
NFL	The number of depthwise Gaussian points through the thickness for the numerical evaluation of stress resultants (axial forces and bending moment) at each spanwise Gaussian station.
NI	Total number of degrees of freedom (unrestrained); it equals the number of nodes times 4. Also, it is the number of rows in the assembled structural mass or stiffness matrix.
NIRREG	Number of irregular rows in the assembled structural mass or stiffness matrix.
NLØAD	Equal 1 means external forces are acting during the current time step; equal to 2 means not acting.
NØDEB(I)	The node number at which the prescribed displacement condition NBC(I) is to be specified.
NØDEV	The node number at which the initial generalized nodal velocity components are to be specified.
NØFT1, NØFT2, NØFT3	The number of concentrated loads, the number of local uniform load distributions, and the number of local sine-shaped load distributions, respectively, which are to be prescribed over the structure.

NØGA	The number of Gaussian stations to be employed for the spanwise numerical integration of the element properties over each element.
NØRP, NØRU	The number of point elastic restraints (elastic restoring springs) and the number of locally distributed elastic restraints, respectively, which are to be specified over the structure.
NQR	Indicator, which if > 0 indicates that this structure is subjected to elastic restraints (point and/or distributed).
NREADF	Dummy variable which controls the reading-in of force-time data.
NREL(I)	The element number at which the Ith point elastic restraint is to be specified.
NRST(I), NREU(I)	The first element and the number of elements, respectively, over which the Ith distributed elastic restraint is to be specified.
NSFL	Equals the number of mechanical sublayers in the strain-hardening material model; also is the number of coordinate pairs defining the piecewise linear stress-strain curve of the material.
NSTF2(I)	The first element number at which the Ith local uniform load distribution is to be specified.
NSTF3(I)	The first element number at which the Ith local sine-shaped load distribution is to be specified.
NV	Indicator, which if > 0 indicates that initial velocity distributions are to be specified over the structure.
P	Constant used in the strain-rate sensitivity formula (see Eq. A.37).
PIE	Represents π = 3.14159265.
PLAST	Total plastic work done on the structure up to the current time step (mechanical work dissipated during plastic flow).
PM(I), PN(I)	Work vectors of dimension 8, required for the evaluation of element generalized nodal load vector due to large deflections and elastic-plastic strains.

RTØV(I)
RTØW(I) — The normalized values of the Ith concentrated load with respect to the nominal amplitudes in the circumferential and the normal direction, respectively.

RTØ2V(I)
RTØ2W(I) — The normalized values of the Ith local uniform load distribution with respect to the nominal amplitudes in the circumferential and the normal direction, respectively.

RTØ3V(I)
RTØ3W(I) — The normalized values of the Ith sine-shaped load distribution with respect to the nominal amplitudes in the circumferential and the normal direction, respectively.

SCTP
SCRP — The translational and torsional restoring spring elastic constants, respectively.

SCTU
SCRU — Elastic foundation modulus in translation and torsion, respectively.

SIG(L) — Input quantities for the ordinate of the uniaxial static stress-strain curve for the Lth mechanical sublayer material model.

SLØPEV
SLØPEW — Slopes of the piecewise linear segment approximation of nominal force versus time curve in the circumferential and the normal direction, respectively, at the current time instant.

SNØ(I) — Uniaxial static yield stress of the Ith mechanical sublayer material model.

SNP(I,J,K,L) — The total plastic strain of the Lth mechanical sublayer at the Kth depthwise Gaussian point at the Jth spanwise Gaussian station of the Ith element.

SNS(I,J,K,L) — Axial stress on the Lth mechanical sublayer at the Kth depthwise Gaussian point at the Jth spanwise Gaussian station of the Ith element.

SNY — Uniaxial yield stress of the mechanical sublayer, taking strain-rate sensitivity into account.

SØL(I) — Contains the solution vector of a system of matrix equations.

SPDEN — Total energy stored in the elastically-restoring springs and/or the elastic foundations at the current time instant.

SPRIN(I)	The assembled effective stiffness matrix supplied by elastic restraints (stored in a linear array form).
STIFK(I)	Assembled structural stiffness matrix, stored in a linear-array form.
T1, T2	Times at which a linear segment of the force versus time curve starts acting and stops acting, respectively.
TBEGIN, TFINAL	Times when overall externally-applied forcing function starts acting and stops acting, respectively.
TIME	Current time (IT×DELTAT)
TRIAL(I)	Mode shape corresponding to the highest natural frequency of the finite-element representation of a linear dynamic system.
TWG(I), TXG(I)	Input vectors with dimension NFL; contain Gaussian quadrature constants x_i and weights, w_i, of $\int_{-1}^{+1} f(x)\,dx = \sum_i f(x_i)\,W_i$ used in the numerical integration of stresses and/or plastic strains through the thickness.
VRAD	The value of the initial tangential velocity to be specified at the node of the element.
WRAD	The value of initial normal velocity to be specified for the local uniform initial normal velocity; also is the peak value of the sine-shaped initial normal velocity distribution.
WRAD1, WRAD2	The values of the initial normal velocity at the two edge nodes of the local uniform initial normal velocity distributed over certain elements of the structure.
YØUNG	Elastic (Young's) modulus (the slope of the 1st segment in the piecewise linear approximation of the uniaxial stress-strain curve).
Y(I), Z(I)	Initial Y coordinate and Z coordinate, respectively, of the Ith node.

3.2.2 Variables Appearing Only in JET 3A and JET 3B

AL — Element arc length (uniform circular ring element).

ASFL(K,L) — Stress and/or plastic strain weighting factor on the Lth mechanical sublayer at the Kth depthwise Gaussian point (equals $\frac{TWG(K)}{2} \times B \times H \times \frac{ES(L) - ES(L+1)}{ES(1)}$).

AX — Subtended angle of the uniform circular ring element.

AXG(I), AWG(I) — Input vectors with dimension NOGA; contain Gaussian quadrature constants, x_i, and weights, W_i of

$$\int_{-1}^{+1} f(x)\,dx = \sum_i f(x_i)\,W_i$$

employed in the spanwise numerical integration over each element.

BEP(J,I,K) — Transformation matrix which relates the strain at the Jth spanwise Gaussian station to the element generalized nodal displacements ($[D_I]$, I = 1, 2, 3, see Eq. A. 42b).

BL — Total arc length of the circular ring.

BX — Total subtended angle of the circular ring (radians).

D(I,J) — A work matrix of dimension 8x8 for the evaluation of element matrix (equals $[m']$ of Eq. A.44).

E(I,J) — A work matrix (equals $[k']$ of Eq. A.47d).

ELR(I,J) — A work matrix of dimension 8x8 for the evaluation of the element effective stiffness matrix supplied by elastic restraints (equals

$$\int_{-\frac{A}{2}}^{\frac{A}{2}} [N]^T [C] [N]\, d\eta$$

of Eq. A.48).

ETA(I) — is the length coordinate along the centroidal axis from the mid point of element JELEM(I) at which the Ith concentrated load is to be specified.

EXANG — Total subtended angle of the circular ring (degrees).

FM1(I,M,N) — A transformation matrix which relates the element generalized load vector and the Ith externally-applied concentrated load (equals $[A^{-1}]^T [f'_c]$ of Eq. A. 45a).

FM2(M,N) — A transformation matrix which relates the element generalized load vector and the uniformly distributed externally-applied load over the element (equals $[A^{-1}]^T[f'_u]$ of Eq. A.45c).

FM3(M,N) — A transformation matrix which relates the element generalized load vector and the linearly distributed externally-applied load over the element (equals $[A^{-1}]^T[f'_{\ell 1}]$ of Eq. A.45e).

FM(M,N), FMC(M,N), FML(M,N) — Matrices of dimension 8x2 defined by $[f'_c]$ of Eq. A.45b, $[f'_u] = [f'_{\ell o}]$ of Eq. A.45d, and $[f'_{\ell 1}]$ of Eq. A.45g, respectively.

GFL(J) — Stress and/or plastic strain weighting factor of the Jth depthwise Gaussian point at each spanwise Gaussian station (equals $\frac{TWG(J)}{2} \times B \times H$).

GZETA(J) — Distance from the centroidal axis of the Jth depthwise Gaussian point at each spanwise Gaussian station (equals $\frac{TXG(J)}{2} \times H$).

H — Thickness of the ring

HHALF — Half the thickness of the ring.

R — Mean radius of the circular ring.

REX(I) — The length coordinate along the centroidal axis from the midpoint of the element NREL(I) at which the Ith point elastic restraint is to be specified.

THETA — The angle between the +Z axis and the radial vector with origin at 0 to the first node of the discrete element representation of the structure.

3.2.3 Variables Appearing Only in JET 3C and JET 3D

AA(I,M,N) — Equals $[A^{-1}]$ of Eq. A.10a; it defines the transformation between the element generalized nodal displacement $\{q\}$ and the parameters $\{\beta\}$ in the assumed displacement field of the Ith element.

AL(I) — Element arc length of the Ith element.

ANG(I) — The slope, which is the angle between the tangent vector and the +Y axis, at the Ith node.

APHA	The angle, α, as defined by Eq. A.6c.
ASFL(I,J,K,L)	Stress and/or plastic strain wieghting factor on the Lth sublayer in the Kth depthwise Gaussian point at the Jth spanwise Gaussian station of the Ith element.
AXG(I), AWG(I)	Input vectors with dimension NOGA; contain Gaussian quadrature constants, x_i, and wieghts, W_i of $\int_0^1 f(x)\,dx = \sum_i f(x_i) W_i$ employed in the spanwise integration over each element.
BEP(IR,J,I,K)	Transformation matrix which relates the strain at the Jth spanwise Gaussian station to the generalized nodal displacements of the IRth element ($[D_I]$, I = 1, 2, 3, see Eq. A.14).
BZER, B1, B2	Coefficients in the quadratic representation of the meridional slope ϕ. Corresponds to b_o, b_1, and b_2, respectively in Eq. A.5.
D(I,J)	A work matrix of dimension 8x8 for the evaluation of the element mass matrix (equals $\int_0^{\eta_i} [N]^T [B] [N]\, d\eta$ of Eq. A.18a)
E(I,J)	A work matrix of dimension 8x8 for the evaluation of the element stiffness matrix (equals $\int_0^{\eta_i} (\{B_1\} Ebh \lfloor B_1 \rfloor + \{B_3\} \frac{Ebh^3}{12} \lfloor B_3 \rfloor) d\eta$ of Eq. A.26a)
ELR(I,J)	A work matrix of dimension 8x8 for the evaluation of the element effective stiffness matrix supplied by elastic restraints (equals $\int_0^{\eta_i} [N]^T [C] [N]\, d\eta$ of Eq. A.29a)
ETA(I)	Equals the length coordinate along the centroidal axis from the node JELEM(I) at which the Ith concentrated load is to be specified on element JELEM(I).
FM1(I,M,N)	A transformation matrix which relates the element generalized load vector and the Ith externally-applied concentrated load (equals $[A^{-1}]^T [f_c']$ of Eq. A.20b).

FM2(I,J,M,N)	A transformation matrix which relates the element generalized load vector and the Jth local uniform distributed externally-applied load over the element [NSTF2(I)+J-1] (equals $[A^{-1}]^T[f'_u]$ of Eq. A.20e).
FM3A(I,J,M,N), FM3B(I,J,M,N)	Transformation matrices which relate the element generalized load vector and the Ith local linear distributed externally-applied load over the element [NSTF3(I) + J - 1] (equals $[A^{-1}]^T[f'_{\ell o}]$ and $[A^{-1}]^T[f'_{\ell 1}]$, respectively, of Eq. A.20g).
FM(M,N)	A work matrix, of dimension 8x2, defined by $[f'_c]$ of Eq. A.20c or $[f'_u]$ of Eq. A.20f.
FMA(M,N), FMB(M,N)	Work matrices, of dimension 8x2, defined by $[f'_{\ell o}]$ and $[f'_{\ell 1}]$, respectively, of Eq. A.20g.
GFL(IR,I,J)	Stress and/or plastic strain weighting factor on the Jth depthwise Gaussian point at the Ith spanwise Gaussian station of the IRth element.
GZETA(IR,I,J)	Distance from the centroidal axis of the Jth depthwise Gaussian point at the Ith spanwise Gaussian station in the IRth element.
H(I)	The thickness of the ring at the Ith node.
HHALF(I)	Half the thickness of the ring at the midpoint of element I.
PHI	ϕ of Eq. A.1 at a given spanwise quadrature station.
PHIP	ϕ' of Eq. A.1 at a given spanwise quadrature station.
REX(I)	The length coordinate along the centroidal axis from the node NREL(I) at which the Ith point elastic restraint is to be specified.
RH	Thickness at a given spanwise quadrature station.
YZET, ZZET	The Y coordinate and Z coordinate, respectively, at a given spanwise quadrature station.

SECTION 4

USE OF THE JET 3 PROGRAM

4.1 Input Information and Procedure

The information required to punch a set of data cards for a run of the program is presented in a step-by-step manner in this section. The variables to be punched on the nth data card are outlined, and in a box to the right is the format to be used for that card; the definition of and some restrictions for each variable are given directly below. This is done for each card, in turn, until all are described. The data cards necessary for analyzing (a) uniform thickness circular rings by using JET 3A or JET 3B; and (b) variable thickness arbitrarily curved rings by using JET 3C or JET 3D are described separately in the following.

4.1.1 Input to JET 3A and/or JET 3B for Analyzing Uniform Thickness Circular Rings

Cards 1 through 10 are used to describe the ring geometry, material properties, the finite-element model makeup, and the prescribed displacement conditions and/or elastic restraints.

Card 1	Format
R, B, H, DENS, EXANG	5E15.6

where

R	The ring mean radius; distance from center to the centroidal axis (inches).
B	The width of the ring (inches).
H	The thickness of the ring (inches).
DENS	The mass density of the ring material, lb-sec^2/in^4.
EXANG	The total subtended angle of the circular ring (degrees). For a complete circular ring, EXANG = 360°.

Card 2

IK, NØGA, NFL, NSFL, MM, M1, M2

7I5

where

IK — The number of uniform size discrete elements used to model the whole structure. This number cannot exceed 50.[+]

NØGA — The number of spanwise Gaussian stations to be used for the spanwise numerical integration over each element in evaluating the element properties $\{p\}$, $[h]$, and/or $\{f_q^{NL}\}$, $\{f_p^L\}$, and $\{f_p^{NL}\}$. NØGA = 3 is used in JET 3.

NFL — The number of depthwise Gaussian points to be used for the numerical integration through the thickness of stress resultants at each spanwise Gaussian station. NFL = 4 is used in JET 3.

NSFL — The number of mechanical sublayers in the strain-hardening material model. Equals the number of co-ordinate pairs defining the polygonal approximation of the stress-strain curve of the material. This number must not be more than 5.

MM — Corresponds to the computation cycle number at which the run is to stop.

M1 — The cycle number at which regular printout is to begin.

M2 — The number of cycles between regular printout (i.e., print every M2 cycles).

[+]This limitation and others which follow, apply to the program as listed in Section 5. These limitations may be circumvented by altering the dimensions of the variables in the program.

Card 3

DELTAT, THETA, CRITS, DS, P

5E15.6

where

DELTAT — The time step size, Δt (seconds) to be employed for the timewise finite-difference operator. In the use of JET 3B wherein Houbolt's operator is employed, the value of Δt must be specified by the user. On the other hand, in the use of JET 3A wherein the central-difference operator is employed, the program will compute the largest natural frequency, ω_{max}, of a corresponding linear system, and will then choose a value of $\Delta t = 0.8(2/\omega_{max})$, if the value of Δt is set equal to zero on this card.

THETA — The angle (degrees) between the +Z axis and the radial vector with origin at 0 to the first node of the discrete element representation of the structure.

CRITS — Critical value of tensile strain at which the material will "fail" (or fracture will appear).

DS, P — The value of the constants D and p, respectively, used in the strain-rate sensitivity formula

$$\sigma_{y\ell} = \sigma_{o\ell} \left(1 + \left| \frac{\dot{\varepsilon}}{D} \right|^{1/p}\right)$$

where D = (1/sec), $\sigma_{o\ell}$ is the static yield stress of the ℓth mechanical sublayer, and $\sigma_{y\ell}$ is the corresponding rate-dependent yield stress. If the material does not exhibit strain-rate sensitivity, set DS = 0, and let P blank.

Card 4

EPS(1), SIG(1), EPS(2), SIG(2)

4E15.6

where

EPS(1), SIG(1) — Make up the first coordinate pair of strain, ε, and stress, σ, coordinates which are used to define the piecewise linear approximation of the uniaxial static stress-strain curve. The stress-strain curve for which these values and those following are obtained must be upwardly-convex with nonnegative slopes (ε(L) = in/in, σ(L) = lb/in^2).

EPS(2), SIG(2) — Make up the second coordinate pair of strain and stress coordinates.

Additional Cards 4a and 4b are punched in exactly the same manner as Card 4 until the number of coordinate pairs equals the value NSFL punched on Card 2. The total number of coordinate pairs must not exceed 5.

Card 5

AXG(1), AXG(2), AXG(3)	4F15.10

where

AXG(I) Vector, of dimension NØGA, contains Gaussian quadrature constants, x_i for the numerical integration of

$$\int_{-1}^{+1} f(x)\,dx = \sum_i f(x_i) W_i$$

If NØGA = 3, for example, then the following data appear on this card:

-0.7745966692 0.0 +0.7745966692

Card 6

AWG(1), AWG(2), AWG(3)	4F15.10

where

AWG(I) Vector, of dimension NØGA, contains Gaussian quadrature weights, W_i, for the numerical integration of

$$\int_{-1}^{+1} f(x)\,dx = \sum_i f(x_i) W_i$$

If NØGA = 3, the following data appear:

0.5555555555 0.8888888888 0.5555555555

Card 7

TXG(1), TXG(2), TXG(3), TXG(4)

4F15.10

Card 8

TWG(1), TWG(2), TWG(3), TWG(4)

4F15.10

where

TXG(I), TWG(I) — Vectors, of dimension NFL, contain Gaussian quadrature constants, x_i, and weights, W_i, respectively, for the numerical integration of

$$\int_{-1}^{+1} f(x)\,dx = \sum_i f(x_i) W_i$$

If NFL = 4, for example, then the following data appear on Card 7:

-0.8611363115 -0.3399810435 0.3399810435 0.8611363115

and the data

0.3478548451 0.6521451548 0.6521451548 0.3478548451

appear on Card 8.

Card 9

NBCØND, NBC(1), NØDEB(1), NBC(2) NØDEB(2) ... NBC(4), NØDEB(4)

9I5

where

NBCØND — The number of prescribed displacement conditions to be specified on the structure. This number must not exceed 4.

NBC(1), NØDEB(1) — The identification number and the node number, respectively, for which the first prescribed displacement condition is to be imposed.

NBC(2)
NØDEB(2) } The second data group of the identification number and node number, respectively, for which the second prescribed displacement condition is to be imposed.

The appropriate form of the data group NBC(I) and NØDEB(I) should be repeated NBCØND times. If NBCØND=0, that means there is no prescribed displacement condition to be imposed on the structure; then, let NBC(I) and NØDEB(I) blank.

The prescribed displacement condition identification number can be equal to 1, 2, or 3, depending upon the type of the prescribed displacement condition. Its description follows:

NBC(I)=1 Symmetry displacement condition. Setting the degrees of freedom v and ψ at the node NODEB(I) to zero.

NBC(I)=2 Ideally-clamped condition. Setting v, w, and ψ at node NODEB(I) to zero.

NBC(I)=3 Smoothly-hinged condition. Setting v and w at node NODEB(I) to zero.

Card 10

NQR, NØRP, NØRU	3I5

where

NQR Indicator, which if > 0 indicates that the structure is subjected to elastic restraints (point and/or distributed).

NØRP The number of point elastic restraints (elastic restoring springs) which are to be prescribed over the structure. This number must not exceed 4.

NØRU The number of local distributed elastic restraints (elastic foundations) which are to be prescribed over the structure. This number must not exceed 4.

If there is no prescribed elastic restraints on the structure, set

NQR=0 and let NØRP and NØRU blank.

If Card 10a and Card 10b are included only if NQR >0 in Card 10. If NØRP=0, skip to Card 10b.

Card 10a

SCTP, SCRP	2E15.6

Card 10aa

NREL(1), REX(1), NREL(2), REX(2), ... NREL(4), REX(4)	4(I5,E15.6)

where

SCTP — The translational restoring spring elastic constant (lb/in).

SCRP — The torsional restoring spring elastic constant (in-lb/radian).

NREL(1), REX(1) — The element number and the length coordinate along the centroidal axis from the midspan point of this element, respectively, at which the first point elastic restraint is to be specified.

NREL(2), REX(2) — The element number and the length coordinate for the second point elastic restraint.

The data group NREL(I), REX(I) should be repeated NØRP times.

If NØRU=0 in Card 10, omit Card 10b, and Card 11 follows directly.

Card 10b

SCTU, SCRU, NRST(1), NREU(1), ... , NRST(4), NREU(4)	2E15.6,8I5

where

SCTU — Elastic foundation modulus in translation (lb/in^2).

SCRU — Elastic foundation modulus in torsion (in-lb)/(rad-in).

NRST(1), NREU(1) — The first element and the number of elements, respectively, over which the first elastic foundation is to be specified (the first elastic foundation is distributed to element NRST(1), through and including element (NRST(1)+NREU(1)-1).

NRST(2), NREU(2) — The first element and the number of elements over which the second elastic foundation is to be specified.

Data group NRST(I) and NREU(I) are repeated NORU times.

Cards 11 through 14 are used to describe the initial velocity distributions.

Card 11

NV, IØTA, IØTB, IØTC	4I5

where

NV	Indicator, which if >0 indicates that the initial velocities are to be prescribed over the structure.
IØTA	Number of local uniform initial normal velocity distributions.
IØTB	Number of nodes at which the initial generalized nodal velocity components are to be specified.
IØTC	Number of local sine-shaped initial normal velocity distributions.

If there is no initial velocity distributions, set NV=0 and let IØTA, IØTB, IØTC blank, then skip to Card 15.

If IØTA>0, the following No. 12 Card(s) must be included directly; otherwise, skip to Card 13.

Card 12a

IE1, IE2	2I5

Card 12aa

WRAD, WRAD1, ANGV1, WRAD2, ANGV2	5E15.6

where

IE1, IE2 — The first element and the number of elements, respectively, over which the first local uniform initial normal velocity is to be prescribed. The number IE2 must be greater than one.

WRAD — The value of the initial normal velocity $\dot{w}_o$ (in/sec) for the first local uniform initial velocity distribution.

WRAD1, ANGV1 — The initial radial velocity $\dot{w}_o$ (in/sec) and initial angular velocity $\dot{\psi}_o$ (rad/sec), respectively, which are to be prescribed on node IE1.

WRAD2, ANGV2 — The initial radial velocity and angular velocity which are to be specified on node IE1+IE2.

Additional Cards 12b, 12bb and 12c, 12cc ... are punched in the same format, until the total number of cards equals IØTA given in Card 11.

It perhaps should be mentioned that the values of WRAD1, ANGV1 and WRAD2, ANGV2 are included here in order to smooth the discontinuous function of the local uniform initial normal velocity distribution at two edge nodes by a continuous function (because in the finite-element model the compatibility of v, w, ψ, and χ at boundary nodes of each element with neighboring elements is required).

If IØTB>0 in Card 11, the following No. 13 Card(s) must be included: otherwise, skip to Card 14.

Card 13

NØDEV, VRAD, WRAD, ANGV

I5, 3E15.6

NØDEV — The node number at which the initial generalized nodal velocity components are to be prescribed.

VRAD, WRAD, ANGV — The initial tangential velocity $\dot{v}_o$ (in/sec), normal velocity $\dot{w}_o$ (in/sec) and angular velocity, $\dot{\psi}_o$ (rad/sec), respectively, which are to be prescribed on node NODEV.

Additional Card(s) 13a, 13b, ... are punched in the same format until the total number of cards specified equals IØTB in Card 11.

Card(s) 14, 14a, 14b ... are included only if IØTC>0 in Card 11.

Card 14

IS1, IS2, WRAD

2I5,E15.6

where

IS1, IS2 — The first element and the number of elements over which the first local sine-shaped initial normal velocity distribution is to be prescribed.

WRAD — The peak value $\dot{w}_o$ (in/sec) of the first sine-shaped initial normal velocity distribution.

Card(s) 14a, 14b ... are punched in the same manner, until the total number of No. 14 cards equals IØTC on Card 11.

The remaining cards (15 through 20) specify the amplitude, direction, and distribution of the subsequent time-dependent externally-applied forcing function.

Card 15

TBEGIN, TFINAL, AMP1FV, AMP1FW	4E15.6

where

TBEGIN, TFINAL — Times (seconds) which define the beginning and the end, respectively, of the complete externally-applied forcing function; i.e., the complete forcing function starts at TBEGIN and ends at TFINAL.

AMP1FV, AMP1FW — The circumferential and the normal components, respectively, of the normal force (amplitudes of the forcing function)(lbs) versus time history at time TBEGIN.

If there is no externally-applied forcing function during the run, set both TBEGIN and TFINAL equal to zero and let AMP1FV, AMP1FW blank; Card 15 will be the last card if no forcing function is to be prescribed.

Card 16

NØFT1, NØFT2, NØFT3	3I5

where

NØFT1 — The number of concentrated loads which are to be prescribed (NØFT1 $\leq$ 4).

NØFT2 — The number of local uniform load distributions which are to be prescribed (NØFT2 $\leq$ 4).

NØFT3 — The number of local sine-shaped load distributions which are to be prescribed (NØFT3 $\leq$ 4).

Omit data group 17 if NØFT1=0 on Card 16.

Card 17

JELEM(1), ETA(1), RTØV(1), RTØW(1)	I5,3E.15.6

where

JELEM(1), ETA(1) — The element number and the length coordinate along the centroidal axis from the midspan point of element

JELEM(1), respectively, at which the first concentrated load is to be prescribed.

RTØV(1), RTØW(1) — The normalized values of the first concentrated load with respect to the nominal forces in the circumferential and the normal directions, respectively, (lb/lb).

Card(s) 17a, 17b, ... are repeated in the same format, until the total number of No. 17 cards equals NØFT1 given in Card 16.

Skip data group Card(s) 18 to Card 19 if NØFT2=0 on Card 16.

Card 18

NSTF2(1), NELF2(1), RTØ2V(1), RTØ2W(1)	2I5,2E15.6

where

NSTF2(1), NELF2(1) — The first element and the number of elements, respectively, over which the first local uniform load is to be distributed.

RTØ2V(1), RTØ2W(1) — The normalized values of the first local uniform load distribution with respect to the nominal amplitudes in the circumferential and the normal directions, respectively, (lb/lb-in).

Card(s) 18a, 18b, ... are repeated in the same format until the total number of No. 18 cards equals NØFT2 on Card 16.

Card(s) 19 are included only if NØFT3>0; otherwise, skip to Card 20.

Card 19

NSTF3(1), NELF(3), RTØ3V(1), RTØ3W(1)	2I5,2E15.6

where

NSTF3(1), NELF3(1) — The first element and the number of elements, respectively, over which the first local sine-shaped forcing function is to be distributed.

RTØ3V(1)
RTØ3W(1) } The normalized values of the first local sine-shaped forcing function with respect to the nominal amplitudes in the circumferential and the normal directions, respectively (lb/lb-in).

Card(s) 19a, 19b, ... are repeated until the total number of No. 19 cards equals NØFT3 on Card 16.

Card 20

T2, AMP2FV, AMP2FW	3E15.6

where

T2 The time (seconds) of the second point to be specified on the normal force versus time curve.

AMP2FV
AMP2FW } The nominal circumferential and normal force amplitudes of the second point to be specified (lbs).

Cards 20a, 20b, ... have the same format as Card 20 and read successive values of T2, AMP2FV, and AMP2FW. T2, AMP2FV, AMP2FW on each card give the coordinates of each succeeding point on the force versus time curve. There is no limit to the number of No. 20 cards that can be used when specifying the total forcing function by coordinates of the force versus time curve. However, it is important that the final No. 20 card specify the nominal force at a time which must be equal to or greater than TFINAL specified on Card 15; otherwise, computation will stop.

4.1.2 Input to JET 3C and/or JET 3D for Analyzing Variable Thickness Arbitrarily Curved Rings

The input information required for JET 3C and/or JET 3D to handle variable thickness arbitrarily curved rings is very similar to that just described for JET 3A and/or JET 3B, except for some slight modifications. The data cards are listed in the following. To avoid needless repetition, only variables which newly appear and/or have different definitions are described.

Card 1 | Format

B, DENS	2E15.6

Card 2

IK, NØGA, NFL, NSFL, MM, M1, M2	7I5

where

IK — The number of finite-elements into which the ring has been discretized for analysis.

Card 2a

Y(1), Z(1), ANG(1), H(1)	4E15.6

where

Y(1), Z(1) — Initial Y coordinate and Z coordinate, respectively, of the first node (inches)

ANG(1) — The slope (degrees) which is the angle between the tangent vector and the +Y axis at the first node.

H(1) — The thickness at the first node (inches).

Additional Cards 2aa, 2ab, ... are punched in exactly the same format as Card 2a until the total number of No. 2a cards equals IK+1 for a partial ring and equals IK for a complete ring, where IK is the value appearing on Card 2. Also, the following conditions must be satisfied by ANG(I): (a) $-180° < \text{ANG(I)} \leq 180°$, and (b) $|\text{ANG(I+1)} - \text{ANG(I)}| \lesssim 15°$.

Card 3

DELTAT, CRITS, DS, P	4E15.6

where

DELTAT — The time step size Δt (seconds) to be employed for the timewise finite-difference operator. In the use of JET 3D wherein the Houbolt operator is employed, the value of Δt must be specified by the user. On the other hand, in the use of JET 3C, wherein the central-difference operator is employed, the program will compute the largest natural frequency, ω_{max} of a corresponding linear system, and will then choose a value of $\Delta t = 0.8 \times (2/\omega_{max})$, if the value of Δt is set equal to zero on Card 3.

Card 4

EPS(1), SIG(1), EPS(2), SIG(2)

4E15.6

Additional Cards 4a and 4b are repeated in the same format until the number of coordinate pairs equals the value of NSFL on Card 2.

Card 5

AXG(1), AXG(2), AXG(3)

4F15.10

Card 6

AWG(1), AWG(2), AWG(3)

4F15.10

where

AXG(I), AWG(I) — Vectors, of dimension NØGA, contain Gaussian quadrature constants, x_i and weights, W_i, respectively, for the numerical evaluation of

$$\int_0^1 f(x)\,dx = \sum_i f(x_i)\,W_i$$

If NØGA=3, the following data appear on Card 5:

0.1127016654 0.5 0.8872983346

and the data

0.2777777778 0.4444444444 0.2777777778

on Card 6.

Card 7

TXG(1), TXG(2), TXG(3), TXG(4)

4F15.10

Card 8

TWG(1), TWG(2), TWG(3), TWG(4)

4F15.10

Card 9

NBCØND, NBC(1), NØDEB(1), ... NBC(4), NØDEB(4)

9I5

The appropriate form of the data group NBC(I), NØDEB(I) should be repeated NBCØND times. If NBCØND=0, let NBC(I) and NØDEB(I) blank.

Card 10

NQR, NØRP, NØRU

3I5

If NQR=0, leave NØRP and NØRU blank.

Card 10a and Card 10b are included only if NQR>0 in Card 10.

If NØRP=0, skip to Card 10b.

Card 10a

SCTP, SCRP

2E15.6

Card 10aa

NREL(1), REX(1), NREL(2), REX(2) ... NREL(4), REX(4)

4(I5,E15.6)

where

REX(I) The length coordinate along the centroidal axis from the node NREL(I) at which the Ith point elastic restraint is to be prescribed on element NREL(I).

Data group NREL(I), REX(I) should be repeated NØRP times.

If NØRU=0 in Card 10, omit Card 10b; Card 11 follows directly.

Card 10b

SCTU, SCRU, NRST(1), NREU(1) ... NRST(4), NREU(4)	2E15.6,8I5

Data group NRST(I) and NREU(I) are repeated NØRU times.

Card 11

NV, IØTA, IØTB, IØTC	4I5

If there is no initial velocity distribution, set NV=0 and let IØTA, IØTB, and IØTC blank; then skip to Card 15.

Cards 12 are included, only if IØTA>0 in Card 11.

Card 12a

IE1, IE2	2I5

Card 12aa

WRAD, WRAD1, ANGV1, WRAD2, ANGV2	5E15.6

Additional Cards 12b, 12bb and 12c, 12cc ... are repeated until the total number of No. 12 cards equals IØTA.

Card(s) 13 are included only if IØTB>0 in Card 11.

Card 13

NØDEV, VRAD, WRAD, ANGV	I5,3E15.6

Additional Card(s) 13a, 13b ... repeated IOTB times.

Card(s) 14, 14a, are included only if IØTC>0 is given in Card 11.

Card 14

IS1, IS2, WRAD	2I5,E15.6

Card(s) 14a, 14b are punched in the same manner, until the total number of No. 14 cards equals IØTC.

Card 15

TBEGIN, TFINAL, AMP1FV, AMP1FW	4E15.6

If there is no externally-applied forcing function during the run, set both TBEGIN and TFINAL equal to zero and let AMP1FV, AMP1FW blank; Card 15 will be the last card if no forcing function is to be prescribed.

Card 16

NØFT1, NØFT2, NØFT3	3I5

where

NØFT1≤4, NØFT2≤2, and NØFT3≤2

Omit data group 17 if NØFT1=0 on Card 16.

Card 17

JELEM(1), ETA(1), RTØV(1), RTØW(1)	I5,3E15.6

where

ETA(1) The length coordinate along the centroidal axis from the node JELEM(1) at which the first concentrated load is to be prescribed on element JELEM(1).

Card(s) 17, 17a, ... are repeated NØFT1 times

Skip data group Card(s) 18 if NØFT2=0 on Card 16.

Card 18

NSTF2(1), NELF2(1), RTØ2V(1), RTØ2W(1)	2I5,2E15.6

where

NELF2(1)≤4.

Card(s) 19 are included only if NØFT3>0; otherwise, skip to Card 20.

Card 19

NSTF3(1), NELF3(1), RTØ3V(1), RTØ3W(1)	2I5,2E15.6

where

NELF3(I)≤4.

Card(s) 19, 19a ... are repeated NØFT3 times.

Card 20

T2, AMP2FV, AMP2FW	3E15.6

Cards 20a, 20b, ... have the same format as Card 20 and read successive values of the coordinate points on the force versus time curve.

On the final No. 20 card, T2 must be equal to or greater than TFINAL specified on Card 15.

4.1.3 Input for Special Cases of the General Stress-Strain Relations

In the following, the specific input data for three special cases of the general elastic, strain-hardening constitutive relation handled by the computer program are given. Only the relevant data are noted:

1. Purely Elastic Case

   Set NSFL=1 on Card 2, and make EPS(1) and SIG(1) on Card 4 sufficiently high so that no plastic deformation occurs; for example, EPS(1)=1.0, SIG(1)=ES(1), where ES(1) equals the elastic (Young's) modulus.

2. Elastic, Perfectly-Plastic Case

   Set NSFL=1 on Card 2 and make EPS(1)=SIG(1)/ES(1) on Card 4.

3. Elastic, Linear Strain-Hardening Case

   Set NSFL=2 on Card 3 and set EPS(1)=SIG(1)/ES(1). Also EPS(2) and SIG(2) on Card 4 are taken sufficiently high in order to avoid plastic deformation in the second sub-flange. For example, EPS(2)=1.0, and SIG(2)=(1. - EPS(1)) x ES(2) + SIG(1), where ES(2) is the slope of the segment in the plastic range.

4.2 Description of the Output

The printed output begins with a partial reiteration of the program input which identifies the problem solved. The information presented varies with the type of problem analyzed. Example outputs are presented in Section 6.

After the initial printout has been completed, the following information is printed out (this is done before the first cycle (J=0), after cycle M1 has been completed, and at every M2 cycle thereafter:

```
J=[IT]          TIME(SEC.)=[TIME]

TØTAL ENERGY INPUT(IN.-LB.)=[CINETT]
KINETIC ENERGY(IN.-LB.)=[CINET]
ELASTIC ENERGY(IN.-LB.)=[ELAST]
PLASTIC WØRK(IN.-LB.)=[PLAST]
ENERGY STØRED IN THE ELASTIC RESTRAINTS(IN.-LB.)=[SPDEN]

I  V  W  PSI  CHI  CØPY  CØPZ  L  M  STRAIN(IN)  STRAIN(ØUT)
1
2
3
.
.
.
.
.
.
.
```

where IT = Cycle number

TIME = Elapsed time corresponding to the end of cycle J(sec.)

CINETT = Total work imparted to the structural ring up to the present time step by the external agencies such as the externally-applied forces and the initially-imparted kinetic energy (in-lb).

CINET = The current value of kinetic energy present in the structural ring* (includes both the rigid body and the relative kinetic energies) (in-lb).

ELAST = Total elastic strain energy stored in the entire structural ring at the present time instant (in-lb).

PLAST = Total plastic work** done on the structural ring (mechanical work dissipated during plastic flow) (in-lb).

SPDEN = Total energy stored in the elastically-restoring springs and/or the elastic foundations at the current time instant (in-lb).

I = Node number in clockwise order. For a partial ring, the value of the total number of nodes equals the value of the total number of elements plus one. For a complete ring, the value of the total number of nodes equals the value of the total number of elements.

V = The middle plane axial displacement at node I (in).

W = The middle plane transverse displacement at node I (in).

---

*It should be noted that the rigid body part of the kinetic energy, which is used to accelerate the "rigid body" mass of the structure, can be extracted and identified separately. However, for the present program dealing with rather general structural geometries and with various support/restraint conditions, it would be very unwieldy (but not impossible) to identify these separate kinetic energies; hence, the total kinetic energy is calculated and printed out.

**The plastic work done on the ring is estimated by subtracting the sum of the elastic and kinetic energies present in the ring from the total input energy (due to the externally-applied load and the initially-imparted kinetic energy); i.e., CINETT=CINET+ELAST+PLAST+SPDEN. It should be mentioned that the approximate nature of this numerical calculation will sometimes yield impossible results such as negative values of plastic work or values greater than zero when the ring has not yet reached a plastic condition; thus, the value of plastic work should be considered only approximate, and spurious results as noted above should be ignored.

PSI = The generalized nodal displacement $\psi = (\partial w/\partial \eta) - v/R$ at node I (rad).

CHI = The generalized nodal displacement $\chi = (\partial v/\partial \eta) + w/R$ at node I (rad).

CØPY = The Y-location of node I in the global (inertial) coordinate system (in).

CØPZ = The Z-location of node I in the global coordinate system (in).

L = Axial internal force resultant over the cross section at the midspan point of element I (lb).

M = Internal bending moment of the cross section at the midspan point of element I (in-lb).

STRAIN(IN) = Strain on the inner surface at the midspan point of element I.

STRAIN(ØUT) = Strain on the outer surface at the midspan point of element I.

At each printout cycle, a strain checking process is carried out. Asterisks are printed to the right of the strain printout only for the cycle when the strain first exceeds the critical value. No further strain checking or action is taken by the program, however, and the computation process proceeds until the end of the run as if the material had not "failed".

At the conclusion of each run, a statement "LARGEST CØMPUTED STRAIN= ... ØCCURS AT THE INNER (or ØUTER) SURFACE MIDSPAN ØF ELEMENT= ... AT TIME(SEC)=..." is printed out. This statement gives the largest computed strain, and the time and the location at which it occurs during the transient response. It should be mentioned that the strains are computed at every printout cycle only and also only on the inner and the outer surface midspan of each element.

SECTION 5

COMPLETE FORTRAN IV LISTING OF THE JET 3 PROGRAM

5.1 JET 3A: Uniform Thickness Circular Ring; Timewise Central-Difference Operator

The JET 3A program consists of the following main programs and subroutines.

1. JET 3A MAIN PROGRAM
2. ASSEM
3. ASSEF
4. IDENT
5. IMPULS
6. PRINT

(partial ring)

7. JET 3A MAIN PROGRAM
8. ASSEM
9. ASSEF
10. IDENT
11. IMPULS
12. PRINT

(complete ring)

13. ELMPP
14. ERC
15. FAC
16. FICOL
17. LOADEQ
18. LOADFT
19. MINV
20. OMULT
21. QREM
22. SOLV
23. STRESS
24. TSTEP

Note that there are two groups of "control programs" in JET 3A: one for partial rings and a second for complete rings; the subroutines in items 13 through 24 are common to each of these two groups.

A complete FORTRAN IV listing of JET 3A is given below in the above order. The number of memory locations required on the IBM 370-155 computer at MIT is approximately 186,000 bytes. This includes the locations required for the MIT computer library subroutines.

```
C       JET3A  MAIN PROGRAM FOR UNIFORM THICKNESS CIRCULAR RING
C       JET3A  CENTRAL DIFFERENCE OPERATOR
C       ***** PARTIAL RING *****
      DIMENSION A(8,8),AMASS(2060),BMASS(2060),Y(51),Z(51),TXG(6),TWG(6)
     *,ES(6),GFL(6),EPS(5),SIG(5),SOL(205),INUM(205),KROW(8),NDEX(8)
       COMMON /TAPE/ MREAD,MWRITE,MPUNCH
       COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
       COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
       COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
       COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
       COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
       COMMON /ELFU/ SPRIN(2060),FQREF(205),NORP,NORU,NREL(4),REX(4),
     *NRST(4),NREU(4)
       REAL*8 A,BEP,AMASS,AL,FLVA,SOL,FMECH,BX,BL,DISP,DELD
       REAL*8 SPRIN,FQREF,BMASS
       MREAD=5
       MWRITE=6
       MPUNCH=7
       READ(MREAD,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL,MM,M1,M2
       READ(MREAD,2) DELTAT,THETA,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
  1    FORMAT(5E15.6/7I5)
  2    FORMAT(5E15.6/(4E15.6))
       READ(MREAD,3)(AXG(K),K=1,NOGA)
       READ(MREAD,3)(AWG(K),K=1,NOGA)
       READ(MREAD,3)(TXG(K),K=1,NFL)
       READ(MREAD,3)(TWG(K),K=1,NFL)
  3    FORMAT(4F15.10)
       READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
  4    FORMAT(9I5)
       READ(MREAD,9) NQR,NORP,NORU
  9    FORMAT(3I5)
             CALL IDENT(EXANG,NQR)
       PIE=3.14159265
       IKP1=IK+1
       NI=IKP1*4
       THETA=THETA*PIE/180.
       BX=PIE*EXANG/180.
       BL=BX*R
       AL=BL/IK
       AX=BX/IK
       DO 70 K=1,NFL
       GFL(K)=H*B*TWG(K)/2.
  70   GZETA(K)=H*TXG(K)/2.
       ES(1)=SIG(1)/EPS(1)
       YOUNG=ES(1)
       IF(NSFL-1)77,77,76
  76   DO 78 L=2,NSFL
  78   ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
  77   ES(NSFL+1)=0.0
       DO 79 L=1,NSFL
  79   SNO(L)=ES(1)*EPS(L)
       DO 71 K=1,NFL
       DO 71 L=1,NSFL
  71   ASFL(K,L)=GFL(K)*(ES(L)-ES(L+1))/ES(1)
       DO 72 K=1,NOGA
```

```
      AXG(K)=AXG(K)*AL/2.
72    AWG(K)=AWG(K)*AL/2.
      DO 15 I=1,8
15    ICOL(I)=1
      DO 16 I=3,IKP1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX=',I5)
            CALL ELMPP(AL,A,AMASS,BMASS,KROW,NDEX,NIRREG,INUM,
     *ISIZE,DELTAT)
      IF (NQR .EQ. 0) GO TO 20
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
      CALL QREM(A,AL,R)
      DO 24 I=1,NI
24    FQREF(I)=0.0
20    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2/(DENS*B*H)
      C2=DENS*B*H/(2.*DELTAT**2)
      HHALF=H/2.
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
      IT=0
      TIME=0.0
      DO 75 I=1,IKP1
      ANG=(I-1)*AX+THETA
      Y(I)=SIN(ANG)*R
75    Z(I)=COS(ANG)*R
```

```
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0    THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
            CALL LOADEQ(A,R,AL,TBEGIN,TFINAL)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 120
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      CALL SOLV(AMASS,FMECH,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 26 I=1,NI
26    DELD(I)=DELD(I)+DTSQ*SOL(I)/2.
      IF(NLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
120   IT=IT+1
      TIME=IT*DELTAT
      DO 121 I=1,NI
      FQREF(I)=0.0
      FLVA(I)=0.0
121   DISP(I)=DISP(I)+DELD(I)
45    CALL STRESS
      IF(NQR .EQ. 0) GO TO 127
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 128 I=1,NI
128   FLVA(I)=FLVA(I)+FQREF(I)
127   NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      DO 123 I=1,NI
123   FLVA(I)=FLVA(I)-FMECH(I)
122   IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVA(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVA(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVA(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVA,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DELD(I)-SOL(I)*DTSQ
      IF(NLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
41    IF(IT .EQ. 1) CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,
     *BMASS,C2,NQR,KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
```

```
 140    M1=M1+M2
              CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
 130    IF(IT-MM) 120,170,150
 170    IF(IBIG) 62,150,62
 62     IF(ISURF-2) 64,65,65
 64     WRITE(MWRITE,66) BIG,IBIG,BTIME
 66     FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
       *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
        GO TO 150
 65     WRITE(MWRITE,67) BIG,IBIG,BTIME
 67     FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
       *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
 150    CALL EXIT
        END




        SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C       ***** PARTIAL RING *****
        DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
        REAL*8 ELMAS,STIFM
        J1=IR*4
        NN(1)=J1-3
        NN(2)=J1-2
        NN(3)=J1-1
        NN(4)=J1
        J2=(IR+1)*4
        NN(5)=J2-3
        NN(6)=J2-2
        NN(7)=J2-1
        NN(8)=J2
 202    DO 402 I=1,8
        M=NN(I)
        DO 402 J=1,8
        N=NN(J)
        IF(M-N)402,403,403
 403    CALL FICOL(M,N,L,ICOL)
        STIFM(L)=STIFM(L)+ELMAS(I,J)
 402    CONTINUE
        RETURN
        END




        SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C       ***** PARTIAL RING *****
        DIMENSION NN(8),FLVA(1),ELFP(1)
        REAL*8 ELFP,FLVA
        J1=IR*4
        NN(1)=J1-3
        NN(2)=J1-2
        NN(3)=J1-1
        NN(4)=J1
 121    J2=(IR+1)*4
        NN(5)=J2-3
```

```
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
  123 DO 101 I=1,8
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
  101 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IDENT(EXANG,NQR)
C     ***** PARTIAL RING *****
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICEL(205),NBCOND,NEC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      WRITE(MWRITE,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL
    1 FORMAT(' ***JET3A**** A SPATIAL FINITE ELEMENT AND TEMPORAL CENTR
     *AL DIFFERENCE PROGRAM',/,'     USED TO CALCULATE THE NONLINEAR RESP
     *ONSES OF A UNIFORM THICKNESS CIRCULAR',/,'     PARTIAL RING WITH TH
     *E FOLLOWING PARAMETERS  ',//,
     *'     MEAN RADIUS OF RING (IN.)          =',E15.6,/,
     *'     WIDTH OF RING (IN.)                =',E15.6,/,
     *'     THICKNESS OF RING (IN.)            =',E15.6,/,
     *'     DENSITY (LB-SEC**2/IN**4)          =',E15.6,/,
     *'     SUBTENDED ANGLE (DEGREE)           =',E15.6,/,
     *'     NUMBER OF ELEMENTS                 =',I5,/,
     *'     NUMBER OF SPANWISE GAUSSIAN PTS    =',I5,/,
     *'     NUMBER OF DEPTHWISE GAUSSIAN PTS   =',I5,/,
     *'     NUMBER OF MECHANICAL SUBLAYERS     =',I5)
   11 IF(NBCOND .EQ. 0) GO TO 12
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
   14 CONTINUE
   15 FORMAT('   SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
   16 FORMAT('    CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
   17 FORMAT('    HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
      GO TO 18
   12 WRITE(MWRITE,13)
   13 FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
   18 IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
   20 FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
      RETURN
   19 WRITE(MWRITE,21)
   21 FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
      RETURN
      END
```

```
      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** PARTIAL RING *****
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCUND,NBC(4),NODEB(4)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 FLVA,DISP,DELD,AL
      DO 50 I=1,NI
      DELD(I)=0.0
 50    DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
      DO 51 L=1,NSFL
 51   SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
 1    FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
 2     FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
 4    FORMAT(/,'    THERE IS NO INITIAL IMPULSE  ')
 6   FORMAT(/,'    IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) RETURN
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
 21   FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
 22   DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
 20   CONTINUE
 10   IF(IOTB .EQ. 0) GO TO 42
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
 31   FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
 30   CONTINUE
 42   IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
 62   FORMAT(2I5,E15.6)
      PIEP=3.14159265/IS2
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP/AL
      DO 63 II=1,IS2
      I=IS1+II
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*II)
```

```
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*II)/AL
61    CONTINUE
60    IF(NBCOND .EQ.0) RETURN
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
      RETURN
      END


      SUBROUTINE PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
C     ***** PARTIAL RING *****
      DIMENSION Y(51),Z(51),COPY(51),COPZ(51),BEPS(3),EPSI(51),EPSO(51)
     *,FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      REAL*8 BEP,FLVA,DISP,DELD,BMASS,FQREF,CINE
      DO 700 I=1,NI
700   CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
701   CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
704   SUM=SUM+SNS(IR,J,K,L)**2*ASFL(K,L)
703   ELAST=ELAST+SUM*AWG(J)
702   CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
      DO 32 I=1,NI
32    SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
31    ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
1     FORMAT(//////,'     J=',I5,'         TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)   =',E15.6,/,
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
```

```
*'          PLASTIC WORK    (IN.-LB.)   =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
34    FORMAT('   ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)   =',
     *E15.6)
33    IKP1=IK+1
      DO 11 I=1,IKP1
      ANG=(I-1)*AX+THETA
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG)+DISP(I*4-2)*SIN(ANG)
11    COPZ(I)=Z(I)-DISP(I*4-3)*SIN(ANG)+DISP(I*4-2)*COS(ANG)
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF*FCUR
      EPSO(IR)=FARE+HHALF*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53 I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,4D12.4,5E12.4,A2,E12.4,A2)
      WRITE(MWRITE,54)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'   STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
```

```
50    DO 21 I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,4D12.4,5E12.4,2X,E12.4)
      WRITE(MWRITE,22)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      RETURN
      END
```

```
C     JET3A  MAIN PROGRAM FOR UNIFORM THICKNESS CIRCULAR RING
C     JET3A  CENTRAL DIFFERENCE OPERATOR
C     ***** COMPLETE RING *****
      DIMENSION A(8,8),AMASS(2060),BMASS(2060),Y(51),Z(51),TXG(6),TWG(6)
     *,ES(6),GFL(6),EPS(5),SIG(5),SOL(205),INUM(205),KROW(8),NDEX(8)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
      COMMON /ELFU/ SPRIN(2060),FQREF(205),NORP,NORU,NREL(4),REX(4),
     *NRST(4),NREU(4)
      REAL*8 A,BEP,AMASS,AL,FLVA,SOL,FMECH,BX,BL,DISP,DELD
      REAL*8 SPRIN,FQREF,BMASS
      MREAD=5
      MWRITE=6
      MPUNCH=7
      READ(MREAD,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL,MM,M1,M2
      READ(MREAD,2) DELTAT,THETA,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
1     FORMAT(5E15.6/7I5)
2     FORMAT(5E15.6/(4E15.6))
      READ(MREAD,3)(AXG(K),K=1,NOGA)
      READ(MREAD,3)(AWG(K),K=1,NOGA)
      READ(MREAD,3)(TXG(K),K=1,NFL)
      READ(MREAD,3)(TWG(K),K=1,NFL)
3     FORMAT(4F15.10)
      READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
4     FORMAT(9I5)
      READ(MREAD,9) NQR,NORP,NORU
9     FORMAT(3I5)
             CALL IDENT(NQR)
      PIE=3.14159265
      NI=IK*4
      THETA=THETA*PIE/180.
      BX=2.*PIE
```

```
      BL=BX*R
      AL=BL/IK
      AX=BX/IK
      DO 70 K=1,NFL
      GFL(K)=H*B*TWG(K)/2.
7C    GZETA(K)=H*TXG(K)/2.
      ES(1)=SIG(1)/EPS(1)
      YOUNG=ES(1)
      IF(NSFL-1)77,77,76
76    DO 78 L=2,NSFL
78    ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
77    ES(NSFL+1)=0.0
      DO 79 L=1,NSFL
79    SNC(L)=ES(1)*EPS(L)
      DO 71 K=1,NFL
      DO 71 L=1,NSFL
71    ASFL(K,L)=GFL(K)*(ES(L)-ES(L+1))/ES(1)
      DO 72 K=1,NOGA
      AXG(K)=AXG(K)*AL/2.
72    AWG(K)=AWG(K)*AL/2.
      DO 15 I=1,8
15    ICCL(I)=1
      IKM1=IK-1
      DO 16 I=3,IKM1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICCL(IK4)=JJ
16    CONTINUE
      ICOL(IK*4)=1
      ICOL(IK*4-1)=1
      ICOL(IK*4-2)=1
      ICCL(IK*4-3)=1
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'   SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX=',I5)
```

```
            CALL ELMPP(AL,A,AMASS,BMASS,KROW,NDEX,NIRREG,INUM,
     *ISIZE,DELTAT)
      IF (NQR .EQ. 0) GO TO 20
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
      CALL QREM(A,AL,R)
      DO 24 I=1,NI
24    FQREF(I)=0.0
20    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2/(DENS*B*H)
      C2=DENS*B*H/(2.*DELTAT**2)
      HHALF=H/2.
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
      IT=0
      TIME=0.0
      DO 75 I=1,IK
      ANG=(I-1)*AX+THETA
      Y(I)=SIN(ANG)*R
75    Z(I)=COS(ANG)*R
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0    THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
            CALL LOADEQ(A,R,AL,TBEGIN,TFINAL)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 120
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      CALL SOLV(AMASS,FMECH,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 26 I=1,NI
26    DELD(I)=DELD(I)+DTSQ*SOL(I)/2.
      IF(NLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
120   IT=IT+1
      TIME=IT*DELTAT
      DO 121 I=1,NI
      FQREF(I)=0.0
      FLVA(I)=0.0
121   DISP(I)=DISP(I)+DELD(I)
      DO 129 K=1,4
      DISP(IK*4+K)=DISP(K)
129   DELD(IK*4+K)=DELD(K)
45    CALL STRESS
      IF(NQR .EQ. 0) GO TO 127
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
```

```
      DO 128 I=1,NI
128   FLVA(I)=FLVA(I)+FQREF(I)
127   NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      DO 123 I=1,NI
123   FLVA(I)=FLVA(I)-FMECH(I)
122   IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVA(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVA(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVA(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVA,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DELD(I)-SOL(I)*DTSQ
      IF(NLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
41    IF(IT .EQ. 1) CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,
     *BMASS,C2,NQR,KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
150   CALL EXIT
      END




      SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C     ***** COMPLETE RING *****
      DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
      REAL*8 ELMAS,STIFM
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 203,204,204
203   J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
```

```
      NN(8)=J2
      GO TO 202
204   NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
202   DO 402 I=1,8
      M=NN(I)
      DO 402 J=1,8
      N=NN(J)
      IF(M-N)402,403,403
403   CALL FICOL(M,N,L,ICOL)
      STIFM(L)=STIFM(L)+ELMAS(I,J)
402   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
      ***** COMPLETE RING *****
      DIMENSION NN(8),FLVA(1),ELFP(1)
      REAL*8 ELFP,FLVA
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 121,122,122
121   J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
      GO TO 123
122   NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
123   DO 101 I=1,8
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
101   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IDENT(NQR)
C     ***** COMPLETE RING *****
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      WRITE(MWRITE,1) R,B,H,DENS,IK,NOGA,NFL,NSFL
 1    FORMAT(' ***JET3A**** A SPATIAL FINITE ELEMENT AND TEMPORAL CENTR
    *AL DIFFERENCE PROGRAM',/,'     USED TO CALCULATE THE NONLINEAR RESP
    *ONSES OF A UNIFORM THICKNESS CIRCULAR',/,'     COMPLETE RING WITH T
    *HE FOLLOWING PARAMETERS  ',//,
    *'      MEAN RADIUS OF RING (IN.)             =',E15.6,/,
    *'      WIDTH OF RING (IN.)                   =',E15.6,/,
    *'      THICKNESS OF RING (IN.)               =',E15.6,/,
    *'      DENSITY (LB-SEC**2/IN**4)             =',E15.6,/,
    *'      NUMBER OF ELEMENTS                    =',I5,/,
    *'      NUMBER OF SPANWISE GAUSSIAN PTS       =',I5,/,
    *'      NUMBER OF DEPTHWISE GAUSSIAN PTS      =',I5,/,
    *'      NUMBER OF MECHANICAL SUBLAYERS        =',I5)
 11   IF(NBCOND .EQ. 0) GO TO 12
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
 14   CONTINUE
 15   FORMAT('    SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
 16   FORMAT('     CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
 17   FORMAT('     HINGED  DISPLACEMENT CONDITION AT NODE =', I5)
      GO TO 18
 12   WRITE(MWRITE,13)
 13  FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
 18   IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
 20   FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
    * BY INPUT ')
      RETURN
 19   WRITE(MWRITE,21)
 21   FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
      RETURN
      END
```

```
      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** COMPLETE RING *****
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
    *BINP(50,3),BIMP(50,3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 FLVA,DISP,DELD,AL
      DO 50 I=1,NI
      DELD(I)=0.0
 50    DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
```

```
      DO 51 L=1,NSFL
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'    THERE IS NO  INITIAL IMPULSE  ')
6    FORMAT(/,'    IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) GO TO 41
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
      IF(I .GT. IK) I=I-IK
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      IF(IE2P1 .GT. IK) IE2P1=IE2P1-IK
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 42
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
42    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      PIEP=3.14159265/IS2
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP/AL
      DO 63 II=1,IS2
      I=IS1+II
      IF(I .GT. IK) I=I-IK
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*II)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*II)/AL
61    CONTINUE
60    IF(NBCOND .EQ.0) GO TO 41
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
41    DO 52 K=1,4
      DISP(IK*4+K)=DISP(K)
52    DELD(IK*4+K)=DELD(K)
      RETURN
      END
```

```
      SUBROUTINE PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,FQREF,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
C     ***** COMPLETE RING *****
      DIMENSION Y(51),Z(51),COPY(51),COPZ(51),BEPS(3),EPSI(51),EPSO(51)
     *,FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNU(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 BEP,FLVA,DISP,DELD,BMASS,FQREF,CINE
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
  700 CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
  701 CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
  704 SUM=SUM+SNS(IR,J,K,L)**2*ASFL(K,L)
  703 ELAST=ELAST+SUM*AWG(J)
  702 CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
      DO 32 I=1,NI
   32 SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
   31 ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
    1 FORMAT('1    J=',I5,'        TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)   =',E15.6,/,
     *'           KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'           ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'           PLASTIC WORK   (IN.-LB.)  =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
   34 FORMAT('    ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
   33 DO 11 I=1,IK
      ANG=(I-1)*AX+THETA
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG)+DISP(I*4-2)*SIN(ANG)
   11 COPZ(I)=Z(I)-DISP(I*4-3)*SIN(ANG)+DISP(I*4-2)*COS(ANG)
      DO 601 IR=1,IK
      DO 604 I=1,3
```

```
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF*FCUR
      EPSO(IR)=FARE+HHALF*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53 I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,4D12.4,5E12.4,A2,E12.4,A2)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'    STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
50    DO 21 I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,4D12.4,5E12.4,2X,E12.4)
      RETURN
      END
```

```
      SUBROUTINE ELMPP(AL,A,AMASS,BMASS,KROW,NDEX,NIRREG,INUM,
     *ISIZE,DELTAT)
C     TO FIND THE MASS MATRIX  STIFFNESS MATRIX AND STRAIN NODAL
C     DISPLACEMENT TRANSFORMATION MATRICES
      DIMENSION A(8,8),LMI(8),MMI(8),D(8,8),ELM(8,8),ELMAS(8,8),
     *E(8,8),EK1(8,8),ELK(8,8),BE1(3,3,8)
      DIMENSION AMASS(1),BMASS(1),KROW(1),NDEX(1),INUM(1)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 AL,X,RHO,RI,STO,SS,A,P2,P3,D,ELM,ELMAS,BE1,BEP,E,EK1,ELK
      REAL*8 AMASS,BMASS
      X=AL/(R*2.)
      RHO=1.
      RI=RHO*H**2/12.
      STO=1.
      SS=STO*H**2/12.
      DO 6 I=1,8
      DO 6 J=1,8
      D(I,J)=0.0
      E(I,J)=0.0
 6    A(I,J)=0.
      A(1,1)=DCOS(X)
      A(1,2)=DSIN(X)
      A(1,3)=(-R)*(1.-DCOS(X)**2)
      A(1,4)=-AL/2.
      A(2,1)=-DSIN(X)
      A(2,2)=DCOS(X)
      A(2,3)=-R*DSIN(X)*DCOS(X)
      A(2,5)=AL**2/4.
      A(2,6)=-AL**3/8.
      A(3,3)=1.
      A(3,4)=AL/R/2.
      A(3,5)=-AL
      A(3,6)=AL**2*3./4.
      A(1,7)=AL**2/4.
      A(1,8)=-AL**3/8.
      A(3,7)=-AL**2/4./R
      A(3,8)=AL**3/8./R
      A(4,4)=1.
      A(4,5)=AL**2/4./R
      A(4,6)=-AL**3/8./R
      A(4,7)=-AL
      A(4,8)=3.*AL**2/4.
      A(5,1)=DCOS(X)
      A(5,2)=-DSIN(X)
      A(5,3)=(-R)*(1.-DCOS(X)**2)
      A(5,4)=AL/2.
      A(5,7)=AL**2/4.
      A(5,8)=AL**3/8.
      A(6,1)=DSIN(X)
      A(6,2)=DCOS(X)
      A(6,3)=R*DSIN(X)*DCOS(X)
      A(6,5)=AL**2/4.
      A(6,6)=AL**3/8.
      A(7,3)=1.
      A(7,4)=-AL/2./R
      A(7,5)=AL
      A(7,6)=AL**2*3./4.
      A(7,7)=-AL**2/4./R
```

```
      A(7,8)=-AL**3/8./R
      A(8,4)=1.
      A(8,5)=AL**2/4./R
      A(8,6)=AL**3/8./R
      A(8,7)=AL
      A(8,8)=3.*AL**2/4.
      CALL MINV(A,8,DET,LMI,MMI)
      P2=2.*X**2*DSIN(X)+4.*X*DCOS(X)-4.*DSIN(X)
      P3=-2.*X**3*DCOS(X)+6.*X**2*DSIN(X)+12.*X*DCOS(X)-12.*DSIN(X)
      D(1,1)=RHO*AL
      D(2,2)=RHO*AL
      D(3,1)=RHO*R*(-R*2.*DSIN(X)+DCOS(X)*AL)
      D(3,3)=RHO*R**2*(AL+DCOS(X)**2*AL-4.*R*DSIN(X)*DCOS(X))+RI*AL
      D(4,2)=-RHO*R**2*(-2.*X*DCOS(X)+2.*DSIN(X))
      D(4,4)=RHO*AL**3/12.+RI*AL**3/R**2/12.
      D(5,2)=RHO*R**3*P2
      D(5,4)=-RI*AL**3/R/6.
      D(5,5)=RHO*AL**5/80.+RI*AL**3/3.
      D(6,1)=RHO*R**4*P3
      D(6,3)=RHO*R**5*DCOS(X)*P3+RI*AL**3/4.
      D(6,6)=RHO*AL**7/448.+RI*AL**5*9./80.
      D(7,1)=RHO*R**3*P2
      D(7,3)=-RHO*R*(AL**3/12.-R**3*DCOS(X)*P2)-RI*AL**3/R/12.
      D(7,6)=-3.*RI*AL**5/R/80.
      D(7,7)=(AL**5/80.)*(RHO+RI/R**2)
      D(8,2)=-RHO*R**4*P3
      D(8,4)=D(7,7)
      D(8,5)=-RI*AL**5/R/40.
      D(8,8)=(AL**7/448.)*(RHO+RI/R**2)
      E(4,4)=AL*(STO+SS/R**2)
      E(5,4)=STO*AL**3/(R*12.)-2.*SS*AL/R
      E(5,5)=STO*AL**5/(R**2*80.)+4.*SS*AL
      E(6,6)=STO*AL**7/(R**2*448.)+3.*SS*AL**3
      E(7,6)=STO*AL**5/(R*40.)-SS*AL**3/R
      E(7,7)=(STO+SS/R**2)*AL**3/3.
      E(8,4)=(STO+SS/R**2)*AL**3/4.
      E(8,5)=3.*STO*AL**5/(R*80.)-SS*AL**3/(R*2.)
      E(8,8)=9.*(STO+SS/R**2)*AL**5/80.
      DO 3 I=1,7
      IP1=I+1
      DO 3 J=IP1,8
      E(I,J)=E(J,I)
3     D(I,J)=D(J,I)
      DO 4 I=1,8
      DO 4 J=1,8
      EK1(I,J)=0.0
      ELM(I,J)=0.
      DO 4 K=1,8
      EK1(I,J)=EK1(I,J)+A(K,I)*E(K,J)
4     ELM(I,J)=ELM(I,J)+A(K,I)*D(K,J)
      DO 5 I=1,8
      DO 5 J=1,8
      ELK(I,J)=0.0
      ELMAS(I,J)=0.
      DO 5 K=1,8
      ELK(I,J)=ELK(I,J)+EK1(I,K)*A(K,J)
5     ELMAS(I,J)=ELMAS(I,J)+ELM(I,K)*A(K,J)
      DO 44 K=1,NOGA
      DO 21 I=1,3
      DO 21 J=1,8
```

```
21      BE1(K,I,J)=0.
        BE1(K,1,4)=1.
        BE1(K,1,5)=AXG(K)**2/R
        BE1(K,1,6)=AXG(K)**3/R
        BE1(K,3,4)=1./R
        BE1(K,3,5)=-2.
        BE1(K,3,6)=-6.*AXG(K)
        BE1(K,2,3)=1.
        BE1(K,2,4)=-AXG(K)/R
        BE1(K,2,5)=2.*AXG(K)
        BE1(K,2,6)=3.*AXG(K)**2
        BE1(K,1,7)=2.*AXG(K)
        BE1(K,1,8)=3.*AXG(K)**2
        BE1(K,3,7)=2.*AXG(K)/R
        BE1(K,3,8)=3.*AXG(K)**2/R
        BE1(K,2,7)=-AXG(K)**2/R
        BE1(K,2,8)=-AXG(K)**3/R
44      CONTINUE
        DO 22 NL=1,NOGA
        DO 22 I=1,3
        DO 22 J=1,8
        BEP(NL,I,J)=0.
        DO 22 K=1,8
        BEP(NL,I,J)=BEP(NL,I,J)+BE1(NL,I,K)*A(K,J)
22      CONTINUE
        WRITE(MWRITE,15)
        WRITE(MWRITE,16) ((ELMAS(I,J),J=1,8),I=1,8)
        WRITE(MWRITE,17)
        WRITE(MWRITE,16) ((ELK(I,J),J=1,8),I=1,8)
16      FORMAT(8D15.6)
15      FORMAT(/,'     ELEMENT MASS MATRIX / (DENS*B*H)     ')
17      FORMAT(/,'     ELEMENT STIFFNESS MATRIX / (YOUNG*B*H)     ')
       DO 18 L=1,ISIZE
18      AMASS(L)=0.0
        DO 19 IR=1,IK
19              CALL ASSEM(IR,IK,ELMAS,AMASS,ICOL,NI)
        IF(NBCOND .EQ.0) GO TO 712
        DO 91 I=1,NBCOND
        JT4=NODEB(I)*4
        JT4M3=JT4-3
        JT4M2=JT4-2
        JT4M1=JT4-1
        CALL ERC(JT4M3,AMASS,NI,ICCL)
        IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,AMASS,NI,ICOL)
        IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,AMASS,NI,ICOL)
91      CONTINUE
712     DO 713 L=1,ISIZE
713     BMASS(L)=AMASS(L)
        CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
        IF(DELTAT .GT. 0.0) RETURN
C
C       DETERMINATION OF DELTAT IF NOT GIVEN
C
                CALL TSTEP(AMASS,ELK,ISIZE,KROW,NDEX,NIRREG,DELTAT)
        RETURN
        END
```

```
      SUBROUTINE ERC(II,STIFM,NI,ICOL)
C      FOR ELIMINATING ROWS AND COLUMNS IN STIFM
       DIMENSION STIFM(1),ICOL(1)
       REAL*8 STIFM
      IC=ICOL(II)
      DO 101 J=IC,II
      CALL FICOL(II,J,L,ICOL)
101   STIFM(L)=0.
      DO 102 I=II,NI
      IC1=ICOL(I)
      IF(II-IC1)102,103,103
103   CALL FICOL(I,II,L,ICOL)
      STIFM(L)=0.
102   CONTINUE
      CALL FICOL(II,II,L,ICOL)
      STIFM(L)=1.
      RETURN
      END
```

```
      SUBROUTINE FAC  (STIFM,NCOL,KROW,NDEX,IDET,NTAPE6,NROWS,NIRREG,IC)
C      LOWER TRIANGULAR FACTOR OF STIFM MATRIX IS COMPUTED AND STORED   FACT0095
      DIMENSION STIFM(1),NCOL(1),KROW(1),NDEX(1),IC(1)
      REAL*8 STIFM,SUM,TES,TEST
C     STIFM                                                            FACT0100
C     PROCESS COLUMN 1                                                 FACT0105
      I=1
      IDET=0                                                           FACT0110
      IF (STIFM(1)) 152,122,101
152   IDET=IDET+1
 101  INDEX=0
      IROW=1                                                           FACT0130
      TEST=1.0                                                         FACT0135
      KN=1                                                             FACT0140
      DO 103 I=2,NROWS                                                 FACT0145
      KN=KN+I-NCOL(I)                                                  FACT0150
      IF (NCOL(I)-1) 103,102,103                                       FACT0155
  102 STIFM(KN)=STIFM(KN)/STIFM(1)                                     FACT0160
  103 CONTINUE                                                         FACT0165
      DO 121 I=2,NROWS                                                 FACT0170
      IP1=I+1                                                          FACT0175
      IM1=I-1                                                          FACT0180
      SUM=0.0                                                          FACT0185
      NCK=0                                                            FACT0190
      III=NCOL(I)                                                      FACT0195
      INDEX=INDEX+I-III                                                FACT0200
      IF (IM1-III) 150,140,140                                         FACT0205
C     DIAGONAL TERMS                                                   FACT0210
  140 DO 104 J=III,IM1                                                 FACT0215
      IJ=INDEX+J                                                       FACT0220
  104 SUM=SUM+STIFM(IJ)*STIFM(IJ)*STIFM(IC(J)+J)
  150 II=INDEX+I                                                       FACT0230
      SUM=STIFM(II)-SUM                                                FACT0235
      IF (SUM) 151,122,105
 151  IDET= IDET +1
105   TES=DABS(SUM/STIFM(II))
```

```
      IF (TES-TEST) 106,107,107                                           FACT0250
  106 TEST=TES                                                            FACT0255
      IROW=I                                                              FACT0260
  107 STIFM(II)= SUM
C     OFF DIAGONAL TERMS                                                  FACT0270
      IF (I-NROWS) 108,121,121                                            FACT0275
  108 KNDEX=INDEX                                                         FACT0280
  109 DO 116 K=IP1,NROWS                                                  FACT0285
      KK=NCOL(K)                                                          FACT0290
      KNDEX=KNDEX+K-KK                                                    FACT0295
      SUM=0.0                                                             FACT0300
      IF (KK-III) 110,130,130                                             FACT0305
  110 KK=III                                                              FACT0310
  130 IF (IM1-KK) 112,131,131                                             FACT0315
  131 DO 111 J=KK,IM1                                                     FACT0320
      IJ=INDEX+J                                                          FACT0325
      KJ=KNDEX+J                                                          FACT0330
  111 SUM=SUM+STIFM(IJ)*STIFM(KJ)*STIFM(IC(J)+J)
  112 IF (I-KK) 114,115,115                                               FACT0340
  114 IF (NIRREG .LE. 0) GO TO 121                                        FACT0345
      IF (NIRREG .GT. NROWS /2) GO TO 116
      GO TO 190                                                           FACT0355
  115 KI=KNDEX+I                                                          FACT0360
      STIFM(KI)=(STIFM(KI)-SUM)/STIFM(II)                                 FACT0365
  116 CONTINUE                                                            FACT0370
      GO TO 121                                                           FACT0375
  190 NCK=NCK+1                                                           FACT0380
      IF (NIRREG .LT. NCK) GO TO 121                                      FACT0385
      IP1=KROW(NCK)                                                       FACT0390
      IF (I .LT. NCOL(IP1)) GO TO 190                                     FACT0395
      IF (IP1 .LT. K) GO TO 190                                           FACT0400
      KNDEX=NDEX(NCK)                                                     FACT0405
      GO TO 109                                                           FACT0410
  121 CONTINUE                                                            FACT0415
      RETURN                                                              FACT0435
  122 WRITE (NTAPE6,1001) I                                               FACT0440
      IDET=-I
 1001 FORMAT (37H1 MATRIX NOT POSITIVE DEFINITE IN ROW,I4)                FACT0450
      WRITE (NTAPE6,1002) SUM                                             FACT0455
 1002 FORMAT (27H0SQUARE OF DIAGONAL TERM = ,D15.8,/28H0PARTIALLY FACTORFACT0460
     1ED K MATRIX,//)                                                     FACT0465
      RETURN                                                              FACT0470
      END
```

```
      SUBROUTINE FICCL(I,J,L,ICOL)
C     USING FORMULA L=J+SUM(K-ICOL(K)),K=1,I TO RELATE I,J,TO L
       DIMENSION ICOL(1)
      IF(J-ICOL(I))200,300,300
 300  ISUM=0
      DO 305 K=1,I
      ISUM=K-ICOL(K)+ISUM
305   CONTINUE
      L=J+ISUM
      RETURN
200    WRITE(6,4)I,J
 4    FORMAT(31H ELEMENT IS NOT IN BAND REGION,3H I=,I5,3H J=,I5)
```

```
      RETURN
      END
```

```
      SUBROUTINE LOADEQ(A,R,AL,TBEGIN,TFINAL)
C     TO FIND GRNERALIZED NODAL LOAD AND EXTERNALLY-APPLIED LOAD TRANS-
C     FORMATION MATRICES
      DIMENSION A(8,8),FM(8,2),FMC(8,2),FML(8,2)
      COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 A,AL
      IF(TFINAL .EQ. 0.0) RETURN
      WRITE(MWRITE,47) TBEGIN,TFINAL
47    FORMAT('0   STARTING TIME CF FORCING FUNCTION (SEC) =',E15.6,/,
     *'     STOPPING TIME OF FORCING FUNCTICN (SEC) =',E15.6)
      READ(MREAD,6) NOFT1,NOFT2,NOFT3
6     FORMAT(3I5)
7     FORMAT(I5,3E15.6)
8     FORMAT(2I5,2E15.6)
      IF(NOFT1 .EQ. 0) GO TO 54
      READ(MREAD,7)(JELEM(I),ETA(I),RTOV(I),RTOW(I),I=1,NOFT1)
      DO 100 I=1,NOFT1
      SL=ETA(I)
      X=AL/R/2
      FM(1,1)=COS(SL/R)
      FM(2,1)=-SIN(SL/R)
      FM(3,1)=-R*(1.-COS(SL/R)*CCS(X))
      FM(4,1)=SL
      FM(5,1)=0.0
      FM(6,1)=0.0
      FM(7,1)=SL**2
      FM(8,1)=SL**3
      FM(1,2)=SIN(SL/R)
      FM(2,2)=COS(SL/R)
      FM(3,2)=R*SIN(SL/R)*COS(X)
      FM(4,2)=0.0
      FM(5,2)=SL**2
      FM(6,2)=SL**3
      FM(7,2)=0.0
      FM(8,2)=0.0
      DO 101 M=1,8
      DO 101 N=1,2
      FM1(I,M,N)=0.0
      DO 101 K=1,8
101   FM1(I,M,N)=FM1(I,M,N)+A(K,M)*FM(K,N)
100   CONTINUE
54    DO 202 M=1,8
      DO 202 N=1,2
      FMC(M,N)=0.0
202   FML(M,N)=0.0
      X=AL/R/2.
      FMC(1,1)=R*2.*SIN(X)
      FMC(3,1)=-R*AL+R**2*SIN(2.*X)
      FMC(7,1)=AL**3/12.
```

```
      FMC(2,2)=R*2.*SIN(X)
      FMC(5,2)=AL**3/12.
      FML(2,1)=-R**2*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(4,1)=AL**2/12.
      FML(8,1)=AL**4/80.
      FML(1,2)=R**2*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(3,2)=R**3*COS(X)*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(6,2)=AL**4/80.
      DO 201 M=1,8
      DO 201 N=1,2
      FM2(M,N)=0.0
      FM3(M,N)=0.0
      DO 201 K=1,8
      FM2(M,N)=FM2(M,N)+A(K,M)*FMC(K,N)
      FM3(M,N)=FM3(M,N)+A(K,M)*FML(K,N)
201   CONTINUE
41    IF(NOFT2 .EQ. 0) GO TO 42
      READ(MREAD,8)(NSTF2(I),NELF2(I),RTO2V(I),RTO2W(I),I=1,NOFT2)
42    IF(NOFT3 .EQ. 0) RETURN
      READ(MREAD,8) (NSTF3(I),NELF3(I),RTC3V(I),RTO3W(I),I=1,NOFT3)
      RETURN
      END


      SUBROUTINE LOADFT(TIME,NREADF)
C     TO FIND THE GENERALIZED NODAL LOAD VECTOR EQUIVALENT TO THE
C     EXTERNALLY-APPLIED LOAD
      DIMENSION ELF(8)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 FMECH,ELF
      IF(NREADF .GT. 0) GO TO 50
51    READ(MREAD,52) T2,AMP2FV,AMP2FW
52    FORMAT(3E15.6)
      NREADF=1
      SLCPEV=(AMP2FV-AMP1FV)/(T2-T1)
      SLOPEW=(AMP2FW-AMP1FW)/(T2-T1)
50    IF(TIME .LE. T2) GO TO 53
      T1=T2
      AMP1FV=AMP2FV
      AMP1FW=AMP2FW
      GO TO 51
53    AMPFV=AMP1FV+(TIME-T1)*SLOPEV
      AMPFW=AMP1FW+(TIME-T1)*SLOPEW
      DO 57 I=1,NI
57    FMECH(I)=0.0
      IF(NOFT1 .EQ. 0) GO TO 54
      DO 100 I=1,NOFT1
      NE=JELEM(I)
      FMV=AMPFV*RTOV(I)
      FMW=AMPFW*RTOW(I)
      DO 101 J=1,8
101   ELF(J)=FM1(I,J,1)*FMV+FM1(I,J,2)*FMW
```

```
 100    CALL ASSEF(NE,IK,ELF,FMECH)
 54     IF(NOFT2 .EQ. 0) GO TO 55
        DO 200 I=1,NOFT2
        NSTAT=NSTF2(I)
        NEND=NELF2(I)
        FMV=AMPFV*RTO2V(I)
        FMW=AMPFW*RTO2W(I)
        DO 201 J=1,8
 201    ELF(J)=FM2(J,1)*FMV+FM2(J,2)*FMW
        DO 202 NN=1,NEND
        NE=(NSTAT-1)+NN
        IF(NE .GT. IK) NE=NE-IK
 202    CALL ASSEF(NE,IK,ELF,FMECH)
 200    CONTINUE
 55     IF(NOFT3 .EQ. 0) GO TO 90
        DO 300 I=1,NOFT3
        PIE=3.14159265
        NSTAT=NSTF3(I)
        NEND=NELF3(I)
        PIEP=PIE/NEND
        FMV=AMPFV*RTO3V(I)
        FMW=AMPFW*RTO3W(I)
        FMW1=0.0
        FMV1=0.0
        DO 301 NN=1,NEND
        NE=(NSTAT-1)+NN
        IF(NE .GT. IK) NE=NE-IK
        X=PIEP*NN
        FMW2=SIN(X)*FMW
        FMV2=SIN(X)*FMV
        AFSW=(FMW1+FMW2)/2.
        BFSW=(FMW2-FMW1)
        AFSV=(FMV1+FMV2)/2.
        BFSV=(FMV2-FMV1)
        FMW1=FMW2
        FMV1=FMV2
        DO 302 J=1,8
 302    ELF(J)=FM2(J,1)*AFSV+FM2(J,2)*AFSW+FM3(J,1)*BFSV+FM3(J,2)*BFSW
 301    CALL ASSEF(NE,IK,ELF,FMECH)
 300    CONTINUE
 90     IF(NBCOND .EQ. 0) RETURN
        DO 91 I=1,NBCOND
        JT4=NODEB(I)*4
        FMECH(JT4-3)=0.0
        IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FMECH(JT4-1)=0.0
        IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FMECH(JT4-2)=0.0
 91     CONTINUE
 56     RETURN
        END


        SUBROUTINE MINV(A,N,DET,L,M)
C       INVERT MATRIX A
        DIMENSION A(1),L(1),M(1)
        DOUBLE PRECISION A,DET,BIGA,HOLD
C                                                                 MINV 053
C          SEARCH FOR LARGEST ELEMENT                             MINV 054
```

```
C
       DET=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10  IF(DABS(BIGA)-DABS(A(IJ)))15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
   45 IF(BIGA) 48,46,48
   46 DET=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
```

```
      IJ=I-N                                                            MINV 114
      DO 65 J=1,N                                                       MINV 115
      IJ=IJ+N                                                           MINV 116
      IF(I-K) 60,65,60                                                  MINV 117
   60 IF(J-K) 62,65,62                                                  MINV 118
   62 KJ=IJ-I+K                                                         MINV 119
      A(IJ)=HOLD*A(KJ)+A(IJ)                                            MINV M02
   65 CONTINUE                                                          MINV 121
C                                                                       MINV 122
C        DIVIDE ROW BY PIVOT                                            MINV 123
C                                                                       MINV 124
      KJ=K-N                                                            MINV 125
      DO 75 J=1,N                                                       MINV 126
      KJ=KJ+N                                                           MINV 127
      IF(J-K) 70,75,70                                                  MINV 128
   70 A(KJ)=A(KJ)/BIGA                                                  MINV 129
   75 CONTINUE                                                          MINV 130
C                                                                       MINV 131
C        PRODUCT OF PIVOTS                                              MINV 132
C                                                                       MINV 133
      DET=DET*BIGA
C                                                                       MINV 135
C        REPLACE PIVOT BY RECIPROCAL                                    MINV 136
C                                                                       MINV 137
      A(KK)=1.0/BIGA                                                    MINV 138
   80 CONTINUE                                                          MINV 139
C                                                                       MINV 140
C        FINAL ROW AND COLUMN INTERCHANGE                               MINV 141
C                                                                       MINV 142
      K=N                                                               MINV 143
  100 K=(K-1)                                                           MINV 144
      IF(K) 150,150,105                                                 MINV 145
  105 I=L(K)                                                            MINV 146
      IF(I-K) 120,120,108                                               MINV 147
  108 JQ=N*(K-1)                                                        MINV 148
      JR=N*(I-1)                                                        MINV 149
      DO 110 J=1,N                                                      MINV 150
      JK=JQ+J                                                           MINV 151
      HOLD=A(JK)                                                        MINV 152
      JI=JR+J                                                           MINV 153
      A(JK)=-A(JI)                                                      MINV 154
  110 A(JI) =HOLD                                                       MINV 155
  120 J=M(K)                                                            MINV 156
      IF(J-K) 100,100,125                                               MINV 157
  125 KI=K-N                                                            MINV 158
      DO 130 I=1,N                                                      MINV 159
      KI=KI+N                                                           MINV 160
      HOLD=A(KI)                                                        MINV 161
      JI=KI-K+J                                                         MINV 162
      A(KI)=-A(JI)                                                      MINV 163
  130 A(JI) =HOLD                                                       MINV 164
      GO TO 100                                                         MINV 165
  150 RETURN                                                            MINV 166
      END
```

```
      SUBROUTINE OMULT(SQVCT,RWVCT,NCOL,NROWS,ACC,KROW,NDEX,NIRREG)
```

```
C       TO FIND ACC OF (SQVCT)*(RWVCT)=(ACC)
        DIMENSION SQVCT(1),RWVCT(1),NCOL(1),ACC(1),KROW(1),NDEX(1)
        REAL*8 SQVCT,RWVCT,SUM,ACC
        INDEX=0
        NROWM=NROWS-1
        IF (NIRREG .GT. 0) GO TO 200
C       HIGH SPEED PRODUCT FOR REGULAR MATRICES
        DO 100 NN=1,NROWM
        SUM=0.0
        IP1=NN+1
        KST=NCOL(NN)
        INDEX=INDEX+NN-KST
        DO 101 KPL=KST,NN
        IJ=INDEX+KPL
 101    SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
C       NOW FOR THE COLUMN ELEMENTS
        JNDEX=IJ
        DO 102 KPL=IP1,NROWS
        IF(NN.LT.NCOL(KPL))GO TO 100
        JNDEX=JNDEX+KPL-NCOL(KPL)
 102    SUM=SUM+SQVCT(JNDEX)*RWVCT(KPL)
 100    ACC(NN)=ACC(NN)+SUM
C       NOW FOR THE LAST ROW
 104    KADD=NCOL(NROWS)
        SUM=0.0
        INDEX=INDEX+NROWS-KADD
        DO 103 KPL=KADD,NROWS
        IJ=INDEX+KPL
 103    SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
        ACC(NROWS)=ACC(NROWS)+SUM
        RETURN
C       MEDIUM SPEED PRODUCT FOR NIRREG .LE. NROWS/2
 200    IF (NIRREG .GT. NROWS/2) GO TO 201
        DO 105 NN=1,NROWM
        IP1=NN+1
        KST=NCOL(NN)
        INDEX=INDEX+NN-KST
        SUM=0.0
        DO 106 KPL=KST,NN
        IJ=INDEX+KPL
 106    SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
        NCK=0
        JNDEX=IJ
 107    DO 108 KPL=IP1,NROWS
        IF(NN .LT. NCOL(KPL)) GO TO 109
        JNDEX=JNDEX+KPL-NCOL(KPL)
 108    SUM=SUM+SQVCT(JNDEX)*RWVCT(KPL)
        GO TO 105
 109    NCK=NCK+1
        IF (NCK .GT.NIRREG) GO TO 105
        IF (KPL .GE. KROW(NCK)) GO TO 109
        IP1=KROW(NCK)
        JNDEX=NDEX(NCK)+NN
        GO TO 107
 105    ACC(NN)=ACC(NN)+SUM
        GO TO 104
 201    DO 503 NN=1,NROWM
        IP1=NN+1
        K=NCOL(NN)
        INDEX=INDEX+NN-K
```

```
      SUM=0.0
      DO 502 KRX=K,NN
      IJ=INDEX+KRX
  502 SUM=SUM+SQVCT(IJ)*RWVCT(KRX)
      JNDEX=IJ
      DO 504 KRX=IP1,NROWS
      K=NCOL(KRX)
      JNDEX=JNDEX+KRX-K
      IF (NN .LT. K) GO TO 504
      SUM=SUM+SQVCT(JNDEX)*RWVCT(KRX)
  504 CONTINUE
  503 ACC(NN)=ACC(NN)+SUM
      GO TO 104
      END
```

```
      SUBROUTINE QREM(A,AL,R)
C     TO FIND EFFECTIVE STIFFNESS MATRIX DUE TO ELASTIC RESTRAINTS
      DIMENSION A(8,8),ELR(8,8),ELRR(8,8),ELRP(8,8)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /ELFU/ SPRIN(2060),FQREF(205),NORP,NORU,NREL(4),REX(4),
     *NRST(4),NREU(4)
      REAL*8 A,AL,FQREF,SPRIN,ELRP
      IF (NORP .EQ. 0) GO TO 1
      READ(MREAD,2) SCTP,SCRP,(NREL(I),REX(I),I=1,NORP)
    2 FORMAT(2E15.6/(4(I5,E15.6)))
      DO 10 IQ=1,NORP
      NE=NREL(IQ)
      SL=REX(IQ)
      X=AL/R/2.
      SX=SL/R
      DO 11 I=1,8
      DO 11 J=1,8
   11 ELR(I,J)=0.0
      ELR(1,1)=SCTP
      ELR(3,1)=SCTP*R*(-COS(SX)+COS(X))
      ELR(4,1)=SL*SCTP*COS(SX)
      ELR(5,1)=SCTP*SL**2*SIN(SX)
      ELR(6,1)=SCTP*SL**3*SIN(SX)
      ELR(2,2)=SCTP
      ELR(3,2)=SCTP*R*SIN(SX)
      ELR(4,2)=-SCTP*SL*SIN(SX)
      ELR(5,2)=SCTP*SL**2*COS(SX)
      ELR(6,2)=SCTP*SL**3*COS(SX)
      ELR(3,3)=SCTP*R**2*(1.-2.*COS(SX)*COS(X)+COS(X)**2)+SCRP
      ELR(4,3)=-SCTP*R*SL*(1.-COS(SX)*COS(X))-SCRP*SL/R
      ELR(5,3)=SCTP*R*SL**2*SIN(SX)*COS(X)+2.*SL*SCRP
      ELR(6,3)=SCTP*R*SL**3*SIN(SX)*COS(X)+3.*SL**2*SCRP
      ELR(4,4)=SCTP*SL**2+SL**2*SCRP/R**2
      ELR(5,4)=-2.*SL**2*SCRP/R
      ELR(6,4)=-3.*SL**3*SCRP/R
      ELR(5,5)=SL**4*SCTP+4.*SL**2*SCRP
      ELR(6,5)=SL**5*SCTP+6.*SCRP*SL**3
      ELR(6,6)=SL**6*SCTP+9.*SL**4*SCRP
      ELR(7,1)=SCTP*SL**2*COS(SX)
      ELR(8,1)=SCTP*SL**3*COS(SX)
```

```
      ELR(7,2)=-SCTP*SL**2*SIN(SX)
      ELR(8,2)=-SCTP*SL**3*SIN(SX)
      ELR(7,3)=-R*(1.-COS(SX)*COS(X))*SCTP*SL**2-SL**2*SCRP/R
      ELR(8,3)=-R*(1.-COS(SX)*COS(X))*SCTP*SL**3-SL**3*SCRP/R
      ELR(7,4)=(SCTP+SCRP/R**2)*SL**3
      ELR(8,4)=(SCTP+SCRP/R**2)*SL**4
      ELR(7,5)=-2.*SL**3*SCRP/R
      ELR(8,5)=-2.*SL**4*SCRP/R
      ELR(7,6)=-3.*SL**4*SCRP/R
      ELR(8,6)=-3.*SL**5*SCRP/R
      ELR(7,7)=ELR(8,4)
      ELR(8,7)=(SCTP+SCRP/R**2)*SL**5
      ELR(8,8)=(SCTP+SCRP/R**2)*SL**6
      DO 12 I=1,7
      IP1=I+1
      DO 12 J=IP1,8
12    ELR(I,J)=ELR(J,I)
      DO 13 I=1,8
      DO 13 J=1,8
      ELRR(I,J)=0.0
      DO 13 K=1,8
13    ELRR(I,J)=ELRR(I,J)+ELR(I,K)*A(K,J)
      DO 14 I=1,8
      DO 14 J=1,8
      ELRP(I,J)=0.0
      DO 14 K=1,8
14     ELRP(I,J)=ELRP(I,J)+A(K,I)*ELRR(K,J)
10    CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
1     IF(NORU .EQ. 0) GO TO 31
      READ(MREAD,3) SCTU,SCRU,(NRST(I),NREU(I),I=1,NORU)
3     FORMAT(2E15.6,8I5)
      DO 4 I=1,8
      DO 4 J=1,8
4     ELR(I,J)=0.0
      X=AL/R/2.
      P2=2.*X**2*SIN(X)+4.*X*COS(X)-4.*SIN(X)
      P3=-2.*X**3*COS(X)+6.*X**2*SIN(X)+12.*X*COS(X)-12.*SIN(X)
      ELR(1,1)=SCTU*AL
      ELR(2,2)=SCTU*AL
      ELR(3,1)=SCTU*R*(-R*2.*SIN(X)+COS(X)*AL)
      ELR(3,3)=SCTU*R**2*(AL+COS(X)**2*AL-2.*R*SIN(2.*X))+SCRU*AL
      ELR(4,2)=-SCTU*R**2*(-2.*X*COS(X)+2.*SIN(X))
      ELR(4,4)=(SCTU+SCRU/R**2)*AL**3/12.
      ELR(5,2)=SCTU*R**3*P2
      ELR(5,4)=-SCRU*AL**3/(6.*R)
      ELR(5,5)=SCTU*AL**5/80.+SCRU*AL**3/3.
      ELR(6,1)=SCTU*R**4*P3
      ELR(6,3)=SCTU*R**5*COS(X)*P3+SCRU*AL**3/4.
      ELR(6,6)=SCTU*AL**7/448.+9.*SCRU*AL**5/80.
      ELR(7,1)=SCTU*R**3*P2
      ELR(7,3)=-SCTU*R*(AL**3/12.-R**3*COS(X)*P2)-SCRU*AL**3/(12.*R)
      ELR(7,6)=-3.*SCRU*AL**5/(R*80.)
      ELR(7,7)=(SCTU+SCRU/R**2)*AL**5/80.
      ELR(8,2)=-SCTU*R**4*P3
      ELR(8,4)=ELR(7,7)
      ELR(8,5)=-SCRU*AL**5/(40.*R)
      ELR(8,8)=(SCTU+SCRU/R**2)*AL**7/448.
      DO 5 I=1,7
      IP1=I+1
      DO 5 J=IP1,8
```

```
 5      ELR(I,J)=ELR(J,I)
        DO 6 I=1,8
        DO 6 J=1,8
        ELRR(I,J)=0.0
        DO 6 K=1,8
 6      ELRR(I,J)=ELRR(I,J)+ELR(I,K)*A(K,J)
        DO 7 I=1,8
        DO 7 J=1,8
        ELRP(I,J)=C.0
        DO 7 K=1,8
 7      ELRP(I,J)=ELRP(I,J)+A(K,I)*ELRR(K,J)
        DO 20 IQ=1,NORU
        NSTAT=NRST(IQ)
        NEND=NREU(IQ)
        DO 21 NN=1,NEND
        NE=(NSTAT-1)+NN
        IF(NE .GT. IK) NE=NE-IK
 21     CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
 20     CONTINUE
 31     IF(NBCOND .EQ. 0) RETURN
        DO 91 I=1,NBCOND
        JT4=NODEB(I)*4
        JT4M3=JT4-3
        JT4M2=JT4-2
        JT4M1=JT4-1
        CALL ERC(JT4M3,SPRIN,NI,ICOL)
        IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,SPRIN,NI,ICOL)
        IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,SPRIN,NI,ICOL)
 91     CONTINUE
        RETURN
        END
```

```
      SUBROUTINE SOLV (STIFM,G,SOL,NCOL,KRCW,NDEX,NROWS,NIRREG)
C     SOLVE (LL*)(SOL)=(FORCE) FOR DISPLACEMENTS (SOL)
      CIMENSION STIFM(1),G(1),SOL(1), NCOL(1),KROW(1),NDEX(1)
       REAL*8 STIFM,G,SOL,SUM,SU
C     INTERMEDIATE SOLUTICN USING THE LOWER TRIANGLE
  100 INDEX=0
      SOL(1)=G(1)
      DO 104 I=2,NROWS
      IM1=I-1
      SUM=0.0
      K=NCOL(I)
      INDEX=INDEX+I-K
      IF (IM1-K) 103,101,101
  101 DO 102 J=K,IM1
      IJ=INDEX+J
      SU=SOL(J)
  102 SUM=SUM+STIFM(IJ)*SU
  103 II=INDEX+I
  104 SOL(I)= G(I)-SUM
C     SOL CONTAINS THE INTERMEDIATE SOLUTICN
C     COMPLETE THE SOLUTION USING THE UPPER TRIANGLE
      SOL(NROWS)=SOL(NROWS)/STIFM(II)
      INDEX=INDEX-NROWS+NCOL(NROWS)
      IF (NIRREG .GT. 0) GO TO 111
```

```
      DO 109 KK=2,NROWS
      I=NROWS+1-KK
      IP1=I+1
      SUM=0.0
      JNDEX=INDEX+I
      DO 107 J=IP1,NROWS
      K=NCOL(J)
      IF (I-K) 108,106,106
  106 JNDEX=JNDEX+J-K
      SU=SOL(J)
  107 SUM=SUM+STIFM(JNDEX)*SU
  108 II=INDEX+I
      SOL(I)= SOL(I)/STIFM (II)-SUM
  109 INDEX=INDEX-I+NCOL(I)
      RETURN
  111 IF (NIRREG-NROWS /2) 116,116,112
C     TOO MANY IRREGULAR ROWS FOR ACCELERATED SOLUTION
  112 DO 115 KK=2,NROWS
      I=NROWS+1-KK
      IP1=I+1
      JNDEX=INDEX+I
      SUM=0.0
      JNDEX=INDEX+I
      DO 114 J=IP1,NROWS
      K=NCOL(J)
      JNDEX=JNDEX+J-K
      IF (I-K) 114,113,113
 113  SU=SOL(J)
      SUM=SUM+STIFM(JNDEX)*SU
  114 CONTINUE
      II=INDEX+I
      SOL(I)= SOL(I)/STIFM(II) -SUM
  115 INDEX=INDEX-I+NCOL(I)
      RETURN
C     ACCELERATED SOLUTION FOR CASE WITH IRREGULAR ROWS
  116 DO 125 KK=2,NROWS
      I=NROWS+1-KK
      IP1=I+1
      SUM=0.0
      NCK=0
       JNDEX=INDEX+I
  117 DO 119 J=IP1,NROWS
      K=NCOL(J)
      IF (I-K) 120,118,118
  118 JNDEX=JNDEX+J-K
      SU=SOL(J)
  119 SUM=SUM+STIFM(JNDEX)*SU
      GO TO 124
  120 NCK=NCK+1
      IF (NIRREG-NCK) 124,121,121
  121 IP1=KROW(NCK)
      IF (I-NCOL(IP1)) 120,122,122
  122 IF (IP1-J) 120,123,123
  123 JNDEX=NDEX(NCK)+I
      GO TO 117
  124 II=INDEX+I
      SOL(I)= SOL(I)/STIFM(II) -SUM
  125 INDEX=INDEX-I+NCOL(I)
      RETURN
      END
```

```
      SUBROUTINE STRESS
C     TO EVALUATE GENERALIZED NODAL LOAD VECTOR DUE TO LARGE DEFLECTION
C     AND ELASTIC-PLASTIC STRAIN
      DIMENSION ELFP(8),BEPS(3),CEPS(3,3),BINPW(3),BIMPW(3),HWB(3,3),
     *PN(8),PM(8),HNL(8)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      REAL*8 BEP,FLVA,ELFP,DISP,DELD
      DO 502 IR=1,IK
      DO 503 J=1,NOGA
      BINP(IR,J)=0.
      BIMP(IR,J)=0.
 202  DO 402 I=1,3
      BEPS(I)=0.
      DO 402 K=1,8
      INDEX=(IR-1)*4+K
 402  BEPS(I)=BEPS(I)+BEP(J,I,K)*DELD(INDEX)
      CEPS(J,2)=0.0
      DO 403 K=1,8
      INDEX=(IR-1)*4+K
 403  CEPS(J,2)=CEPS(J,2)+BEP(J,2,K)*DISP(INDEX)
 205  FARE=BEPS(1)+CEPS(J,2)*BEPS(2)-BEPS(2)**2/2.
      FCUR=BEPS(3)
      DO 151 K=1,NFL
      BFNP=0.
      BEPX=FARE+GZETA(K)*FCUR
      IF(DS.GT. 0.0) RFACTR=1.+(C6*ABS(BEPX))**C5
      DO 35 L=1,NSFL
      SNS(IR,J,K,L)=SNS(IR,J,K,L)+YOUNG*BEPX
      IF(DS.EQ. 0.0) GO TO 255
      IF(SNS(IR,J,K,L)-SNO(L))30,301,91
 91   SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)-SNY)301,301,20
 20   SNS(IR,J,K,L)=SNY
      GO TO 301
 30   IF(SNS(IR,J,K,L)+SNO(L))92,301,301
 92   SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)+SNY)40,301,301
 40   SNS(IR,J,K,L)=-SNY
      GO TO 301
 255  IF(SNS(IR,J,K,L)-SNO(L)) 18,301,17
 17   SNS(IR,J,K,L)=SNO(L)
      GO TO 301
 18   IF(SNS(IR,J,K,L)+SNO(L)) 19, 301,301
 19   SNS(IR,J,K,L)=-SNO(L)
 301  BFNP=BFNP+SNS(IR,J,K,L)*ASFL(K,L)
 35   CONTINUE
      BINP(IR,J)=BINP(IR,J)+BFNP
      BIMP(IR,J)=BIMP(IR,J)+BFNP*GZETA(K)
 151  CONTINUE
 503  CONTINUE
 107  DO 101 J=1,NOGA
```

```
      BINPW(J)=BINP(IR,J)*AWG(J)
      BIMPW(J)=BIMP(IR,J)*AWG(J)
      HWB(J,2)=CEPS(J,2)*AWG(J)*BINP(IR,J)
101    CONTINUE
      DO 102 I=1,8
      PN(I)=0.
      PM(I)=0.
      HNL(I)=0.0
      DO 102 J=1,NOGA
      PN(I)=PN(I)+BEP(J,1,I)*BINPW(J)
      PM(I)=PM(I)+BEP(J,3,I)*BIMPW(J)
102   HNL(I)=HNL(I)+BEP(J,2,I)*HWB(J,2)
200   DO 105 I=1,8
105   ELFP(I)=PN(I)+PM(I)+HNL(I)
502   CALL ASSEF(IR,IK,ELFP,FLVA)
      RETURN
      END




      SUBROUTINE TSTEP(AMASS,ELK,ISIZE,KROW,NDEX,NIRREG,DELTAT)
C     TO FIND DELTAT IF IT IS NOT SPECIFIED
      DIMENSION AMASS(1),STIFK(2060),ELK(8,8),TRIAL(205),VMULT(205),
     *VECTR(205),KROW(1),NDEX(1)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      REAL*8 AMASS,STIFK,ELK,VMULT,BONE,EPSLN,TRIAL,VECTR,BOLD,BNEW,
     *BKTH,FREQ
      DO 80 L=1,ISIZE
80    STIFK(L)=0.0
      DO 81 IR=1,IK
81          CALL ASSEM(IR,IK,ELK,STIFK,ICOL,NI)
      DO 3 K=1,NI
3     TRIAL(K)=1.0
      IF(NBCOND .EQ. 0) GO TO 90
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,STIFK,NI,ICOL)
      TRIAL(JT4M3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,STIFK,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,STIFK,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) TRIAL(JT4M1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) TRIAL(JT4M2)=0.0
91    CONTINUE
90    MRANK=NI
      BONE=0.
      EPSLN=1.0D-07
2     BOLD=1.0
      DO 14 IKK=1,4
      DO 12 ILL=1,50
      DO 4 I=1,MRANK
4     VMULT(I)=0.0
      CALL OMULT(STIFK,TRIAL,ICOL,NI,VMULT,KROW,NDEX,NIRREG)
      CALL SOLV(AMASS,VMULT,VECTR,ICOL,KROW,NDEX,NI,NIRREG)
```

```
      BNEW=-1.
      DO 6 K=1,MRANK
      IF(BNEW-DABS(VECTR(K)))60,60,6
60    BNEW=DABS(VECTR(K))
6     CONTINUE
      DO 7 K=1,MRANK
      IF(BNEW-DABS(VECTR(K)))7,8,7
7     CONTINUE
8     MROW=K
      BNEW=VECTR(K)
      DO 9 K=1,MRANK
9     TRIAL(K)=VECTR(K)/BNEW
      IF(DABS(BNEW/BOLD-1.0)-EPSLN)15,15,10
C     ITERATION
10    BKTH=BOLD
      BOLD=BNEW
12    CONTINUE
      EPSLN=EPSLN*10.
14    CONTINUE
C     NOT CONVERGING AFTER IL*IK ITERATIONS
      EPSLN=1.0
      BONE=BNEW
      GO TO 32
C     EIGEN VALUE FOUND
15    BONE=BNEW
32    WRITE(MWRITE,24) (TRIAL(J),J=1,NI)
24    FORMAT(/,'     EIGEN VECTOR OF HIGHEST MODE',/,21X,'V',19X,'W',17X
     *,'PSI',17X,'CHI',/,(11X,4D20.8))
      FREQ=DSQRT(YOUNG*BONE/DENS)
      FACTCL=0.8
      DELTAT=FACTCL*2./FREQ
      WRITE(MWRITE,25)FREQ
25    FORMAT(/,'     HIGHEST NATURAL FREQUENCY (RAD/SEC) =',E17.8)
      RETURN
      END
```

5.2 JET 3B: Uniform Thickness Circular Ring, Houbolt's Timewise Operator

The JET 3B program consists of the following main programs and subroutines:

1.	JET 3B MAIN PROGRAM	(partial ring)
2.	ASSEM	
3.	ASSEF	
4.	IDENT	
5.	IMPULS	
6.	Print	
7.	JET 3B MAIN PROGRAM	(complete ring)
8.	ASSEM	
9.	ASSEF	
10.	IDENT	
11.	IMPULS	
12.	PRINT	

13. ELMPP
14. LOADEQ
15. LOADFT
16. QREM
17. STRESS
18. ERC
19. FAC
20. FICOL
21. MINV
22. OMULT
23. SOLV

Note that the subroutines in items 13 through 23 are common to each of the two groups of "control programs".

A complete FORTRAN IV listing of JET 3B is given below in the above order. The number of memory locations required is approximately 160,000 bytes.

```
C        JET3B MAIN PROGRAM FOR UNIFORM THICKNESS CIRCULAR RING
C        JET3B HOUBOLT OPERATOR
C        ***** PARTIAL RING *****
       DIMENSION A(6,3),AMASS(2060),BMASS(2060),Y(51),Z(51),TXG(6),TWG(6)
      *,ES(6),GFL(6),EPS(5),SIG(5),INUM(205),KROW(8),NDEX(8)
        DIMENSION DDELD(205),DISUM(205),DIS(205),DISM1(205),DISM2(205),
      *FLR(205),FLN(205),FLVM(205),STIFK(2060)
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICGL(205),NBCOND,NBC(4),NODEB(4)
       COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELC(205),SNS(50,3,6,5),
      *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
        COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
        COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
        COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
      *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
      *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
      *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
        COMMON /ELFU/ SPRIN(2060),NORP,NORL,NREL(4),REX(4),
      *NRST(4),NREU(4)
        MREAD=5
        MWRITE=6
        MPUNCH=7
        READ(MREAD,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL,MM,M1,M2
        READ(MREAD,2) DELTAT,THETA,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
  1     FORMAT(5E15.6/7I5)
  2     FORMAT(5E15.6/(4E15.6))
        READ(MREAD,3)(AXG(K),K=1,NOGA)
        READ(MREAD,3)(AWG(K),K=1,NOGA)
        READ(MREAD,3)(TXG(K),K=1,NFL)
        READ(MREAD,3)(TWG(K),K=1,NFL)
  3     FORMAT(4F15.10)
        READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
  4     FORMAT(9I5)
        READ(MREAD,9) NQR,NORP,NORU
  9     FORMAT(3I5)
              CALL IDENT(EXANG,NQR)
        PIE=3.14159265
        IKP1=IK+1
        NI=IKP1*4
        THETA=THETA*PIE/180.
        BX=PIE*EXANG/180.
        BL=BX*R
        AL=BL/IK
        AX=BX/IK
        DO 70 K=1,NFL
        GFL(K)=H*B*TWG(K)/2.
  70    GZETA(K)=H*TXG(K)/2.
        ES(1)=SIG(1)/EPS(1)
        YOUNG=ES(1)
        IF(NSFL-1)77,77,76
  76    DO 78 L=2,NSFL
  78    ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
  77    ES(NSFL+1)=0.0
        DO 79 L=1,NSFL
  79    SNO(L)=ES(1)*EPS(L)
        DO 71 K=1,NFL
        DO 71 L=1,NSFL
  71    ASFL(K,L)=GFL(K)*(ES(L)-ES(L+1))/ES(1)
        DO 72 K=1,NOGA
```

```
      AXG(K)=AXG(K)*AL/2.
72    AWG(K)=AWG(K)*AL/2.
      DO 15 I=1,8
15    ICOL(I)=1
      DO 16 I=3,IKP1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX =',I5)
             CALL ELMPP(AL,A,AMASS,STIFK,ISIZE)
      DO 36 L=1,ISIZE
36    BMASS(L)=AMASS(L)
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
      IF (NQR .EQ. 0) GO TO 20
      CALL QREM(A,AL,R)
20    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2
      C2=1./(2.*DELTAT**2)
      HHALF=H/2.
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
      IT=0
      TIME=0.0
      DO 75 I=1,IKP1
      ANG=(I-1)*AX+THETA
      Y(I)=SIN(ANG)*R
75    Z(I)=COS(ANG)*R
             CALL IMPULS(DELTAT,AL)
```

```
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0   THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
            CALL LOADEQ(A,R,AL,TBEGIN,TFINAL)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      DO 34 I=1,NI
34    FMECH(I)=0.0
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 30
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      CALL SOLV(AMASS,FMECH,DDELD,ICOL,KROW,NDEX,NI,NIRREG)
      GO TO 31
30    DO 32 I=1,NI
32    DDELD(I)=0.0
31    DO 33 I=1,NI
33    DISUM(I)=2.*DTSQ*DDELD(I)+6.*DELD(I)+6.*DISP(I)
      MLOAD=NLOAD
      DO 35 I=1,NI
      FLR(I)=FMECH(I)
35    FLVM(I)=0.0
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      DO 37 L=1,ISIZE
37    AMASS(L)=6.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      ITT=1
      TIME=ITT*DELTAT
      NLOAD=2
      DO 60 I=1,NI
      FLVA(I)=0.C
60    FMECH(I)=0.0
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 38
      NLOAD=1
      CALL LOADFT(TIME,NREADF)
 38   DO 39 I=1,NI
39    FLVM(I)=DTSQ*FMECH(I)+FLVM(I)
      CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 61 I=1,NI
      DELD(I)=DIS(I)-DISP(I)
61    DISM1(I)=DTSQ*DDELD(I)-DIS(I)+2.*DISP(I)
      DO 100 L=1,ISIZE
100   AMASS(L)=2.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      IF(MLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
120   ITT=ITT+1
      TIME=ITT*DELTAT
45    DO 121 I=1,NI
      DISM2(I)=DISM1(I)
```

```
      DISM1(I)=DISP(I)
      DISP(I)=DIS(I)
      FLR(I)=FMECH(I)
      FLN(I)=FLVA(I)
      FLVA(I)=0.0
      FMECH(I)=0.0
      FLVM(I)=0.0
121   DISUM(I)=5.*DISP(I)-4.*DISM1(I)+DISM2(I)
      MLOAD=NLOAD
      CALL STRESS
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
      CALL LOADFT(TIME,NREADF)
122   DO 123 I=1,NI
123   FLVM(I)=(FMECH(I)-(2.*FLVA(I)-FLN(I)))*DTSQ+FLVM(I)
      IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVM(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVM(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVM(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DIS(I)-DISP(I)
      IF(MLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
41    IT=ITT-1
      TIME=IT*DELTAT
      IF(IT .EQ. 1) CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,
     *BMASS,C2,NQR,KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
150   CALL EXIT
      END
```

```
      SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C     ***** PARTIAL RING *****
      DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
 202  DO 402 I=1,8
      M=NN(I)
      DO 402 J=1,8
      N=NN(J)
      IF(M-N)402,403,403
 403  CALL FICOL(M,N,L,ICOL)
      STIFM(L)=STIFM(L)+ELMAS(I,J)
 402  CONTINUE
      RETURN
      END


      SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C     ***** PARTIAL RING *****
      DIMENSION NN(8),FLVA(1),ELFP(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
 121  J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
 123  DO 101 I=1,8
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
 101  CONTINUE
      RETURN
      END


      SUBROUTINE IDENT(EXANG,NOR)
C     ***** PARTIAL RING *****
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      WRITE(MWRITE,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL
 1    FORMAT(' ***JET3B**** A SPATIAL FINITE ELEMENT AND HOUBOLT TEMPOR
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     *AL OPERATOR PROGRAM',/,'     USED TO CALCULATE THE NONLINEAR RESPON
     *SES OF A UNIFORM THICKNESS CIRCULAR',/,'     PARTIAL RING WITH THE
     *FOLLOWING PARAMETERS  ',//,
     *'     MEAN RADIUS OF RING (IN.)          =',E15.6,/,
     *'     WIDTH OF RING (IN.)                =',E15.6,/,
     *'     THICKNESS OF RING (IN.)            =',E15.6,/,
     *'     DENSITY (LB-SEC**2/IN**4)          =',E15.6,/,
     *'     SUBTENDED ANGLE (DEGREE)           =',E15.6,/,
     *'     NUMBER OF ELEMENTS                 =',I5,/,
     *'     NUMBER OF SPANWISE GAUSSIAN PTS    =',I5,/,
     *'     NUMBER OF DEPTHWISE GAUSSIAN PTS   =',I5,/,
     *'     NUMBER OF MECHANICAL SUBLAYERS     =',I5)
 11     IF(NBCOND .EQ. 0) GO TO 12
        DO 14 I=1,NBCOND
        IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
        IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
        IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
 14     CONTINUE
 15     FORMAT('    SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
 16     FORMAT('     CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
 17     FORMAT('     HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
        GO TO 18
 12     WRITE(MWRITE,13)
 13    FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
 18     IF(NQR .EQ. 0) GO TO 19
        WRITE(MWRITE,20)
 20     FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
        RETURN
 19     WRITE(MWRITE,21)
 21     FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
        RETURN
        END



        SUBROUTINE IMPULS(DELTAT,AL)
C       ***** PARTIAL RING *****
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        DO 50 I=1,NI
        DELD(I)=0.0
 50      DISP(I)=0.0
        DO 51 IR=1,IK
        DO 51 J=1,NOGA
        BINP(IR,J)=0.0
        BIMP(IR,J)=0.0
        DO 51 K=1,NFL
        DO 51 L=1,NSFL
        SNP(IR,J,K,L)=0.0
 51     SNS(IR,J,K,L)=0.0
        READ(MREAD,1) NV,IOTA,IOTB,IOTC
 1      FORMAT(4I5)
        WRITE(MWRITE,2) DELTAT
 2       FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
        IF(NV .EQ. 0) WRITE(MWRITE,4)
```

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      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'     THERE IS NO INITIAL IMPULSE   ')
6    FORMAT(/,'     IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
    * INPUT ')
      IF(NV .EQ. 0) RETURN
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21 ) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 42
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
42    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAC
62    FORMAT(2I5,E15.6)
      PIEP=3.14159265/IS2
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP/AL
      DO 63 II=1,IS2
      I=IS1+II
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*II)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*II)/AL
61    CONTINUE
60    IF(NBCOND .EQ.0) RETURN
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
C     ***** PARTIAL RING *****
      DIMENSION Y(51),Z(51),COPY(51),COPZ(51),BEPS(3),EPSI(51),EPSO(51)
      DIMENSION FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),SPRIN(1)
     *,FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
```

```
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
  700 CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
  701 CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
  704 SUM=SUM+SNS(IR,J,K,L)**2*ASFL(K,L)
  703 ELAST=ELAST+SUM*AWG(J)
  702 CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
      DO 30 I=1,NI
   30 FQREF(I)=0.0
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 32 I=1,NI
   32 SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
   31 ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
    1 FORMAT(//////,'    J=',I5,'       TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)  =',E15.6,/,
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          PLASTIC WORK   (IN.-LB.)  =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
   34 FORMAT('   ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
   33 IKP1=IK+1
      DO 11 I=1,IKP1
      ANG=(I-1)*AX+THETA
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG)+DISP(I*4-2)*SIN(ANG)
   11 COPZ(I)=Z(I)-DISP(I*4-3)*SIN(ANG)+DISP(I*4-2)*COS(ANG)
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
  604 BEPS(I)=BEPS(I)+BEP(2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF*FCUR
      EPSO(IR)=FARE+HHALF*FCUR
  601 CONTINUE
```

```
      DO 60  IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I  ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51  I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53  I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,54)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'    STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
50    DO 21  I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,9E12.4,2X,E12.4)
      WRITE(MWRITE,22)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      RETURN
      END
```

```
C       JET3B MAIN PROGRAM FOR UNIFORM THICKNESS CIRCULAR RING
C       JET3B HOUBOLT OPERATOR
C       ***** COMPLETE RING ****
       DIMENSION A(8,8),AMASS(2060),BMASS(2060),Y(51),Z(51),TXG(6),TWG(6)
     *,ES(6),GFL(6),EPS(5),SIG(5),INUM(205),KROW(8),NDEX(8)
        DIMENSION DDELD(205),DISUM(205),DIS(205),DISM1(205),DISM2(205),
     *FLR(205),FLN(205),FLVM(205),STIFK(2060)
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
       COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
        COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
        COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
        COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
        COMMON /ELFU/ SPRIN(2060),NORP,NORU,NREL(4),REX(4),
     *NRST(4),NREU(4)
        MREAD=5
        MWRITE=6
        MPUNCH=7
        READ(MREAD,1) R,B,H,DENS,EXANG,IK,NOGA,NFL,NSFL,MM,M1,M2
        READ(MREAD,2) DELTAT,THETA,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
 1      FORMAT(5E15.6/7I5)
 2      FORMAT(5E15.6/(4E15.6))
        READ(MREAD,3)(AXG(K),K=1,NOGA)
        READ(MREAD,3)(AWG(K),K=1,NOGA)
        READ(MREAD,3)(TXG(K),K=1,NFL)
        READ(MREAD,3)(TWG(K),K=1,NFL)
 3      FORMAT(4F15.10)
        READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
 4      FORMAT(9I5)
        READ(MREAD,9) NQR,NORP,NORU
 9      FORMAT(3I5)
               CALL IDENT(EXANG,NQR)
        PIE=3.14159265
        IKP1=IK+1
        NI=IK*4
        THETA=THETA*PIE/180.
        BX=2.*PIE
        BL=BX*R
        AL=BL/IK
        AX=BX/IK
        DO 70 K=1,NFL
        GFL(K)=H*B*TWG(K)/2.
 70     GZETA(K)=H*TXG(K)/2.
        ES(1)=SIG(1)/EPS(1)
        YOUNG=ES(1)
        IF(NSFL-1)77,77,76
 76     DO 78 L=2,NSFL
 78     ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
 77     ES(NSFL+1)=0.0
        DO 79 L=1,NSFL
 79     SNO(L)=ES(1)*EPS(L)
        DO 71 K=1,NFL
        DO 71 L=1,NSFL
```

```
71    ASFL(K,L)=GFL(K)*(ES(L)-ES(L+1))/ES(1)
      DO 72 K=1,NUGA
      AXG(K)=AXG(K)*AL/2.
72    AWG(K)=AWG(K)*AL/2.
      DO 15 I=1,8
15    ICOL(I)=1
      IKM1=IK-1
      DO 16 I=3,IKM1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      ICOL(IK*4)=1
      ICOL(IK*4-1)=1
      ICOL(IK*4-2)=1
      ICOL(IK*4-3)=1
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX =',I5)
            CALL ELMPP(AL,A,AMASS,STIFK,ISIZE)
      DO 36 L=1,ISIZE
36    BMASS(L)=AMASS(L)
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
      IF (NQR .EQ. 0) GO TO 20
      CALL QREM(A,AL,R)
20    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2
      C2=1./(2.*DELTAT**2)
      HHALF=H/2.
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
```

```
      IT=0
      TIME=0.0
      DO 75 I=1,IK
      ANG=(I-1)*AX+THETA
      Y(I)=SIN(ANG)*R
75    Z(I)=COS(ANG)*R
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0    THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
            CALL LOADEQ(A,R,AL,TBEGIN,TFINAL)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      DO 34 I=1,NI
34    FMECH(I)=0.0
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 30
      NLOAD=1
            CALL LOADFT(TIME,NREADF)
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      CALL SOLV(AMASS,FMECH,DDELD,ICOL,KROW,NDEX,NI,NIRREG)
      GO TO 31
30    DO 32 I=1,NI
32    DDELD(I)=0.0
31    DO 33 I=1,NI
33    DISUM(I)=2.*DTSQ*DDELD(I)+6.*DELD(I)+6.*DISP(I)
      MLOAD=NLOAD
      DO 35 I=1,NI
      FLR(I)=FMECH(I)
35    FLVM(I)=0.0
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      DO 37 L=1,ISIZE
37    AMASS(L)=6.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      ITT=1
      TIME=ITT*DELTAT
      NLOAD=2
      DO 60 I=1,NI
      FLVA(I)=0.0
60    FMECH(I)=0.0
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 38
      NLOAD=1
      CALL LOADFT(TIME,NREADF)
38    DO 39 I=1,NI
39    FLVM(I)=DTSQ*FMECH(I)+FLVM(I)
      CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 61 I=1,NI
      DELD(I)=DIS(I)-DISP(I)
61    DISM1(I)=DTSQ*DDELD(I)-DIS(I)+2.*DISP(I)
      DO 100 L=1,ISIZE
100   AMASS(L)=2.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      IF(MLOAD .EQ. 2) GO TO 120
      APD=0.0
```

```
      DO 46 I=1,NI
46     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
120   ITT=ITT+1
      TIME=ITT*DELTAT
45    DO 121 I=1,NI
      DISM2(I)=DISM1(I)
      DISM1(I)=DISP(I)
      DISP(I)=DIS(I)
      FLR(I)=FMECH(I)
      FLN(I)=FLVA(I)
      FLVA(I)=0.0
      FMECH(I)=0.0
      FLVM(I)=0.0
121   DISUM(I)=5.*DISP(I)-4.*DISM1(I)+DISM2(I)
      DO 47 K=1,4
      DISP(IK*4+K)=DISP(K)
47    DELD(IK*4+K)=DELD(K)
      MLOAD=NLOAD
      CALL STRESS
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
      CALL LOADFT(TIME,NREADF)
122   DO 123 I=1,NI
123   FLVM(I)=(FMECH(I)-(2.*FLVA(I)-FLN(I)))*DTSQ+FLVM(I)
      IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVM(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVM(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVM(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DIS(I)-DISP(I)
      IF(MLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
41    IT=ITT-1
      TIME=IT*DELTAT
      IF(IT .EQ. 1) CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,
     *BMASS,C2,NQR,KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
          CALL PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
```

```
 150    CALL EXIT
        END



        SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C       ***** COMPLETE RING *****
        DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
        J1=IR*4
        NN(1)=J1-3
        NN(2)=J1-2
        NN(3)=J1-1
        NN(4)=J1
        IF(IR-IK) 203,204,204
 203    J2=(IR+1)*4
        NN(5)=J2-3
        NN(6)=J2-2
        NN(7)=J2-1
        NN(8)=J2
        GO TO 202
 204    NN(5)=1
        NN(6)=2
        NN(7)=3
        NN(8)=4
 202    DO 402 I=1,8
        M=NN(I)
        DO 402 J=1,8
        N=NN(J)
        IF(M-N)402,403,403
 403    CALL FICOL(M,N,L,ICOL)
        STIFM(L)=STIFM(L)+ELMAS(I,J)
 402    CONTINUE
        RETURN
        END



        SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C       ***** COMPLETE RING *****
        DIMENSION NN(8),FLVA(1),ELFP(1)
        J1=IR*4
        NN(1)=J1-3
        NN(2)=J1-2
        NN(3)=J1-1
        NN(4)=J1
        IF(IR-IK) 121,122,122
 121    J2=(IR+1)*4
        NN(5)=J2-3
        NN(6)=J2-2
        NN(7)=J2-1
        NN(8)=J2
        GO TO 123
 122    NN(5)=1
        NN(6)=2
        NN(7)=3
        NN(8)=4
```

```
123    DO 101 I=1,8
       M=NN(I)
       FLVA(M)=FLVA(M)+ELFP(I)
101    CONTINUE
       RETURN
       END
```

```
       SUBROUTINE IDENT(EXANG,NQR)
C      ***** COMPLETE RING *****
       COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNU(5)
       COMMON /TAPE/ MREAD,MWRITE,MPUNCH
       WRITE(MWRITE,1) R,B,H,DENS,IK,NOGA,NFL,NSFL
1      FORMAT(' ***JET3B**** A SPATIAL FINITE ELEMENT AND HOUBOLT TEMPOR
     *AL OPERATOR PROGRAM',/,'    USED TO CALCULATE THE NONLINEAR RESPON
     *SES OF A UNIFORM THICKNESS CIRCULAR',/,'    COMPLETE RING WITH THE
     * FOLLOWING PARAMETERS  ',//,
     *'    MEAN RADIUS OF RING (IN.)          =',E15.6,/,
     *'    WIDTH OF RING (IN.)                =',E15.6,/,
     *'    THICKNESS OF RING (IN.)            =',E15.6,/,
     *'    DENSITY (LB-SEC**2/IN**4)          =',E15.6,/,
     *'    NUMBER OF ELEMENTS                 =',I5,/,
     *'    NUMBER OF SPANWISE GAUSSIAN PTS    =',I5,/,
     *'    NUMBER OF DEPTHWISE GAUSSIAN PTS   =',I5,/,
     *'    NUMBER OF MECHANICAL SUBLAYERS     =',I5)
11     IF(NBCOND .EQ. 0) GO TO 12
       DO 14 I=1,NBCOND
       IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
       IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
       IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
14     CONTINUE
15     FORMAT('   SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
16     FORMAT('    CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
17     FORMAT('    HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
       GO TO 18
12     WRITE(MWRITE,13)
13    FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
18     IF(NQR .EQ. 0) GO TO 19
       WRITE(MWRITE,20)
20     FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
       RETURN
19     WRITE(MWRITE,21)
21     FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
       RETURN
       END
```

```
       SUBROUTINE IMPULS(DELTAT,AL)
C      ***** COMPLETE RING *****
       COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
       COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
```

```
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 50 I=1,NI
      DELD(I)=0.0
50     DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
      DO 51 L=1,NSFL
      SNP(IR,J,K,L)=0.0
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'    THERE IS NO INITIAL IMPULSE   ')
6    FORMAT(/,'    IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) GO TO 41
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
      IF(I .GT. IK) I=I-IK
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      IF(IE2P1 .GT. IK) IE2P1=IE2P1-IK
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 42
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
42    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      PIEP=3.14159265/IS2
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP/AL
      DO 63 II=1,IS2
      I=IS1+II
      IF(I .GT. IK) I=I-IK
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*II)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*II)/AL
61    CONTINUE
60    IF(NBCOND .EQ.0) GO TO 41
```

```
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
41    DO 43 K=1,4
      DISP(IK*4+K)=DISP(K)
43    DELD(IK*4+K)=DELD(K)
      RETURN
      END




      SUBROUTINE PRINT(IT,TIME,HHALF,AX,Y,Z,THETA,APDEN,SPRIN,BMASS,C2,
     *NQR,KROW,NDEX,NIRREG,CINETO)
C     ***** COMPLETE RING *****
      DIMENSION Y(51),Z(51),COPY(51),COPZ(51),BEPS(3),EPSI(51),EPSO(51)
      DIMENSION FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),SPRIN(1)
     *,FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNU(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
700   CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
701   CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
704   SUM=SUM+SNS(IR,J,K,L)**2*ASFL(K,L)
703   ELAST=ELAST+SUM*AWG(J)
702   CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
      DO 30 I=1,NI
30    FQREF(I)=0.0
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 32 I=1,NI
32    SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
31    ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
1     FORMAT('1   J=',I5,'       TIME (SEC.) =',E15.6,/,
     *'    TOTAL ENERGY INPUT (IN.-LB.)  =',E15.6,/,
```

```
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          PLASTIC WORK   (IN.-LB.)  =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
34    FORMAT('   ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
33    IKP1=IK+1
      DO 11 I=1,IK
      ANG=(I-1)*AX+THETA
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG)+DISP(I*4-2)*SIN(ANG)
11    COPZ(I)=Z(I)-DISP(I*4-3)*SIN(ANG)+DISP(I*4-2)*COS(ANG)
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF*FCUR
      EPSO(IR)=FARE+HHALF*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'   I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53 I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'   STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
```

```
50    DO 21 I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,9E12.4,2X,E12.4)
      RETURN
      END
```

```
      SUBROUTINE ELMPP(AL,A,AMASS,STIFK,ISIZE)
C     TO FIND THE MASS MATRIX STIFFNESS MATRIX AND STRAIN NODAL
C     DISPLACEMENT TRANSFORMATION MATRICES
      DIMENSION A(8,8),LMI(8),MMI(8),D(8,8),ELM(8,8),ELMAS(8,8),
     *E(8,8),EK1(8,8),ELK(8,8),BE1(3,3,8)
      DIMENSION AMASS(1),STIFK(1)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      X=AL/(R*2.)
      RHO=DENS*B*H
      RI=RHO*H**2/12.
      STO=YOUNG*B*H
      SS=STO*H**2/12.
      DO 6 I=1,8
      DO 6 J=1,8
      D(I,J)=0.0
      E(I,J)=0.0
 6    A(I,J)=0.
      A(1,1)= COS(X)
      A(1,2)= SIN(X)
      A(1,3)=(-R)*(1.- COS(X)**2)
      A(1,4)=-AL/2.
      A(2,1)=- SIN(X)
      A(2,2)= COS(X)
      A(2,3)=-R* SIN(X)* COS(X)
      A(2,5)=AL**2/4.
      A(2,6)=-AL**3/8.
      A(3,3)=1.
      A(3,4)=AL/R/2.
      A(3,5)=-AL
      A(3,6)=AL**2*3./4.
      A(1,7)=AL**2/4.
      A(1,8)=-AL**3/8.
      A(3,7)=-AL**2/4./R
      A(3,8)=AL**3/8./R
      A(4,4)=1.
      A(4,5)=AL**2/4./R
      A(4,6)=-AL**3/8./R
      A(4,7)=-AL
      A(4,8)=3.*AL**2/4.
      A(5,1)= COS(X)
      A(5,2)=- SIN(X)
      A(5,3)=(-R)*(1.- COS(X)**2)
```

```
      A(5,4)=AL/2.
      A(5,7)=AL**2/4.
      A(5,8)=AL**3/8.
      A(6,1)= SIN(X)
      A(6,2)= COS(X)
      A(6,3)=R* SIN(X)* COS(X)
      A(6,5)=AL**2/4.
      A(6,6)=AL**3/8.
      A(7,3)=1.
      A(7,4)=-AL/2./R
      A(7,5)=AL
      A(7,6)=AL**2*3./4.
      A(7,7)=-AL**2/4./R
      A(7,8)=-AL**3/8./R
      A(8,4)=1.
      A(8,5)=AL**2/4./R
      A(8,6)=AL**3/8./R
      A(8,7)=AL
      A(8,8)=3.*AL**2/4.
      CALL MINV(A,8,DET,LMI,MMI)
      P2=2.*X**2* SIN(X)+4.*X* COS(X)-4.* SIN(X)
      P3=-2.*X**3* COS(X)+6.*X**2* SIN(X)+12.*X* COS(X)-12.* SIN(X)
      D(1,1)=RHO*AL
      D(2,2)=RHO*AL
      D(3,1)=RHO*R*(-R*2.* SIN(X)+ COS(X)*AL)
      D(3,3)=RHO*R**2*(AL+ COS(X)**2*AL-4.*R* SIN(X)* COS(X))+RI*AL
      D(4,2)=-RHO*R**2*(-2.*X* COS(X)+2.* SIN(X))
      D(4,4)=RHO*AL**3/12.+RI*AL**3/R**2/12.
      D(5,2)=RHO*R**3*P2
      D(5,4)=-RI*AL**3/R/6.
      D(5,5)=RHO*AL**5/80.+RI*AL**3/3.
      D(6,1)=RHO*R**4*P3
      D(6,3)=RHO*R**5* COS(X)*P3+RI*AL**3/4.
      D(6,6)=RHO*AL**7/448.+RI*AL**5*9./80.
      D(7,1)=RHO*R**3*P2
      D(7,3)=-RHO*R*(AL**3/12.-R**3* COS(X)*P2)-RI*AL**3/R/12.
      D(7,6)=-3.*RI*AL**5/R/80.
      D(7,7)=(AL**5/80.)*(RHO+RI/R**2)
      D(8,2)=-RHO*R**4*P3
      D(8,4)=D(7,7)
      D(8,5)=-RI*AL**5/R/40.
      D(8,8)=(AL**7/448.)*(RHO+RI/R**2)
      E(4,4)=AL*(STO+SS/R**2)
      E(5,4)=STO*AL**3/(R*12.)-2.*SS*AL/R
      E(5,5)=STO*AL**5/(R**2*80.)+4.*SS*AL
      E(6,6)=STO*AL**7/(R**2*448.)+3.*SS*AL**3
      E(7,6)=STO*AL**5/(R*40.)-SS*AL**3/R
      E(7,7)=(STO+SS/R**2)*AL**3/3.
      E(8,4)=(STO+SS/R**2)*AL**3/4.
      E(8,5)=3.*STO*AL**5/(R*80.)-SS*AL**3/(R*2.)
      E(8,8)=9.*(STO+SS/R**2)*AL**5/80.
      DO 3 I=1,7
      IP1=I+1
      DO 3 J=IP1,8
      E(I,J)=E(J,I)
3     D(I,J)=D(J,I)
      DO 4 I=1,8
      DO 4 J=1,8
      EK1(I,J)=0.0
      ELM(I,J)=0.
```

```
      DO 4 K=1,8
      EK1(I,J)=EK1(I,J)+A(K,I)*E(K,J)
4     ELM(I,J)=ELM(I,J)+A(K,I)*D(K,J)
      DO 5 I=1,8
      DO 5 J=1,8
      ELK(I,J)=0.0
      ELMAS(I,J)=0.
      DO 5 K=1,8
      ELK(I,J)=ELK(I,J)+EK1(I,K)*A(K,J)
5     ELMAS(I,J)=ELMAS(I,J)+ELM(I,K)*A(K,J)
      DO 44 K=1,NOGA
      DO 21 I=1,3
      DO 21 J=1,8
21    BE1(K,I,J)=0.
      BE1(K,1,4)=1.
      BE1(K,1,5)=AXG(K)**2/R
      BE1(K,1,6)=AXG(K)**3/R
      BE1(K,3,4)=1./R
      BE1(K,3,5)=-2.
      BE1(K,3,6)=-6.*AXG(K)
      BE1(K,2,3)=1.
      BE1(K,2,4)=-AXG(K)/R
      BE1(K,2,5)=2.*AXG(K)
      BE1(K,2,6)=3.*AXG(K)**2
      BE1(K,1,7)=2.*AXG(K)
      BE1(K,1,8)=3.*AXG(K)**2
      BE1(K,3,7)=2.*AXG(K)/R
      BE1(K,3,8)=3.*AXG(K)**2/R
      BE1(K,2,7)=-AXG(K)**2/R
      BE1(K,2,8)=-AXG(K)**3/R
44    CONTINUE
      DO 22 NL=1,NOGA
      DO 22 I=1,3
      DO 22 J=1,8
      BEP(NL,I,J)=0.
      DO 22 K=1,8
      BEP(NL,I,J)=BEP(NL,I,J)+BE1(NL,I,K)*A(K,J)
22    CONTINUE
      WRITE(MWRITE,15)
      WRITE(MWRITE,16) ((ELMAS(I,J),J=1,8),I=1,8)
      WRITE(MWRITE,17)
      WRITE(MWRITE,16) ((ELK(I,J),J=1,8),I=1,8)
16    FORMAT(8D15.6)
15    FORMAT(/,'     ELEMENT MASS MATRIX ')
17    FORMAT(/,'     ELEMENT STIFFNESS MATRIX ')
     DO 18 L=1,ISIZE
      STIFK(L)=0.0
18    AMASS(L)=0.0
      DO 19 IR=1,IK
      CALL ASSEM(IR,IK,ELK,STIFK,ICOL,NI)
19          CALL ASSEM(IR,IK,ELMAS,AMASS,ICOL,NI)
      IF(NBCOND .EQ. 0) RETURN
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,AMASS,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,AMASS,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,AMASS,NI,ICOL)
```

```
      CALL ERC(JT4M3,STIFK,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,STIFK,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,STIFK,NI,ICOL)
 91   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOADEQ(A,R,AL,TBEGIN,TFINAL)
C     TO FIND GENERALIZED NODAL LOAD AND EXTERNALLY-APPLIED LOAD TRANS-
C     FORMATION MATRICES
      DIMENSION A(8,8),FM(8,2),FMC(8,2),FML(8,2)
      COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      IF(TFINAL .EQ. 0.0) RETURN
      WRITE(MWRITE,47) TBEGIN,TFINAL
 47   FORMAT('0   STARTING TIME OF FORCING FUNCTION (SEC) =',E15.6,/,
     *'    STOPPING TIME OF FORCING FUNCTION (SEC) =',E15.6)
      READ(MREAD,6) NOFT1,NOFT2,NOFT3
 6    FORMAT(3I5)
 7    FORMAT(I5,3E15.6)
 8    FORMAT(2I5,2E15.6)
      IF(NOFT1 .EQ. 0) GO TO 54
      READ(MREAD,7)(JELEM(I),ETA(I),RTOV(I),RTOW(I),I=1,NOFT1)
      DO 100 I=1,NOFT1
      SL=ETA(I)
      X=AL/R/2
      FM(1,1)=COS(SL/R)
      FM(2,1)=-SIN(SL/R)
      FM(3,1)=-R*(1.-COS(SL/R)*COS(X))
      FM(4,1)=SL
      FM(5,1)=0.0
      FM(6,1)=0.0
      FM(7,1)=SL**2
      FM(8,1)=SL**3
      FM(1,2)=SIN(SL/R)
      FM(2,2)=COS(SL/R)
      FM(3,2)=R*SIN(SL/R)*COS(X)
      FM(4,2)=0.0
      FM(5,2)=SL**2
      FM(6,2)=SL **3
      FM(7,2)=0.0
      FM(8,2)=0.0
      DO 101 M=1,8
      DO 101 N=1,2
      FM1(I,M,N)=0.0
      DO 101 K=1,8
 101  FM1(I,M,N)=FM1(I,M,N)+A(K,M)*FM(K,N)
 100  CONTINUE
 54   DO 202 M=1,8
      DO 202 N=1,2
      FMC(M,N)=0.0
 202  FML(M,N)=0.0
      X=AL/R/2.
```

```
      FMC(1,1)=R*2.*SIN(X)
      FMC(3,1)=-R*AL+R**2*SIN(2.*X)
      FMC(7,1)=AL**3/12.
      FMC(2,2)=R*2.*SIN(X)
      FMC(5,2)=AL**3/12.
      FML(2,1)=-R**2*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(4,1)=AL**2/12.
      FML(8,1)=AL**4/80.
      FML(1,2)=R**2*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(3,2)=R**3*COS(X)*(-2.*X*COS(X)+2.*SIN(X))/AL
      FML(6,2)=AL**4/80.
      DO 201 M=1,8
      DO 201 N=1,2
      FM2(M,N)=0.0
      FM3(M,N)=0.0
      DO 201 K=1,8
      FM2(M,N)=FM2(M,N)+A(K,M)*FMC(K,N)
      FM3(M,N)=FM3(M,N)+A(K,M)*FML(K,N)
201   CONTINUE
41    IF(NOFT2 .EQ.0) GO TO 42
      READ(MREAD,8)(NSTF2(I),NELF2(I),RTO2V(I),RTO2W(I),I=1,NOFT2)
42    IF(NOFT3 .EQ. 0) RETURN
      READ(MREAD,8) (NSTF3(I),NELF3(I),RTO3V(I),RTO3W(I),I=1,NOFT3)
      RETURN
      END



      SUBROUTINE LOADFT(TIME,NREADF)
C     TO FIND THE GENERALIZED NODAL LOAD VECTOR EQUIVALENT TO THE
C     EXTERNALLY-APPLIED LOAD
      DIMENSION ELF(8)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /FORCE/ FMECH(205),T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(8,2),FM3(8,2),SLOPEV,SLOPEW
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      IF(NREADF .GT. 0) GO TO 50
51    READ(MREAD,52) T2,AMP2FV,AMP2FW
52    FORMAT(3E15.6)
      NREADF=1
      SLOPEV=(AMP2FV-AMP1FV)/(T2-T1)
      SLOPEW=(AMP2FW-AMP1FW)/(T2-T1)
50    IF(TIME .LE. T2) GO TO 53
      T1=T2
      AMP1FV=AMP2FV
      AMP1FW=AMP2FW
      GO TO 51
53    AMPFV=AMP1FV+(TIME-T1)*SLOPEV
      AMPFW=AMP1FW+(TIME-T1)*SLOPEW
      DO 57 I=1,NI
57    FMECH(I)=0.0
      IF(NOFT1 .EQ. 0) GO TO 54
      DO 100 I=1,NOFT1
      NE=JELEM(I)
      FMV=AMPFV*RTOV(I)
      FMW=AMPFW*RTOW(I)
```

```
      DO 101 J=1,8
 101  ELF(J)=FM1(I,J,1)*FMV+FM1(I,J,2)*FMW
 100  CALL ASSEF(NE,IK,ELF,FMECH)
 54   IF(NOFT2 .EQ. 0) GO TO 55
      DO 200 I=1,NOFT2
      NSTAT=NSTF2(I)
      NEND=NELF2(I)
      FMV=AMPFV*RTO2V(I)
      FMW=AMPFW*RTO2W(I)
      DO 201 J=1,8
 201  ELF(J)=FM2(J,1)*FMV+FM2(J,2)*FMW
      DO 202 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
 202  CALL ASSEF(NE,IK,ELF,FMECH)
 200  CONTINUE
 55   IF(NOFT3 .EQ. 0) GO TO 90
      DO 300 I=1,NOFT3
      PIE=3.14159265
      NSTAT=NSTF3(I)
      NEND=NELF3(I)
      PIEP=PIE/NEND
      FMV=AMPFV*RTO3V(I)
      FMW=AMPFW*RTO3W(I)
      FMW1=0.0
      FMV1=0.0
      DO 301 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
      X=PIEP*NN
      FMW2=SIN(X)*FMW
      FMV2=SIN(X)*FMV
      AFSW=(FMW1+FMW2)/2.
      BFSW=(FMW2-FMW1)
      AFSV=(FMV1+FMV2)/2.
      BFSV=(FMV2-FMV1)
      FMW1=FMW2
      FMV1=FMV2
      DO 302 J=1,8
 302  ELF(J)=FM2(J,1)*AFSV+FM2(J,2)*AFSW+FM3(J,1)*BFSV+FM3(J,2)*BFSW
 301  CALL ASSEF(NE,IK,ELF,FMECH)
 300  CONTINUE
 90   IF(NBCOND .EQ. 0) RETURN
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      FMECH(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FMECH(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FMECH(JT4-2)=0.0
 91   CONTINUE
 56   RETURN
      END



      SUBROUTINE QREM(A,AL,R)
C     TO FIND EFFECTIVE STIFFNESS MATRIX DUE TO ELASTIC RESTRAINTS
      DIMENSION A(8,8),ELR(8,8),ELRR(8,8),ELRP(8,8)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
```

```
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICCL(205),NBCOND,NBC(4),NODEB(4)
      COMMON /ELFU/ SPRIN(2060),NORP,NORU,NREL(4),REX(4),
     *NRST(4),NREU(4)
      IF (NORP .EQ. 0) GO TO 1
      READ(MREAD,2) SCTP,SCRP,(NREL(I),REX(I),I=1,NORP)
2     FORMAT(2E15.6/(4(I5,E15.6)))
      DO 10 IQ=1,NORP
      NE=NREL(IQ)
      SL=REX(IQ)
      X=AL/R/2.
      SX=SL/R
      DO 11 I=1,8
      DO 11 J=1,8
11    ELR(I,J)=0.0
      ELR(1,1)=SCTP
      ELR(3,1)=SCTP*R*(-COS(SX)+COS(X))
      ELR(4,1)=SL*SCTP*COS(SX)
      ELR(5,1)=SCTP*SL**2*SIN(SX)
      ELR(6,1)=SCTP*SL**3*SIN(SX)
      ELR(2,2)=SCTP
      ELR(3,2)=SCTP*R*SIN(SX)
      ELR(4,2)=-SCTP*SL*SIN(SX)
      ELR(5,2)=SCTP*SL**2*COS(SX)
      ELR(6,2)=SCTP*SL**3*COS(SX)
      ELR(3,3)=SCTP*R**2*(1.-2.*COS(SX)*COS(X)+COS(X)**2)+SCRP
      ELR(4,3)=-SCTP*R*SL*(1.-COS(SX)*COS(X))-SCRP*SL/R
      ELR(5,3)=SCTP*R*SL**2*SIN(SX)*COS(X)+2.*SL*SCRP
      ELR(6,3)=SCTP*R*SL**3*SIN(SX)*COS(X)+3.*SL**2*SCRP
      ELR(4,4)=SCTP*SL**2+SL**2*SCRP/R**2
      ELR(5,4)=-2.*SL**2*SCRP/R
      ELR(6,4)=-3.*SL**3*SCRP/R
      ELR(5,5)=SL**4*SCTP+4.*SL**2*SCRP
      ELR(6,5)=SL**5*SCTP+6.*SCRP*SL**3
      ELR(6,6)=SL**6*SCTP+9.*SL**4*SCRP
      ELR(7,1)=SCTP*SL**2*COS(SX)
      ELR(8,1)=SCTP*SL**3*COS(SX)
      ELR(7,2)=-SCTP*SL**2*SIN(SX)
      ELR(8,2)=-SCTP*SL**3*SIN(SX)
      ELR(7,3)=-R*(1.-COS(SX)*COS(X))*SCTP*SL**2-SL**2*SCRP/R
      ELR(8,3)=-R*(1.-COS(SX)*COS(X))*SCTP*SL**3-SL**3*SCRP/R
      ELR(7,4)=(SCTP+SCRP/R**2)*SL**3
      ELR(8,4)=(SCTP+SCRP/R**2)*SL**4
      ELR(7,5)=-2.*SL**3*SCRP/R
      ELR(8,5)=-2.*SL**4*SCRP/R
      ELR(7,6)=-3.*SL**4*SCRP/R
      ELR(8,6)=-3.*SL**5*SCRP/R
      ELR(7,7)=ELR(8,4)
      ELR(8,7)=(SCTP+SCRP/R**2)*SL**5
      ELR(8,8)=(SCTP+SCRP/R**2)*SL**6
      DO 12 I=1,7
      IP1=I+1
      DO 12 J=IP1,8
12    ELR(I,J)=ELR(J,I)
      DO 13 I=1,8
      DO 13 J=1,8
      ELRR(I,J)=0.0
      DO 13 K=1,8
13    ELRR(I,J)=ELRR(I,J)+ELR(I,K)*A(K,J)
      DO 14 I=1,8
      DO 14 J=1,8
```

```
      ELRP(I,J)=0.0
      DO 14 K=1,8
14     ELRP(I,J)=ELRP(I,J)+A(K,I)*ELRR(K,J)
10    CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
1     IF(NORU .EQ. 0) GO TO 31
      READ(MREAD,3) SCTU,SCRU,(NRST(I),NREU(I),I=1,NORU)
3     FORMAT(2E15.6,8I5)
      DO 4 I=1,8
      DO 4 J=1,8
4     ELR(I,J)=0.0
      X=AL/R/2.
      P2=2.*X**2*SIN(X)+4.*X*COS(X)-4.*SIN(X)
      P3=-2.*X**3*COS(X)+6.*X**2*SIN(X)+12.*X*COS(X)-12.*SIN(X)
      ELR(1,1)=SCTU*AL
      ELR(2,2)=SCTU*AL
      ELR(3,1)=SCTU*R*(-R*2.*SIN(X)+COS(X)*AL)
      ELR(3,3)=SCTU*R**2*(AL+COS(X)**2*AL-2.*R*SIN(2.*X))+SCRU*AL
      ELR(4,2)=-SCTU*R**2*(-2.*X*COS(X)+2.*SIN(X))
      ELR(4,4)=(SCTU+SCRU/R**2)*AL**3/12.
      ELR(5,2)=SCTU*R**3*P2
      ELR(5,4)=-SCRU*AL**3/(6.*R)
      ELR(5,5)=SCTU*AL**5/80.+SCRU*AL**3/3.
      ELR(6,1)=SCTU*R**4*P3
      ELR(6,3)=SCTU*R**5*COS(X)*P3+SCRU*AL**3/4.
      ELR(6,6)=SCTU*AL**7/448.+9.*SCRU*AL**5/80.
      ELR(7,1)=SCTU*R**3*P2
      ELR(7,3)=-SCTU*R*(AL**3/12.-R**3*COS(X)*P2)-SCRU*AL**3/(12.*R)
      ELR(7,6)=-3.*SCRU*AL**5/(R*80.)
      ELR(7,7)=(SCTU+SCRU/R**2)*AL**5/80.
      ELR(8,2)=-SCTU*R**4*P3
      ELR(8,4)=ELR(7,7)
      ELR(8,5)=-SCRU*AL**5/(40.*R)
      ELR(8,8)=(SCTU+SCRU/R**2)*AL**7/448.
      DO 5 I=1,7
      IP1=I+1
      DO 5 J=IP1,8
5     ELR(I,J)=ELR(J,I)
      DO 6 I=1,8
      DO 6 J=1,8
      ELRR(I,J)=0.0
      DO 6 K=1,8
6     ELRR(I,J)=ELRR(I,J)+ELR(I,K)*A(K,J)
      DO 7 I=1,8
      DO 7 J=1,8
      ELRP(I,J)=0.0
      DO 7 K=1,8
7     ELRP(I,J)=ELRP(I,J)+A(K,I)*ELRR(K,J)
      DO 20 IQ=1,NORU
      NSTAT=NRST(IQ)
      NEND=NREU(IQ)
      DO 21 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
21    CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
20    CONTINUE
31    IF(NBCOND .EQ. 0) RETURN
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
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      JT4M1=JT4-1
      CALL ERC(JT4M3,SPRIN,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,SPRIN,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,SPRIN,NI,ICOL)
 91   CONTINUE
      RETURN
      END




      SUBROUTINE STRESS
C     TO EVALUATE GENERALIZED NODAL LOAD VECTOR DUE TO LARGE DEFLECTION
C     AND ELASTIC-PLASTIC STRAIN
      DIMENSION ELFP(8),BEPS(3),CEPS(3,3),BINPW(3),BIMPW(3),HWB(3,3),
     *PN(8),PM(8),HNL(8),BINPP(3),BIMPP(3)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     COMMON /HM/ R,B,H,DENS,YOUNG,DS,C5,C6,ASFL(6,5),GZETA(6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(3,3,8),AXG(3),AWG(3)
      DO 502 IR=1,IK
      DO 503 J=1,NOGA
      BINP(IR,J)=0.
      BIMP(IR,J)=0.
      BINPP(J)=0.0
      BIMPP(J)=0.0
 202  DO 402 I=1,3
      BEPS(I)=0.
      DO 402 K=1,8
      INDEX=(IR-1)*4+K
 402  BEPS(I)=BEPS(I)+BEP(J,I,K)*DELD(INDEX)
      CEPS(J,1)=0.0
      CEPS(J,2)=0.0
      DO 403 K=1,8
      INDEX=(IR-1)*4+K
      CEPS(J,1)=CEPS(J,1)+BEP(J,1,K)*DISP(INDEX)
 403  CEPS(J,2)=CEPS(J,2)+BEP(J,2,K)*DISP(INDEX)
 205  FARE=BEPS(1)+CEPS(J,2)*BEPS(2)-BEPS(2)**2/2.
      FCUR=BEPS(3)
      DO 151 K=1,NFL
      BFNP=0.
      BFNPP=0.0
      BEPX=FARE+GZETA(K)*FCUR
      IF(DS.GT. 0.0) RFACTR=1.+(C6*ABS(BEPX))**C5
      DO 35 L=1,NSFL
      DESNP=0.0
      SNS(IR,J,K,L)=SNS(IR,J,K,L)+YOUNG*BEPX
      IF(DS.EQ. 0.0) GO TO 255
      IF(SNS(IR,J,K,L)-SNO(L))30,301,91
 91   SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)-SNY)301,301,20
 20   DESNP=SNS(IR,J,K,L)-SNY
      SNS(IR,J,K,L)=SNY
      GO TO 301
 30   IF(SNS(IR,J,K,L)+SNO(L))92,301,301
 92   SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)+SNY)40,301,301
 40   DESNP=SNS(IR,J,K,L)+SNY
```

```
      SNS(IR,J,K,L)=-SNY
      GO TO 301
255   IF(SNS(IR,J,K,L)-SNO(L)) 18,301,17
17    DESNP=SNS(IR,J,K,L)-SNO(L)
      SNS(IR,J,K,L)=SNO(L)
      GO TO 301
18    IF(SNS(IR,J,K,L)+SNO(L)) 19, 301,301
19    DESNP=SNS(IR,J,K,L)+SNO(L)
      SNS(IR,J,K,L)=-SNO(L)
301   BFNP=BFNP+SNS(IR,J,K,L)*ASFL(K,L)
      SNP(IR,J,K,L)=SNP(IR,J,K,L)+DESNP
      BFNPP=BFNPP+SNP(IR,J,K,L)*ASFL(K,L)
35    CONTINUE
      BINP(IR,J)=BINP(IR,J)+BFNP
      BIMP(IR,J)=BIMP(IR,J)+BFNP*GZETA(K)
      BINPP(J)=BINPP(J)+BFNPP
      BIMPP(J)=BIMPP(J)+BFNPP*GZETA(K)
151   CONTINUE
503   CONTINUE
107   DO 101 J=1,NOGA
      BINPW(J)=(YOUNG*B*H*CEPS(J,2)**2/2.-BINPP(J))*AWG(J)
      BIMPW(J)=-BIMPP(J)*AWG(J)
      HWB(J,2)=(YOUNG*B*H*(CEPS(J,1)+CEPS(J,2)**2/2.)-BINPP(J))*
     *CEPS(J,2)*AWG(J)
101    CONTINUE
      DO 102 I=1,8
      PN(I)=0.
      PM(I)=0.
      HNL(I)=0.0
      DO 102 J=1,NOGA
      PN(I)=PN(I)+BEP(J,1,I)*BINPW(J)
      PM(I)=PM(I)+BEP(J,3,I)*BIMPW(J)
102   HNL(I)=HNL(I)+BEP(J,2,I)*HWB(J,2)
200   DO 105 I=1,8
105   ELFP(I)=PN(I)+PM(I)+HNL(I)
502   CALL ASSEF(IR,IK,ELFP,FLVA)
      RETURN
      END



      SUBROUTINE ERC(II,STIFM,NI,ICOL)
C     FOR ELIMINATING ROWS AND COLUMNS IN STIFM
      DIMENSION STIFM(1),ICOL(1)
      IC=ICOL(II)
      DO 101 J=IC,II
      CALL FICOL(II,J,L,ICOL)
101   STIFM(L)=0.
      DO 102 I=II,NI
      IC1=ICOL(I)
      IF(II-IC1)102,103,103
103   CALL FICOL(I,II,L,ICOL)
      STIFM(L)=0.
102   CONTINUE
      CALL FICOL(II,II,L,ICOL)
      STIFM(L)=1.
      RETURN
      END
```

```
      SUBROUTINE FAC  (STIFM,NCOL,KROW,NDEX,IDET,NTAPE6,NROWS,NIRREG,IC)
C      LOWER TRIANGULAR FACTOR OF STIFM MATRIX IS COMPUTED AND STORED   FACT0095
      DIMENSION STIFM(1),NCOL(1),KROW(1),NDEX(1),IC(1)
C     STIFM                                                             FACT0100
C     PROCESS COLUMN 1                                                  FACT0105
      I=1
      IDET=0                                                            FACT0110
      IF (STIFM(1)) 152,122,101
152   IDET=IDET+1
 101  INDEX=0
      IROW=1                                                            FACT0130
      TEST=1.0                                                          FACT0135
      KN=1                                                              FACT0140
      DO 103 I=2,NROWS                                                  FACT0145
      KN=KN+I-NCOL(I)                                                   FACT0150
      IF (NCOL(I)-1) 103,102,103                                        FACT0155
  102 STIFM(KN)=STIFM(KN)/STIFM(1)                                      FACT0160
  103 CONTINUE                                                          FACT0165
      DO 121 I=2,NROWS                                                  FACT0170
      IP1=I+1                                                           FACT0175
      IM1=I-1                                                           FACT0180
      SUM=0.0                                                           FACT0185
      NCK=0                                                             FACT0190
      III=NCOL(I)                                                       FACT0195
      INDEX=INDEX+I-III                                                 FACT0200
      IF (IM1-III) 150,140,140                                          FACT0205
C     DIAGONAL TERMS                                                    FACT0210
  140 DO 104 J=III,IM1                                                  FACT0215
      IJ=INDEX+J                                                        FACT0220
  104 SUM=SUM+STIFM(IJ)*STIFM(IJ)*STIFM(IC(J)+J)
  150 II=INDEX+I                                                        FACT0230
      SUM=STIFM(II)-SUM                                                 FACT0235
      IF (SUM) 151,122,105
 151  IDET= IDET +1
105   TES= ABS(SUM/STIFM(II))
      IF (TES-TEST) 106,107,107                                         FACT0250
  106 TEST=TES                                                          FACT0255
      IROW=I                                                            FACT0260
  107 STIFM(II)= SUM
C     OFF DIAGONAL TERMS                                                FACT0270
      IF (I-NROWS) 108,121,121                                          FACT0275
  108 KNDEX=INDEX                                                       FACT0280
  109 DO 116 K=IP1,NROWS                                                FACT0285
      KK=NCOL(K)                                                        FACT0290
      KNDEX=KNDEX+K-KK                                                  FACT0295
      SUM=0.0                                                           FACT0300
      IF (KK-III) 110,130,130                                           FACT0305
  110 KK=III                                                            FACT0310
  130 IF (IM1-KK) 112,131,131                                           FACT0315
  131 DO 111 J=KK,IM1                                                   FACT0320
      IJ=INDEX+J                                                        FACT0325
      KJ=KNDEX+J                                                        FACT0330
  111 SUM=SUM+STIFM(IJ)*STIFM(KJ)*STIFM(IC(J)+J)
  112 IF (I-KK) 114,115,115                                             FACT0340
  114 IF (NIRREG .LE. 0) GO TO 121                                      FACT0345
```

```
      IF (NIRREG .GT. NROWS /2) GO TO 116
      GO TO 190                                                         FACT0355
  115 KI=KNDEX+I                                                        FACT0360
      STIFM(KI)=(STIFM(KI)-SUM)/STIFM(II)                               FACT0365
  116 CONTINUE                                                          FACT0370
      GO TO 121                                                         FACT0375
  190 NCK=NCK+1                                                         FACT0380
      IF (NIRREG .LT. NCK) GO TO 121                                    FACT0385
      IP1=KROW(NCK)                                                     FACT0390
      IF (I .LT. NCOL(IP1)) GO TO 190                                   FACT0395
      IF (IP1 .LT. K) GO TO 190                                         FACT0400
      KNDEX=NDEX(NCK)                                                   FACT0405
      GO TO 109                                                         FACT0410
  121 CONTINUE                                                          FACT0415
      RETURN                                                            FACT0435
  122 WRITE (NTAPE6,1001) I                                             FACT0440
      IDET=-I
 1001 FORMAT (37H1 MATRIX NOT POSITIVE DEFINITE IN ROW,I4)              FACT0450
      WRITE (NTAPE6,1002) SUM                                           FACT0455
 1002 FORMAT (27H0SQUARE OF DIAGONAL TERM = ,E15.8,/28H0PARTIALLY FACTORFACT0460
     1ED K MATRIX,//)                                                   FACT0465
      RETURN                                                            FACT0470
      END


      SUBROUTINE FICOL(I,J,L,ICOL)
C     USING FORMULA L=J+SUM(K-ICOL(K)),K=1,I TO RELATE I,J,TO L
       DIMENSION ICOL(1)
      IF(J-ICOL(I))200,300,300
 300  ISUM=0
      DO 305 K=1,I
      ISUM=K-ICOL(K)+ISUM
305   CONTINUE
      L=J+ISUM
      RETURN
200    WRITE(6,4)I,J
 4    FORMAT(31H ELEMENT IS NOT IN BAND REGION,3H I=,I5,3H J=,I5)
      RETURN
      END


       SUBROUTINE MINV(A,N,DET,L,M)
C      INVERT MATRIX A
       DIMENSION A(1),L(1),M(1)
C                                                                       MINV 053
C         SEARCH FOR LARGEST ELEMENT                                    MINV 054
C                                                                       MINV 055
       DET=1.0
      NK=-N                                                             MINV 057
      DO 80 K=1,N                                                       MINV 058
      NK=NK+N                                                           MINV 059
      L(K)=K                                                            MINV 060
      M(K)=K                                                            MINV 061
      KK=NK+K                                                           MINV 062
```

```
      BIGA=A(KK)                                                        MINV 063
      DO 20 J=K,N                                                       MINV 064
      IZ=N*(J-1)                                                        MINV 065
      DO 20 I=K,N                                                       MINV 066
      IJ=IZ+I                                                           MINV 067
 10    IF( ABS(BIGA)- ABS(A(IJ)))15,20,20
   15 BIGA=A(IJ)                                                        MINV 069
      L(K)=I                                                            MINV 070
      M(K)=J                                                            MINV 071
   20 CONTINUE                                                          MINV 072
C                                                                       MINV 073
C        INTERCHANGE ROWS                                               MINV 074
C                                                                       MINV 075
      J=L(K)                                                            MINV 076
      IF(J-K) 35,35,25                                                  MINV 077
   25 KI=K-N                                                            MINV 078
      DO 30 I=1,N                                                       MINV 079
      KI=KI+N                                                           MINV 080
      HOLD=-A(KI)                                                       MINV 081
      JI=KI-K+J                                                         MINV 082
      A(KI)=A(JI)                                                       MINV 083
   30 A(JI) =HOLD                                                       MINV 084
C                                                                       MINV 085
C        INTERCHANGE COLUMNS                                            MINV 086
C                                                                       MINV 087
   35 I=M(K)                                                            MINV 088
      IF(I-K) 45,45,38                                                  MINV 089
   38 JP=N*(I-1)                                                        MINV 090
      DO 40 J=1,N                                                       MINV 091
      JK=NK+J                                                           MINV 092
      JI=JP+J                                                           MINV 093
      HOLD=-A(JK)                                                       MINV 094
      A(JK)=A(JI)                                                       MINV 095
   40 A(JI) =HOLD                                                       MINV 096
C                                                                       MINV 097
C        DIVIDE COLUMN BY MINUS PIVOT (VALLE OF PIVOT ELEMENT IS        MINV 098
C        CONTAINEC IN BIGA)                                             MINV 099
C                                                                       MINV 100
   45 IF(BIGA) 48,46,48                                                 MINV 101
   46 DET=0.0
      RETURN                                                            MINV 103
   48 DO 55 I=1,N                                                       MINV 104
      IF(I-K) 50,55,50                                                  MINV 105
   50 IK=NK+I                                                           MINV 106
      A(IK)=A(IK)/(-BIGA)                                               MINV 107
   55 CONTINUE                                                          MINV 108
C                                                                       MINV 109
C        REDUCE MATRIX                                                  MINV 110
C                                                                       MINV 111
      DO 65 I=1,N                                                       MINV 112
      IK=NK+I                                                           MINV 113
      HOLD=A(IK)                                                        MINV M01
      IJ=I-N                                                            MINV 114
      DO 65 J=1,N                                                       MINV 115
      IJ=IJ+N                                                           MINV 116
      IF(I-K) 60,65,60                                                  MINV 117
   60 IF(J-K) 62,65,62                                                  MINV 118
   62 KJ=IJ-I+K                                                         MINV 119
      A(IJ)=HOLD*A(KJ)+A(IJ)                                            MINV M02
   65 CONTINUE                                                          MINV 121
```

```
C                                                                       MINV 122
C        DIVIDE ROW BY PIVOT                                            MINV 123
C                                                                       MINV 124
      KJ=K-N                                                            MINV 125
      DO 75 J=1,N                                                       MINV 126
      KJ=KJ+N                                                           MINV 127
      IF(J-K) 70,75,7C                                                  MINV 128
   70 A(KJ)=A(KJ)/BIGA                                                  MINV 129
   75 CONTINUE                                                          MINV 130
C                                                                       MINV 131
C        PRODUCT OF PIVOTS                                              MINV 132
C                                                                       MINV 133
      DET=DET*BIGA
C                                                                       MINV 135
C        REPLACE PIVOT BY RECIPROCAL                                    MINV 136
C                                                                       MINV 137
      A(KK)=1.0/BIGA                                                    MINV 138
   80 CONTINUE                                                          MINV 139
C                                                                       MINV 140
C        FINAL ROW AND COLUMN INTERCHANGE                               MINV 141
C                                                                       MINV 142
      K=N                                                               MINV 143
  100 K=(K-1)                                                           MINV 144
      IF(K) 150,150,105                                                 MINV 145
  105 I=L(K)                                                            MINV 146
      IF(I-K) 120,120,108                                               MINV 147
  108 JQ=N*(K-1)                                                        MINV 148
      JR=N*(I-1)                                                        MINV 149
      DO 110 J=1,N                                                      MINV 150
      JK=JQ+J                                                           MINV 151
      HOLD=A(JK)                                                        MINV 152
      JI=JR+J                                                           MINV 153
      A(JK)=-A(JI)                                                      MINV 154
  110 A(JI) =HOLD                                                       MINV 155
  120 J=M(K)                                                            MINV 156
      IF(J-K) 100,100,125                                               MINV 157
  125 KI=K-N                                                            MINV 158
      DO 130 I=1,N                                                      MINV 159
      KI=KI+N                                                           MINV 160
      HOLD=A(KI)                                                        MINV 161
      JI=KI-K+J                                                         MINV 162
      A(KI)=-A(JI)                                                      MINV 163
  130 A(JI) =HOLD                                                       MINV 164
      GO TO 100                                                         MINV 165
  150 RETURN                                                            MINV 166
      END


       SUBROUTINE OMULT(SQVCT,RWVCT,NCOL,NROWS,ACC,KROW,NDEX,NIRREG)
C      TO FIND ACC OF (SQVCT)*(RWVCT)=(ACC)
       DIMENSION SQVCT(1),RWVCT(1),NCOL(1),ACC(1),KROW(1),NDEX(1)
       INDEX=0
       NROWM=NROWS-1
       IF (NIRREG .GT. 0) GO TO 200
C      HIGH SPEED PRODUCT FOR REGULAR MATRICES
       DO 100 NN=1,NROWM
       SUM=0.0
```

```
      IP1=NN+1
      KST=NCOL(NN)
      INDEX=INDEX+NN-KST
      DO 101 KPL=KST,NN
      IJ=INDEX+KPL
  101 SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
C     NOW FOR THE COLUMN ELEMENTS
      JNDEX=IJ
      DO 102 KPL=IP1,NROWS
      IF(NN.LT.NCOL(KPL))GO TO 100
      JNDEX=JNDEX+KPL-NCOL(KPL)
  102 SUM=SUM+SQVCT(JNDEX)*RWVCT(KPL)
  100 ACC(NN)=ACC(NN)+SUM
C     NOW FOR THE LAST ROW
  104 KADD=NCOL(NROWS)
      SUM=0.0
      INDEX=INDEX+NROWS-KADD
      DO 103 KPL=KADD,NROWS
      IJ=INDEX+KPL
  103 SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
      ACC(NROWS)=ACC(NROWS)+SUM
      RETURN
C     MEDIUM SPEED PRODUCT FOR NIRREG .LE. NROWS/2
  200 IF (NIRREG .GT. NROWS/2) GO TO 201
      DO 105 NN=1,NROWM
      IP1=NN+1
      KST=NCOL(NN)
      INDEX=INDEX+NN-KST
      SUM=0.0
      DO 106 KPL=KST,NN
      IJ=INDEX+KPL
  106 SUM=SUM+SQVCT(IJ)*RWVCT(KPL)
      NCK=0
      JNDEX=IJ
  107 DO 108 KPL=IP1,NROWS
      IF(NN .LT. NCOL(KPL)) GO TO 109
      JNDEX=JNDEX+KPL-NCOL(KPL)
  108 SUM=SUM+SQVCT(JNDEX)*RWVCT(KPL)
      GO TO 105
  109 NCK=NCK+1
      IF (NCK .GT.NIRREG) GO TO 105
      IF (KPL .GE. KROW(NCK)) GO TO 109
      IP1=KROW(NCK)
      JNDEX=NDEX(NCK)+NN
      GO TO 107
  105 ACC(NN)=ACC(NN)+SUM
      GO TO 104
  201 DO 503 NN=1,NROWM
      IP1=NN+1
      K=NCOL(NN)
      INDEX=INDEX+NN-K
      SUM=0.0
      DO 502 KRX=K,NN
      IJ=INDEX+KRX
  502 SUM=SUM+SQVCT(IJ)*RWVCT(KRX)
      JNDEX=IJ
      DO 504 KRX=IP1,NROWS
      K=NCOL(KRX)
      JNDEX=JNDEX+KRX-K
      IF (NN .LT. K) GO TO 504
```

```
      SUM=SUM+SQVCT(JNDEX)*RWVCT(KRX)
  504 CONTINUE
  503 ACC(NN)=ACC(NN)+SUM
      GO TO 104
      END
```

```
      SUBROUTINE SOLV (STIFM,G,SOL,NCOL,KRCW,NDEX,NROWS,NIRREG)
C     SOLVE (LL*)(SOL)=(FORCE) FOR DISPLACEMENTS (SOL)
      DIMENSION STIFM(1),G(1),SOL(1), NCOL(1),KROW(1),NDEX(1)
C     INTERMEDIATE SOLUTION USING THE LOWER TRIANGLE
  100 INDEX=0
      SOL(1)=G(1)
      DO 104 I=2,NROWS
      IM1=I-1
      SUM=0.0
      K=NCOL(I)
      INDEX=INDEX+I-K
      IF (IM1-K) 103,101,101
  101 DO 102 J=K,IM1
      IJ=INDEX+J
      SU=SOL(J)
  102 SUM=SUM+STIFM(IJ)*SU
  103 II=INDEX+I
  104 SOL(I)= G(I)-SUM
C     SOL CONTAINS THE INTERMEDIATE SOLUTICN
C     COMPLETE THE SOLUTION USING THE UPPER TRIANGLE
      SOL(NROWS)=SOL(NROWS)/STIFM(II)
      INDEX=INDEX-NROWS+NCOL(NROWS)
      IF (NIRREG .GT. 0) GO TO 111
      DO 109 KK=2,NROWS
      I=NROWS+1-KK
      IP1=I+1
      SUM=0.0
      JNDEX=INDEX+I
      DO 107 J=IP1,NROWS
      K=NCOL(J)
      IF (I-K) 108,106,106
  106 JNDEX=JNDEX+J-K
      SU=SOL(J)
  107 SUM=SUM+STIFM(JNDEX)*SU
  108 II=INDEX+I
      SOL(I)= SOL(I)/STIFM (II)-SUM
  109 INDEX=INDEX-I+NCOL(I)
      RETURN
  111 IF (NIRREG-NROWS /2) 116,116,112
C     TOO MANY IRREGULAR ROWS FOR ACCELERATED SOLUTION
  112 DO 115 KK=2,NROWS
      I=NROWS+1-KK
      IP1=I+1
      JNDEX=INDEX+I
      SUM=0.0
      JNDEX=INDEX+I
      DO 114 J=IP1,NROWS
      K=NCOL(J)
      JNDEX=JNDEX+J-K
      IF (I-K) 114,113,113
```

```
 113   SU=SOL(J)
       SUM=SUM+STIFM(JNDEX)*SU
  114  CONTINUE
       II=INDEX+I
       SOL(I)= SOL(I)/STIFM(II) -SUM
  115  INDEX=INDEX-I+NCOL(I)
       RETURN
C      ACCELERATED SOLUTION FOR CASE WITH IRREGULAR ROWS
  116  DO 125 KK=2,NROWS
       I=NROWS+1-KK
       IP1=I+1
       SUM=0.0
       NCK=0
        JNDEX=INDEX+I
  117  DO 119 J=IP1,NROWS
       K=NCOL(J)
       IF (I-K) 120,118,118
  118  JNDEX=JNDEX+J-K
       SU=SOL(J)
  119  SUM=SUM+STIFM(JNDEX)*SU
       GO TO 124
  120  NCK=NCK+1
       IF (NIRREG-NCK) 124,121,121
  121  IP1=KROW(NCK)
       IF (I-NCOL(IP1)) 120,122,122
  122  IF (IP1-J) 120,123,123
  123  JNDEX=NDEX(NCK)+I
       GO TO 117
  124  II=INDEX+I
       SOL(I)= SOL(I)/STIFM(II) -SUM
  125  INDEX=INDEX-I+NCOL(I)
       RETURN
       END
```

5.3 JET 3C: Variable Thickness Arbitrarily Curved Ring; Timewise Central-Difference Operator

The JET 3C consists of the following main programs and subroutines:

1.	JET 3C MAIN PROGRAM	(partial ring)
2.	ASSEM	
3.	ASSEF	
4.	IDENT	
5.	IMPULS	
6.	PRINT	
7.	JET 3C MAIN PROGRAM	(complete ring)
8.	ASSEM	
9.	ASSEF	
10.	IDENT	
11.	IMPULS	
12.	PRINT	

13. ELMPP
14. STRESS
15. LOADEQ
16. LOADFT
17. QREM
18. ERC
19. FAC
20. FICOL
21. MINV
22. OMULT
23. SOLV
24. TSTEP

The subroutines in items 13 through 24 are common to each of the two groups of "control programs".

The number of memory locations required is approximately 204,000 bytes. The subroutines ERC, FAC, FICOL, MINV, OMULT, and SOLV (No. 18 through No. 23) are the same as those listed in Subsection 5.2. To avoid needless repetition, only the main programs and subroutines No. 1 through No. 17 and No. 24 are listed in this subsection.

```
C      JET3C  MAIN PROGRAM FOR VARIABLE THICKNESS ARBITRARILY CURVED RING
C      JET3C  CENTRAL DIFFERENCE OPERATOR
C       ***** PARTIAL RING *****
        DIMENSION AMASS(2060),AA(50,8,8),TXG(6),TWG(6),ES(6),GFL(50,3,6),
     *SOL(205),INUM(205),FMECH(205),HHALF(50),KROW(8),NDEX(8),
     *BMASS(2060),EPS(5),SIG(5)
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
        COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
        COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
        COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
        COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
        COMMON /ELFU/ SPRIN(2060),FQREF(205),NQR,NORP,NORU,NREL(4),
     *REX(4),NRST(4),NREU(4)
        MREAD=5
        MWRITE=6
        MPUNCH=7
        READ(MREAD,1) B,DENS,IK,NOGA,NFL,NSFL,MM,M1,M2
        IKP1=IK+1
        PIE=3.14159265
        READ(MREAD,11) (Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
 11     FORMAT(4E15.6)
        DO 111 I=1,IKP1
 111    ANG(I)=ANG(I)*PIE/180.
        READ(MREAD,2) DELTAT,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
 1      FORMAT(2E15.6/7I5)
 2      FORMAT(4E15.6/(4E15.6))
        READ(MREAD,3)(AXG(K),K=1,NOGA)
        READ(MREAD,3)(AWG(K),K=1,NOGA)
        READ(MREAD,3)(TXG(K),K=1,NFL)
        READ(MREAD,3)(TWG(K),K=1,NFL)
 3      FORMAT(4F15.10)
        NI=IKP1*4
        READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
 4      FORMAT(9I5)
        READ(MREAD,9) NQR,NORP,NORU
 9      FORMAT(3I5)
                CALL IDENT(B,DENS,NQR)
        DO 70 IR=1,IK
        DO 70 J=1,NOGA
        RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
        DO 70 K=1,NFL
        GFL(IR,J,K)=RH*TWG(K)*B/2.
 70     GZETA(IR,J,K)=RH*TXG(K)/2.
        ES(1)=SIG(1)/EPS(1)
        IF(NSFL-1)77,77,76
 76     DO 78 L=2,NSFL
 78     ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
 77     ES(NSFL+1)=0.0
        DO 79 L=1,NSFL
 79     SNO(L)=ES(1)*EPS(L)
        YOUNG=ES(1)
        DO 71 IR=1,IK
        DO 71 J=1,NOGA
```

```
      DO 71 K=1,NFL
      DO 71 L=1,NSFL
71    ASFL(IR,J,K,L)=GFL(IR,J,K)*(ES(L)-ES(L+1))/ES(1)
      DO 73 IR=1,IK
73    HHALF(IR)=(H(IR+1)+H(IR))/2./2.
      DO 15 I=1,8
15    ICOL(I)=1
      DO 16 I=3,IKP1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX =',I5)
            CALL ELMPP(AMASS,DELTAT,AA,ISIZE,KROW,NDEX,NIRREG,INUM,
     *DENS,YOUNG,BMASS)
      IF (NQR .EQ. 0) GO TO 22
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
            CALL QREM(AA,AL,AXG,AWG)
      DO 24 I=1,NI
24    FQREF(I)=0.0
22    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2/(DENS*B*0.1)
      C2=DENS*B*0.1/(2.*DELTAT**2)
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
      IT=0
      TIME=0.0
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
```

```
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0   THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
           CALL LOADEQ(Y,Z,ANG,AL,NOGA,AXC,AWG,AA,TBEGIN,TFINAL,IK)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 120
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
      CALL SOLV(AMASS,FMECH,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 26 I=1,NI
26    DELD(I)=DELD(I)+DTSQ*SOL(I)/2.
      IF(NLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
120   IT=IT+1
      TIME=IT*DELTAT
      DO 121 I=1,NI
      FQREF(I)=0.0
      FLVA(I)=0.0
121   DISP(I)=DISP(I)+DELD(I)
45    CALL STRESS
      IF(NQR .EQ. 0) GO TO 127
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 128 I=1,NI
128   FLVA(I)=FLVA(I)+FQREF(I)
127   NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
      DO 123 I=1,NI
123   FLVA(I)=FLVA(I)-FMECH(I)
122   IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVA(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVA(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVA(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVA,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DELD(I)-SOL(I)*DTSQ
      IF(NLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
41    IF(IT.EQ.1) CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,
     *KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
```

```
     *NDEX,NIRREG,CINETO)
 130   IF(IT-MM) 120,170,150
 170   IF(IBIG) 62,150,62
 62    IF(ISURF-2) 64,65,65
 64    WRITE(MWRITE,66) BIG,IBIG,BTIME
 66    FORMAT(///,'    LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
       GO TO 150
 65    WRITE(MWRITE,67) BIG,IBIG,BTIME
 67    FORMAT(///,'    LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
 150   CALL EXIT
       END
```

```
       SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C      ***** PARTIAL RING *****
       DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
       J1=IR*4
       NN(1)=J1-3
       NN(2)=J1-2
       NN(3)=J1-1
       NN(4)=J1
       J2=(IR+1)*4
       NN(5)=J2-3
       NN(6)=J2-2
       NN(7)=J2-1
       NN(8)=J2
 202   DO 402 I=1,8
       M=NN(I)
       DO 402 J=1,8
       N=NN(J)
       IF(M-N)402,403,403
 403   CALL FICOL(M,N,L,ICOL)
       STIFM(L)=STIFM(L)+ELMAS(I,J)
 402   CONTINUE
       RETURN
       END
```

```
       SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C      ***** PARTIAL RING *****
       DIMENSION NN(8),FLVA(1),ELFP(1)
       J1=IR*4
       NN(1)=J1-3
       NN(2)=J1-2
       NN(3)=J1-1
       NN(4)=J1
 121   J2=(IR+1)*4
       NN(5)=J2-3
       NN(6)=J2-2
       NN(7)=J2-1
       NN(8)=J2
 123   DO 101 I=1,8
```

```
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
101   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IDENT(B,DENS,NQR)
C     ***** PARTIAL RING *****
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      WRITE(MWRITE,1) B,DENS,IK,NOGA,NFL,NSFL
1     FORMAT(' ***JET3C***  A SPATIAL FINITE ELEMENT AND TEMPORAL CENTR
     *AL DIFFERENCE PROGRAM',/,'    USED TC CALCULATE THE NONLINEAR RESP
     *ONSES OF A VARIABLE THICKNESS ARBITRARILY',/,'    CURVED PARTIAL
     *RING WITH THE FOLLOWING PARAMETERS  ',//,
     *'    WIDTH OF RING (IN)                   =',E15.6,/,
     *'    DENSITY (LB-SEC**2/IN**4)            =',E15.6,/,
     *'    NUMBER OF ELEMENTS                   =',I5,/,
     *'    NUMBER OF SPANWISE GAUSSIAN PTS      =',I5,/,
     *'    NUMBER OF DEPTHWISE GAUSSIAN PTS     =',I5,/,
     *'    NUMBER OF MECHANICAL SUBLAYERS       =',I5)
      IF(NBCOND .EQ. 0) GO TO 5
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
14    CONTINUE
15    FORMAT('    SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
16    FORMAT('     CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
17    FORMAT('     HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
      GO TO 18
5     WRITE(MWRITE,13)
13   FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
18    IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
20    FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
      GO TO 23
19    WRITE(MWRITE,21)
21    FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
23    IKP1=IK+1
      WRITE(MWRITE,11)
      WRITE(MWRITE,12) (I,Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
12    FORMAT(2(I5,4E15.6))
11    FORMAT(/,' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS',3X,
     *' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS')
      RETURN
      END
```

```
      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** PARTIAL RING *****
      DIMENSION AL(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCUND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 50 I=1,NI
      DELD(I)=0.0
50     DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
      DO 51 L=1,NSFL
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'    THERE IS NO INITIAL IMPULSE  ')
6    FORMAT(/,'    IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) RETURN
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 41
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
41    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      TX=0.0
      DO 65 NN=1,IS2
      NE=(IS1-1)+NN
```

```
      IF(NE .GT. IK) NE=NE-IK
65    TX=TX+AL(NE)
      PIEP=3.14159265/TX
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP
      XX=0.0
      DO 63 II=1,IS2
      I=IS1+II
      NE=I-1
      IF(NE .GT. IK) NE=NE-IK
      XX=XX+AL(NE)
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*XX)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*XX)
61    CONTINUE
60    IF(NBCOND .EQ.0) RETURN
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
      RETURN
      END



      SUBROUTINE PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
C     ***** PARTIAL RING *****
      DIMENSION COPY(51),COPZ(51),HHALF(50),BEPS(3),EPSI(50),EPSO(50)
     *,FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
700   CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
701   CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
704   SUM=SUM+SNS(IR,J,K,L)**2*ASFL(IR,J,K,L)
703   ELAST=ELAST+SUM*AWG(J)*AL(IR)
702   CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
```

```
      DO 32 I=1,NI
32    SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
31    ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
1     FORMAT(//////,'     J=',I5,'       TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)  =',E15.6,/,
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          PLASTIC WORK   (IN.-LB.)  =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
34    FORMAT('   ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
33    IKP1=IK+1
      DO 11 I=1,IKP1
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG(I))-DISP(I*4-2)*SIN(ANG(I))
11    COPZ(I)=Z(I)+DISP(I*4-3)*SIN(ANG(I))+DISP(I*4-2)*COS(ANG(I))
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(IR,2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF(IR)*FCUR
      EPSO(IR)=FARE+HHALF(IR)*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
```

```
      DO 53  I=1,IK
 53   WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
 54   FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,54)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      WRITE(MWRITE,55) ASTER
 55   FORMAT(//,5X,A2,'   STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
 50   DO 21  I=1,IK
 21   WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
 22   FORMAT(I5,9E12.4,2X,E12.4)
      WRITE(MWRITE,22)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      RETURN
      END
```

```
C      JET3C  MAIN PROGRAM FOR VARIABLE THICKNESS ARBITRARILY CURVED RING
C      JET3C  CENTRAL DIFFERENCE OPERATOR
C       ***** COMPLETE RING *****
      DIMENSION AMASS(2060),AA(50,8,8),TXG(6),TWG(6),ES(6),GFL(50,3,6),
     *SOL(205),INUM(205),FMECH(205),HHALF(50),KROW(8),NDEX(8),
     *BMASS(2060),EPS(5),SIG(5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELC(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
      COMMON /ELFU/ SPRIN(2060),FQREF(205),NQR,NORP,NORU,NREL(4),
     *REX(4),NRST(4),NREU(4)
      MREAD=5
      MWRITE=6
      MPUNCH=7
      READ(MREAD,1) B,DENS,IK,NOGA,NFL,NSFL,MM,M1,M2
      IKP1=IK+1
      PIE=3.14159265
      READ(MREAD,11) (Y(I),Z(I),ANG(I),H(I),I=1,IK)
 11   FORMAT(4E15.6)
      DO 111  I=1,IK
 111  ANG(I)=ANG(I)*PIE/180.
      Y(IKP1)=Y(1)
      Z(IKP1)=Z(1)
      H(IKP1)=H(1)
```

```
      ANG(IKP1)=ANG(1)
      READ(MREAD,2) DELTAT,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
1     FORMAT(2E15.6/7I5)
2     FORMAT(4E15.6/(4E15.6))
      READ(MREAD,3)(AXG(K),K=1,NOGA)
      READ(MREAD,3)(AWG(K),K=1,NOGA)
      READ(MREAD,3)(TXG(K),K=1,NFL)
      READ(MREAD,3)(TWG(K),K=1,NFL)
3     FORMAT(4F15.10)
      NI=IK*4
      READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
4     FORMAT(9I5)
      READ(MREAD,9) NQR,NORP,NORU
9     FORMAT(3I5)
            CALL IDENT(B,DENS,NQR)
      DO 70 IR=1,IK
      DO 70 J=1,NOGA
      RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
      DO 70 K=1,NFL
      GFL(IR,J,K)=RH*TWG(K)*B/2.
70    GZETA(IR,J,K)=RH*TXG(K)/2.
      ES(1)=SIG(1)/EPS(1)
      IF(NSFL-1)77,77,76
76    DO 78 L=2,NSFL
78    ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
77    ES(NSFL+1)=0.0
      DO 79 L=1,NSFL
79    SNO(L)=ES(1)*EPS(L)
      YOUNG=ES(1)
      DO 71 IR=1,IK
      DO 71 J=1,NOGA
      DO 71 K=1,NFL
      DO 71 L=1,NSFL
71    ASFL(IR,J,K,L)=GFL(IR,J,K)*(ES(L)-ES(L+1))/ES(1)
      DO 73 IR=1,IK
73    HHALF(IR)=(H(IR+1)+H(IR))/2./2.
      DO 15 I=1,8
15    ICOL(I)=1
      IKM1=IK-1
      DO 16 I=3,IKM1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICOL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      ICOL(IK*4)=1
      ICOL(IK*4-1)=1
      ICOL(IK*4-2)=1
      ICOL(IK*4-3)=1
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
```

```
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KROW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'   SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX =',I5)
            CALL ELMPP(AMASS,DELTAT,AA,ISIZE,KROW,NDEX,NIRREG,INUM,
     *DENS,YOUNG,BMASS)
      IF (NQR .EQ. 0) GO TO 22
      DO 23 L=1,ISIZE
23    SPRIN(L)=0.0
            CALL QREM(AA,AL,AXG,AWG)
      DO 24 I=1,NI
24    FQREF(I)=0.0
22    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2/(DENS*B*0.1)
      C2=DENS*B*0.1/(2.*DELTAT**2)
      MCRIT=0
      BIG=10.**(-10)
      IBIG=0
      IT=0
      TIME=0.0
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0   THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
           CALL LOADEQ(Y,Z,ANG,AL,NOGA,AXG,AWG,AA,TBEGIN,TFINAL)
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 120
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
      CALL SOLV(AMASS,FMECH,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 26 I=1,NI
26    DELD(I)=DELD(I)+DTSQ*SOL(I)/2.
      IF(NLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
120   IT=IT+1
```

```
      TIME=IT*DELTAT
      DO 121 I=1,NI
      FQREF(I)=0.0
      FLVA(I)=0.0
121   DISP(I)=DISP(I)+DELD(I)
      DO 40 K=1,4
      DISP(IK*4+K)=DISP(K)
40    DELD(IK*4+K)=DELD(K)
45    CALL STRESS
      IF(NQR .EQ. 0) GO TO 127
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 128 I=1,NI
128   FLVA(I)=FLVA(I)+FQREF(I)
127   NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
      DO 123 I=1,NI
123   FLVA(I)=FLVA(I)-FMECH(I)
122   IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVA(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVA(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVA(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVA,SOL,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DELD(I)-SOL(I)*DTSQ
      IF(NLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42    APD=APD+FMECH(I)*DELD(I)
      APDEN=APDEN+APD
41    IF(IT.EQ.1) CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,
     *KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
150   CALL EXIT
      END
```

```
      SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C     ***** COMPLETE RING *****
      DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 203,204,204
  203 J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
      GO TO 202
  204 NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
  202 DO 402 I=1,8
      M=NN(I)
      DO 402 J=1,8
      N=NN(J)
      IF(M-N)402,403,403
  403 CALL FICOL(M,N,L,ICOL)
      STIFM(L)=STIFM(L)+ELMAS(I,J)
  402 CONTINUE
      RETURN
      END


      SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C     ***** COMPLETE RING *****
      DIMENSION NN(8),FLVA(1),ELFP(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 121,122,122
  121 J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
      GO TO 123
  122 NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
  123 DO 101 I=1,8
```

```
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
  101 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IDENT(B,DENS,NQR)
C     ***** COMPLETE RING *****
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      WRITE(MWRITE,1) B,DENS,IK,NOGA,NFL,NSFL
    1 FORMAT(' ***JET3C***  A SPATIAL FINITE ELEMENT AND TEMPORAL CENTR
     *AL DIFFERENCE PROGRAM',/,'     USED TC CALCULATE THE NONLINEAR RESP
     *CNSES OF A VARIABLE THICKNESS ARBITRARILY',/,'     CURVED COMPLETE
     *RING WITH THE FOLLOWING PARAMETERS  ',//,
     *'     WIDTH OF RING (IN)                   =',E15.6,/,
     *'     DENSITY (LB-SEC**2/IN**4)            =',E15.6,/,
     *'     NUMBER OF ELEMENTS                   =',I5,/,
     *'     NUMBER OF SPANWISE GAUSSIAN PTS      =',I5,/,
     *'     NUMBER OF DEPTHWISE GAUSSIAN PTS     =',I5,/,
     *'     NUMBER OF MECHANICAL SUBLAYERS       =',I5)
      IF(NBCOND .EQ. 0) GO TO 5
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
   14 CONTINUE
   15 FORMAT('     SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
   16 FORMAT('      CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
   17 FORMAT('      HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
      GO TO 18
    5 WRITE(MWRITE,13)
   13 FORMAT(/,'     THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
   18 IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
   20 FORMAT(/,'     CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
      GO TO 23
   19 WRITE(MWRITE,21)
   21 FORMAT(/,'     THERE ARE NO ELASTIC SPRING CONSTRAINTS')
   23 IKP1=IK+1
      WRITE(MWRITE,11)
      WRITE(MWRITE,12) (I,Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
   12 FORMAT(2(I5,4E15.6))
   11 FORMAT(/,' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS',3X,
     *' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS')
      RETURN
      END
```

```
      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** COMPLETE RING *****
```

```
      DIMENSION AL(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 50 I=1,NI
      DELD(I)=0.0
50     DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
      DO 51 L=1,NSFL
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'    TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'    THERE IS NO INITIAL IMPULSE  ')
6    FORMAT(/,'    IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) GO TO 43
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
      IF(I .GT. IK) I=I-IK
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      IF(IE2P1 .GT. IK) IE2P1=IE2P1-IK
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 41
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
41    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      TX=0.0
      DO 65 NN=1,IS2
      NE=(IS1-1)+NN
      IF(NE .GT. IK) NE=NE-IK
65    TX=TX+AL(NE)
      PIEP=3.14159265/TX
```

```
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP
      XX=0.0
      DO 63 II=1,IS2
      I=IS1+II
      NE=I-1
      IF(I .GT. IK) I=I-IK
      IF(NE .GT. IK) NE=NE-IK
      XX=XX+AL(NE)
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*XX)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*XX)
61    CONTINUE
60    IF(NBCOND .EQ.0) GO TO 43
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
43    DO 44 K=1,4
      DISP(IK*4+K)=DISP(K)
44    DELD(IK*4+K)=DELD(K)
      RETURN
      END
```

```
      SUBROUTINE PRINT(IT,TIME,HHALF,APDEN,FQREF,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
C     ***** COMPLETE RING *****
      DIMENSION COPY(51),COPZ(51),HHALF(50),BEPS(3),EPSI(50),EPSO(50)
     *,FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
700   CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
701   CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
704   SUM=SUM+SNS(IR,J,K,L)**2*ASFL(IR,J,K,L)
703   ELAST=ELAST+SUM*AWG(J)*AL(IR)
702   CONTINUE
      SPDEN=0.0
```

```
      IF(NQR .EQ. 0) GO TO 31
      DO 32 I=1,NI
32    SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
31    ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
1     FORMAT('1    J=',I5,'        TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)  =',E15.6,/,
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          PLASTIC WORK   (IN.-LB.)  =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
34    FORMAT('    ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
33    DO 11 I=1,IK
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG(I))-DISP(I*4-2)*SIN(ANG(I))
11    COPZ(I)=Z(I)+DISP(I*4-3)*SIN(ANG(I))+DISP(I*4-2)*COS(ANG(I))
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(IR,2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF(IR)*FCUR
      EPSO(IR)=FARE+HHALF(IR)*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
```

```
      DO 53 I=1,IK
 53   WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
 54   FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,55) ASTER
 55   FORMAT(//,5X,A2,'   STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
 50   DO 21 I=1,IK
 21   WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
 22   FORMAT(I5,9E12.4,2X,E12.4)
      RETURN
      END
      SUBROUTINE ELMPP(AMASS,DELTAT,AA,ISIZE,KROW,NDEX,NIRREG,INUM,
     *DENS,YOUNG,BMASS)
C     TO FIND THE MASS MATRIX STIFFNESS MATRIX AND STRAIN NODAL
C     DISPLACEMENT TRANSFORMATION MATRICES
      DIMENSION A(8,8),AA(50,8,8),LMI(8),MMI(8),D(8,8),ELM(8,8),
     *ELMAS(8,8),AMASS(1),E(8,8),EK1(8,8),ELK(8,8),STIFK(2060),
     *BE1(3,3,8),KROW(1),NDEX(1),INUM(1),BMASS(1),BNG(51)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 18 L=1,ISIZE
 18   AMASS(L)=0.0
      IF(DELTAT .GT. 0.0) GO TO 50
      DO 51 L=1,ISIZE
 51   STIFK(L)=0.0
 50   DO 101 IR=1,IK
      P5=Z(IR+1)-Z(IR)
      P6=Y(IR+1)-Y(IR)
      P7=ANG(IR+1)-ANG(IR)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      IF(P7 .EQ. 0.0) GO TO 60
      AL(IR)=P7*SQRT(P5**2+P6**2)/SIN(P7/2.)/2.
      GO TO 61
 60   AL(IR)=SQRT(P5**2+P6**2)
 61   BNG(IR+1)=ANG(IR+1)
      BNG(IR)=ANG(IR)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(IR+1)=ANG(IR+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(IR)=ANG(IR)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(IR+1)=ANG(IR+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(IR)=ANG(IR)-6.2831853
      BZER=BNG(IR)-APHA
      B1=(-2.*BNG(IR+1)-4.*BNG(IR)+6.*APHA)/AL(IR)
      B2=(3.*BNG(IR+1)+3.*BNG(IR)-6.*APHA)/AL(IR)**2
      DO 102 I=1,8
      DO 102 J=1,8
      A(I,J)=0.0
      E(I,J)=0.0
 102  D(I,J)=0.0
      A(1,1)= COS(BNG(IR)-APHA)
      A(1,2)= SIN(BNG(IR)-APHA)
      A(2,1)=-SIN(BNG(IR)-APHA)
      A(2,2)= COS(BNG(IR)-APHA)
      A(3,3)=1.
      A(5,1)=COS(BNG(IR+1)-APHA)
```

```
      A(5,2)=SIN(BNG(IR+1)-APHA)
      A(5,3)=P6*SIN(BNG(IR+1))-P5*COS(BNG(IR+1))
      A(6,1)=-SIN(BNG(IR+1)-APHA)
      A(6,2)=COS(BNG(IR+1)-APHA)
      A(6,3)=P6*COS(BNG(IR+1))+P5*SIN(BNG(IR+1))
      A(7,3)=1.
      A(4,4)=1.
      A(5,4)=AL(IR)
      A(5,7)=AL(IR)**2
      A(5,8)=AL(IR)**3
      A(6,5)=AL(IR)**2
      A(6,6)=AL(IR)**3
      P8=B1+2.*B2*AL(IR)
      A(7,4)=AL(IR)*P8
      A(7,5)=2.*AL(IR)
      A(7,6)=3.*AL(IR)**2
      A(7,7)=AL(IR)**2*P8
      A(7,8)=AL(IR)**3*P8
      A(8,4)=1.
      A(8,5)=-AL(IR)**2*P8
      A(8,6)=-AL(IR)**3*P8
      A(8,7)=2.*AL(IR)
      A(8,8)=3.*AL(IR)**2
      CALL MINV(A,8,DET,LMI,MMI)
      DO 52 I=1,8
      DO 52 J=1,8
52    AA(IR,I,J)=A(I,J)
      DO 103 J=1,NOGA
      ZET=AL(IR)*AXG(J)
      RH=H(IR+1)*AXG(J)+H(IR)*(1.-AXG(J))
      RI=RH**3/12.
      RH=RH*10.
      RI=RI*10.
      PHIP=B1+2.*B2*ZET
      PHI=BZER+B1*ZET+B2*ZET**2
      WET=AL(IR)*AWG(J)
      YZET=0.0
      ZZET=0.0
      DO 104 JJ=1,NOGA
      P2=BZER+B1*ZET*AXG(JJ)+B2*(ZET*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*ZET*AWG(JJ)
104   ZZET=ZZET+SIN(P2)*ZET*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      D(1,1)=D(1,1)+RH*WET
      D(2,2)=D(2,2)+RH*WET
      D(3,1)=D(3,1)+(P3*COS(PHI)-P4*SIN(PHI))*RH*WET
      D(3,2)=D(3,2)+(P3*SIN(PHI)+P4*COS(PHI))*RH*WET
      D(3,3)=D(3,3)+(P3**2*RH+P4**2*RH+RI)*WET
      D(4,1)=D(4,1)+ZET*COS(PHI)*RH*WET
      D(4,2)=D(4,2)+ZET*SIN(PHI)*RH*WET
      D(4,3)=D(4,3)+(P3*ZET*RH+ZET*PHIP*RI)*WET
      D(4,4)=D(4,4)+(RH+PHIP**2*RI)*ZET**2*WET
       D(5,1)=D(5,1)-ZET**2*SIN(PHI)*RH*WET
      D(6,1)=D(6,1)-ZET**3*SIN(PHI)*RH*WET
      D(7,1)=D(7,1)+ZET**2*COS(PHI)*RH*WET
      D(8,1)=D(8,1)+ZET**3*COS(PHI)*RH*WET
      D(5,3)=D(5,3)+(P4*ZET**2*RH+2.*ZET*RI)*WET
      D(6,3)=D(6,3)+(P4*ZET**3*RH+3.*ZET**2*RI)*WET
      D(7,3)=D(7,3)+(P3*RH+PHIP*RI)*ZET**2*WET
      D(8,3)=D(8,3)+(P3*RH+PHIP*RI)*ZET**3*WET
```

```
      D(5,4)=D(5,4)+2.*ZET**2*PHIP*RI*WET
      D(6,4)=D(6,4)+3.*ZET**3*PHIP*RI*WET
      D(7,4)=D(7,4)+(RH+PHIP**2*RI)*ZET**3*WET
      D(8,4)=D(8,4)+(RH+PHIP**2*RI)*ZET**4*WET
      D(5,5)=D(5,5)+(ZET**4*RH+4.*ZET**2*RI)*WET
      D(6,5)=D(6,5)+(ZET**5*RH+6.*ZET**3*RI)*WET
      D(7,5)=D(7,5)+2.*ZET**3*PHIP*RI*WET
      D(8,5)=D(8,5)+2.*ZET**4*PHIP*RI*WET
      D(6,6)=D(6,6)+(ZET**6*RH+9.*ZET**4*RI)*WET
      D(7,6)=D(7,6)+3.*ZET**4*PHIP*RI*WET
      D(8,6)=D(8,6)+3.*ZET**5*PHIP*RI*WET
      D(7,7)=D(7,7)+(RH+PHIP**2*RI)*ZET**4*WET
      D(8,7)=D(8,7)+(RH+PHIP**2*RI)*ZET**5*WET
      D(8,8)=D(8,8)+(RH+PHIP**2*RI)*ZET**6*WET
      DO 201 M=1,3
      DO 201 N=1,8
201   BE1(J,M,N)=0.0
      BE1(J,1,4)=1.
      BE1(J,1,5)=-ZET**2*PHIP
      BE1(J,1,6)=-ZET**3*PHIP
      BE1(J,1,7)=2.*ZET
      BE1(J,1,8)=3.*ZET**2
      BE1(J,2,3)=1.
      BE1(J,2,4)=ZET*PHIP
      BE1(J,2,5)=2.*ZET
      BE1(J,2,6)=3.*ZET**2
      BE1(J,2,7)=ZET**2*PHIP
      BE1(J,2,8)=ZET**3*PHIP
      BE1(J,3,4)=-PHIP-ZET*2.*B2
      BE1(J,3,5)=-2.
      BE1(J,3,6)=-6.*ZET
      BE1(J,3,7)=-2.*ZET*PHIP-ZET**2*2.*B2
      BE1(J,3,8)=-3.*ZET**2*PHIP-ZET**3*2.*B2
      DO 202 M=1,3
      DO 202 N=1,8
      BEP(IR,J,M,N)=0.0
      DO 202 K=1,8
202   BEP(IR,J,M,N)=BEP(IR,J,M,N)+BE1(J,M,K)*A(K,N)
      IF(DELTAT .GT. 0.0) GO TO 103
      T1=PHIP+ZET*2.*B2
      T2=2.*ZET*PHIP+ZET**2*2.*B2
      T3=3.*ZET**2*PHIP+ZET**3*2.*B2
      E(4,4)=E(4,4)+(RH+T1**2*RI)*WET
      E(5,4)=E(5,4)+(-ZET**2*PHIP*RH+2.*T1*RI)*WET
      E(6,4)=E(6,4)+(-ZET**3*PHIP*RH+6.*ZET*T1*RI)*WET
      E(7,4)=E(7,4)+(2.*ZET*RH+T2*T1*RI)*WET
      E(8,4)=E(8,4)+(3.*ZET**2*RH+T3*T1*RI)*WET
      E(5,5)=E(5,5)+(ZET**4*PHIP**2*RH+4.*RI)*WET
      E(6,5)=E(6,5)+(ZET**5*PHIP**2*RH+12.*ZET*RI)*WET
      E(7,5)=E(7,5)+(-2.*ZET**3*PHIP*RH+2.*T2*RI)*WET
      E(8,5)=E(8,5)+(-3.*ZET**4*PHIP*RH+2.*T3*RI)*WET
      E(6,6)=E(6,6)+(ZET**6*PHIP**2*RH+36.*ZET**2*RI)*WET
      E(7,6)=E(7,6)+(-2.*ZET**4*PHIP*RH+6.*ZET*T2*RI)*WET
      E(8,6)=E(8,6)+(-3.*ZET**5*PHIP*RH+6.*ZET*T3*RI)*WET
      E(7,7)=E(7,7)+(4.*ZET**2*RH+T2**2*RI)*WET
      E(8,7)=E(8,7)+(6.*ZET**3*RH+T2*T3*RI)*WET
      E(8,8)=E(8,8)+(9.*ZET**4*RH+T3**2*RI)*WET
103   CONTINUE
      D(5,2)=D(7,1)
      D(6,2)=D(8,1)
```

```
      D(7,2)=-D(5,1)
      D(8,2)=-D(6,1)
      DO 105 I=1,7
      IP1=I+1
      DO 105 J=IP1,8
  105 D(I,J)=D(J,I)
      DO 106 I=1,8
      DO 106 J=1,8
      ELM(I,J)=0.0
      DO 106 K=1,8
  106 ELM(I,J)=ELM(I,J)+A(K,I)*D(K,J)
      DO 107 I=1,8
      DO 107 J=1,8
      ELMAS(I,J)=0.0
      DO 107 K=1,8
  107 ELMAS(I,J)=ELMAS(I,J)+ELM(I,K)*A(K,J)
      CALL ASSEM(IR,IK,ELMAS,AMASS,ICOL,NI)
      IF(DELTAT .GT. 0.0) GO TO 101
      DO 20 I=1,7
      IP1=I+1
      DO 20 J=IP1,8
   20 E(I,J)=E(J,I)
      DO 21 I=1,8
      DO 21 J=1,8
     EK1(I,J)=0.0
      DO 21 K=1,8
   21 EK1(I,J)=EK1(I,J)+A(K,I)*E(K,J)
      DO 22 I=1,8
      DO 22 J=1,8
      ELK(I,J)=C.0
      DO 22 K=1,8
   22 ELK(I,J)=ELK(I,J)+EK1(I,K)*A(K,J)
      CALL ASSEM(IR,IK,ELK,STIFK,ICOL,NI)
  101 CONTINUE
      IF(NBCOND .EQ.0) GO TO 90
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,AMASS,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,AMASS,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,AMASS,NI,ICOL)
   91 CONTINUE
   90 DO 92 L=1,ISIZE
   92 BMASS(L)=AMASS(L)
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      IF(DELTAT .GT. 0.0) RETURN
C
C     DETERMINATION OF DELTAT IF NOT GIVEN
C
      CALL TSTEP(AMASS,STIFK,DENS,YOUNG,KROW,NDEX,NIRREG,DELTAT)
      RETURN
      END



      SUBROUTINE STRESS
C     TO EVALUATE GENERALIZED NODAL LOAD VECTOR DUE TO LARGE DEFLECTION
```

```
C       AND ELASTIC-PLASTIC STRAIN
        DIMENSION ELFP(8),BEPS(3),CEPS(3,3),BINPW(3),BIMPW(3),HWB(3,3),
     *PN(8),PM(8),HNL(8)
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
        COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3)
        COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3)
        DO 502 IR=1,IK
        DO 503 J=1,NOGA
        BINP(IR,J)=0.
        BIMP(IR,J)=0.
 202    DO 402 I=1,3
        BEPS(I)=0.
        DO 402 K=1,8
        INDEX=(IR-1)*4+K
 402    BEPS(I)=BEPS(I)+BEP(IR,J,I,K)*DELD(INDEX)
        CEPS(J,2)=0.0
        DO 403 K=1,8
        INDEX=(IR-1)*4+K
 403    CEPS(J,2)=CEPS(J,2)+BEP(IR,J,2,K)*DISP(INDEX)
 205    FARE=BEPS(1)+CEPS(J,2)*BEPS(2)-BEPS(2)**2/2.
        FCUR=BEPS(3)
        DO 151 K=1,NFL
        BFNP=0.
        BEPX=FARE+GZETA(IR,J,K)*FCUR
        IF(DS.GT. 0.0) RFACTR=1.+(C6*ABS(BEPX))**C5
        DO 35 L=1,NSFL
        SNS(IR,J,K,L)=SNS(IR,J,K,L)+YOUNG*BEPX
        IF(DS.EQ. 0.0) GO TO 255
        IF(SNS(IR,J,K,L)-SNO(L))30,301,91
 91     SNY=SNO(L)*RFACTR
        IF(SNS(IR,J,K,L)-SNY)301,301,20
 20     SNS(IR,J,K,L)=SNY
        GO TO 301
 30     IF(SNS(IR,J,K,L)+SNO(L))92,301,301
 92     SNY=SNO(L)*RFACTR
        IF(SNS(IR,J,K,L)+SNY)40,301,301
 40     SNS(IR,J,K,L)=-SNY
        GO TO 301
 255    IF(SNS(IR,J,K,L)-SNO(L)) 18,301,17
 17     SNS(IR,J,K,L)=SNO(L)
        GO TO 301
 18     IF(SNS(IR,J,K,L)+SNO(L)) 19, 301,301
 19     SNS(IR,J,K,L)=-SNO(L)
 301    BFNP=BFNP+SNS(IR,J,K,L)*ASFL(IR,J,K,L)
 35     CONTINUE
        BINP(IR,J)=BINP(IR,J)+BFNP
        BIMP(IR,J)=BIMP(IR,J)+BFNP*GZETA(IR,J,K)
 151    CONTINUE
 503    CONTINUE
 107    DO 101 J=1,NOGA
        BINPW(J)=BINP(IR,J)*AWG(J)*AL(IR)
        BIMPW(J)=BIMP(IR,J)*AWG(J)*AL(IR)
        HWB(J,2)=CEPS(J,2)*AWG(J)*BINP(IR,J)*AL(IR)
 101     CONTINUE
        DO 102 I=1,8
        PN(I)=0.
        PM(I)=0.
```

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      HNL(I)=0.0
      DO 102 J=1,NOGA
      PN(I)=PN(I)+BEP(IR,J,1,I)*BINPW(J)
      PM(I)=PM(I)+BEP(IR,J,3,I)*BIMPW(J)
102   HNL(I)=HNL(I)+BEP(IR,J,2,I)*HWB(J,2)
200   DO 105 I=1,8
105   ELFP(I)=PN(I)+PM(I)+HNL(I)
502   CALL ASSEF(IR,IK,ELFP,FLVA)
      RETURN
      END




      SUBROUTINE LOADEG(Y,Z,ANG,AL,NOGA,AXG,AWG,AA,TBEGIN,TFINAL,IK)
C     TO FIND GENERALIZED NODAL LOAD AND EXTERNALLY-APPLIED LOAD TRANS-
C     FORMATION MATRICES
      DIMENSION FM(8,2),AA(50,8,8),Y(1),Z(1),ANG(1),AL(1),AXG(1),AWG(1)
     *,FMA(8,2),FMB(8,2),BNG(51)
      COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      IF(TFINAL .EQ. 0.0) RETURN
      WRITE(MWRITE,47) TBEGIN,TFINAL
47    FORMAT('0   STARTING TIME OF FORCING FUNCTION (SEC) =',E15.6,/,
     *'    STOPPING TIME OF FORCING FUNCTION (SEC) =',E15.6)
      READ(MREAD,6) NOFT1,NOFT2,NOFT3
6     FORMAT(3I5)
7     FORMAT(I5,3E15.6)
8     FORMAT(2I5,2E15.6)
      IF(NOFT1 .EQ. 0) GO TO 54
      READ(MREAD,7)(JELEM(I),ETA(I),RTOV(I),RTOW(I),I=1,NOFT1)
      DO 100 I=1,NOFT1
      NE=JELEM(I)
      SL=ETA(I)
      P5=Z(NE+1)-Z(NE)
      P6=Y(NE+1)-Y(NE)
      P7=ANG(NE+1)-ANG(NE)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      BNG(NE+1)=ANG(NE+1)
      BNG(NE)=ANG(NE)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(NE+1)=ANG(NE+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(NE)=ANG(NE)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(NE+1)=ANG(NE+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(NE)=ANG(NE)-6.2831853
      BZER=BNG(NE)-APHA
      B1=(-2.*BNG(NE+1)-4.*BNG(NE)+6.*APHA)/AL(NE)
      B2=(3.*BNG(NE+1)+3.*BNG(NE)-6.*APHA)/AL(NE)**2
      PHI=BZER+B1*SL+B2*SL**2
      PHIP=B1+2.*B2*SL
      YZET=0.0
      ZZET=0.0
      DO 101 JJ=1,NOGA
      P2=BZER+B1*SL*AXG(JJ)+B2*(SL*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*SL*AWG(JJ)
101   ZZET=ZZET+SIN(P2)*SL*AWG(JJ)
```

```
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      FM(1,1)=COS(PHI)
      FM(2,1)=SIN(PHI)
      FM(1,2)=-SIN(PHI)
      FM(2,2)=COS(PHI)
      FM(3,1)=P3
      FM(3,2)=P4
      FM(4,1)=SL
      FM(4,2)=0.0
      FM(5,1)=0.0
      FM(5,2)=SL**2
      FM(6,1)=0.0
      FM(6,2)=SL**3
      FM(7,1)=SL**2
      FM(7,2)=0.0
      FM(8,1)=SL**3
      FM(8,2)=0.0
      DO 102 M=1,8
      DO 102 N=1,2
      FM1(I,M,N)=0.0
      DO 102 K=1,8
102   FM1(I,M,N)=FM1(I,M,N)+AA(NE,K,M)*FM(K,N)
100   CONTINUE
54    IF(NOFT2 .EQ. 0) GO TO 55
      READ(MREAD,8)(NSTF2(I),NELF2(I),RTO2V(I),RTO2W(I),I=1,NOFT2)
      DO 200 I=1,NOFT2
      NSTAT=NSTF2(I)
      NEND=NELF2(I)
      DO 201 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
      P5=Z(NE+1)-Z(NE)
      P6=Y(NE+1)-Y(NE)
      P7=ANG(NE+1)-ANG(NE)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      BNG(NE+1)=ANG(NE+1)
      BNG(NE)=ANG(NE)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(NE+1)=ANG(NE+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(NE)=ANG(NE)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(NE+1)=ANG(NE+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(NE)=ANG(NE)-6.2831853
      BZER=BNG(NE)-APHA
      B1=(-2.*BNG(NE+1)-4.*BNG(NE)+6.*APHA)/AL(NE)
      B2=(3.*BNG(NE+1)+3.*BNG(NE)-6.*APHA)/AL(NE)**2
      DO 202 M=1,8
      DO 202 N=1,2
202   FM(M,N)=0.0
      DO 203 J=1,NOGA
      ZET=AL(NE)*AXG(J)
      PHIP=B1+2.*B2*ZET
      PHI=BZER+B1*ZET+B2*ZET**2
      WET=AL(NE)*AWG(J)
      YZET=0.0
      ZZET=0.0
      DO 204 JJ=1,NOGA
      P2=BZER+B1*ZET*AXG(JJ)+B2*(ZET*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*ZET*AWG(JJ)
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```
204   ZZET=ZZET+SIN(P2)*ZET*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      FM(1,1)=FM(1,1)+COS(PHI)*WET
      FM(1,2)=FM(1,2)-SIN(PHI)*WET
      FM(2,1)=FM(2,1)+SIN(PHI)*WET
      FM(2,2)=FM(2,2)+COS(PHI)*WET
      FM(3,1)=FM(3,1)+P3*WET
      FM(4,1)=FM(4,1)+ZET*WET
      FM(7,1)=FM(7,1)+ZET**2*WET
      FM(8,1)=FM(8,1)+ZET**3*WET
      FM(3,2)=FM(3,2)+P4*WET
      FM(5,2)=FM(5,2)+ZET**2*WET
      FM(6,2)=FM(6,2)+ZET**3*WET
203   CONTINUE
      DO 205 M=1,8
      DO 205 N=1,2
      FM2(I,NN,M,N)=0.0
      DO 205 K=1,8
205   FM2(I,NN,M,N)=FM2(I,NN,M,N)+AA(NE,K,M)*FM(K,N)
201   CONTINUE
200   CONTINUE
55    IF(NOFT3 .EQ. 0) RETURN
      READ(MREAD,8) (NSTF3(I),NELF3(I),RTO3V(I),RTO3W(I),I=1,NOFT3)
      DO 300 I=1,NOFT3
      NSTAT=NSTF3(I)
      NEND=NELF3(I)
      DO 301 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
      P5=Z(NE+1)-Z(NE)
      P6=Y(NE+1)-Y(NE)
      P7=ANG(NE+1)-ANG(NE)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      BNG(NE+1)=ANG(NE+1)
      BNG(NE)=ANG(NE)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(NE+1)=ANG(NE+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(NE)=ANG(NE)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(NE+1)=ANG(NE+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(NE)=ANG(NE)-6.2831853
      BZER=BNG(NE)-APHA
      B1=(-2.*BNG(NE+1)-4.*BNG(NE)+6.*APHA)/AL(NE)
      B2=(3.*BNG(NE+1)+3.*BNG(NE)-6.*APHA)/AL(NE)**2
      DO 302 M=1,8
      DO 302 N=1,2
      FMA(M,N)=0.0
302   FMB(M,N)=0.0
      DO 303 J=1,NOGA
      ZET=AL(NE)*AXG(J)
      PHIP=B1+2.*B2*ZET
      PHI=BZER+B1*ZET+B2*ZET**2
      WET=AL(NE)*AWG(J)
      YZET=0.0
      ZZET=0.0
      DO 304 JJ=1,NOGA
      P2=BZER+B1*ZET*AXG(JJ)+B2*(ZET*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*ZET*AWG(JJ)
304   ZZET=ZZET+SIN(P2)*ZET*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
```

```
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      FMA(1,1)=FMA(1,1)+COS(PHI)*WET
      FMA(2,1)=FMA(2,1)+SIN(PHI)*WET
      FMA(3,1)=FMA(3,1)+P3*WET
      FMA(4,1)=FMA(4,1)+ZET*WET
      FMA(7,1)=FMA(7,1)+ZET**2*WET
      FMA(8,1)=FMA(8,1)+ZET**3*WET
      FMA(1,2)=FMA(1,2)-SIN(PHI)*WET
      FMA(2,2)=FMA(2,2)+COS(PHI)*WET
      FMA(3,2)=FMA(3,2)+P4*WET
      FMA(5,2)=FMA(5,2)+ZET**2*WET
      FMA(6,2)=FMA(6,2)+ZET**3*WET
      FMB(1,1)=FMB(1,1)+COS(PHI)*ZET*WET/AL(NE)
      FMB(2,1)=FMB(2,1)+SIN(PHI)*ZET*WET/AL(NE)
      FMB(3,1)=FMB(3,1)+P3*ZET*WET/AL(NE)
      FMB(4,1)=FMB(4,1)+ZET**2*WET/AL(NE)
      FMB(7,1)=FMB(7,1)+ZET**3*WET/AL(NE)
      FMB(8,1)=FMB(8,1)+ZET**4*WET/AL(NE)
      FMB(1,2)=FMB(1,2)-SIN(PHI)*ZET*WET/AL(NE)
      FMB(2,2)=FMB(2,2)+COS(PHI)*ZET*WET/AL(NE)
      FMB(3,2)=FMB(3,2)+P4*ZET*WET/AL(NE)
      FMB(5,2)=FMB(5,2)+ZET**3*WET/AL(NE)
      FMB(6,2)=FMB(6,2)+ZET**4*WET/AL(NE)
  303 CONTINUE
      DO 305 M=1,8
      DO 305 N=1,2
      FM3A(I,NN,M,N)=0.0
      FM3B(I,NN,M,N)=0.0
      DO 305 K=1,8
      FM3A(I,NN,M,N)=FM3A(I,NN,M,N)+AA(NE,K,M)*FMA(K,N)
  305 FM3B(I,NN,M,N)=FM3B(I,NN,M,N)+AA(NE,K,M)*FMB(K,N)
  301 CONTINUE
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOADFT(TIME,NREADF,FMECH,AL)
C     TO FIND THE GENERALIZED NODAL LOAD VECTOR EQUIVALENT TO THE
C     EXTERNALLY-APPLIED LOAD
      DIMENSION FMECH(205),ELF(8),AL(50)
      COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCONC,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      IF(NREADF .GT. 0) GO TO 50
   51 READ(MREAD,52) T2,AMP2FV,AMP2FW
   52 FORMAT(3E15.6)
      NREADF=1
      SLOPEV=(AMP2FV-AMP1FV)/(T2-T1)
      SLOPEW=(AMP2FW-AMP1FW)/(T2-T1)
   50 IF(TIME .LE. T2) GO TO 53
      T1=T2
      AMP1FV=AMP2FV
```

```
      AMP1FW=AMP2FW
      GO TO 51
53    AMPFV=AMP1FV+(TIME-T1)*SLOPEV
      AMPFW=AMP1FW+(TIME-T1)*SLOPEW
      DO 57 I=1,NI
57    FMECH(I)=0.0
      IF(NOFT1 .EQ. 0) GO TO 54
      DO 100 I=1,NOFT1
      NE=JELEM(I)
      FMV=AMPFV*RTOV(I)
      FMW=AMPFW*RTOW(I)
      DO 101 J=1,8
101    ELF(J)=FM1(I,J,1)*FMV+FM1(I,J,2)*FMW
100   CALL ASSEF(NE,IK,ELF,FMECH)
54    IF(NOFT2 .EQ. 0) GO TO 55
      DO 200 I=1,NOFT2
      NSTAT=NSTF2(I)
      NEND=NELF2(I)
      FMV=AMPFV*RTO2V(I)
      FMW=AMPFW*RTO2W(I)
      DO 201 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
      DO 202 J=1,8
202   ELF(J)=FM2(I,NN,J,1)*FMV+FM2(I,NN,J,2)*FMW
201   CALL ASSEF(NE,IK,ELF,FMECH)
200   CONTINUE
55    IF(NOFT3 .EQ. 0) GO TO 90
      DO 300 I=1,NOFT3
      NSTAT=NSTF3(I)
      NEND=NELF3(I)
      TX=0.0
      DO 303 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
303   TX=TX+AL(NE)
      PIEP=3.14159265/TX
      FMV=AMPFV*RTO3V(I)
      FMW=AMPFW*RTO3W(I)
      FMW1=0.0
      FMV1=0.0
      XX=0.0
      DO 301 NN=1,NEND
      NE=(NSTAT-1)+NN
      IF(NE .GT. IK) NE=NE-IK
      XX=XX+AL(NE)
      X=PIEP*XX
      FMW2=SIN(X)*FMW
      FMV2=SIN(X)*FMV
      AFSW=FMW1
      BFSW=(FMW2-FMW1)
      AFSV=FMV1
      BFSV=FMV2-FMV1
      FMW1=FMW2
      FMV1=FMV2
      DO 302 J=1,8
302   ELF(J)=FM3A(I,NN,J,1)*AFSV+FM3A(I,NN,J,2)*AFSW+
     *FM3B(I,NN,J,1)*BFSV+FM3B(I,NN,J,2)*BFSW
301   CALL ASSEF(NE,IK,ELF,FMECH)
300   CONTINUE
90    IF(NBCOND .EQ. 0) RETURN
```

```
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      FMECH(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FMECH(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FMECH(JT4-2)=0.0
91    CONTINUE
56    RETURN
      END
```

```
      SUBROUTINE QREM(AA,AL,AXG,AWG)
C     TO FIND EFFECTIVE STIFFNESS MATRIX DUE TO ELASTIC RESTRAINTS
      DIMENSION AA(50,8,8),AL(1),AXG(1),AWG(1),BNG(51)
     *,ELR(8,8),ELRR(8,8),ELRP(8,8)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /ELFU/ SPRIN(2060),FQREF(205),NQR,NORP,NORU,NREL(4),
     *REX(4),NRST(4),NREU(4)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      IF (NORP .EQ. 0) GO TO 1
      READ(MREAD,2) SCTP,SCRP,(NREL(I),REX(I),I=1,NORP)
2     FORMAT(2E15.6/(4(I5,E15.6)))
      DO 10 IQ=1,NORP
      SL=REX(IQ)
      NE=NREL(IQ)
      P5=Z(NE+1)-Z(NE)
      P6=Y(NE+1)-Y(NE)
      P7=ANG(NE+1)-ANG(NE)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      BNG(NE+1)=ANG(NE+1)
      BNG(NE)=ANG(NE)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(NE+1)=ANG(NE+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(NE)=ANG(NE)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(NE+1)=ANG(NE+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(NE)=ANG(NE)-6.2831853
      BZER=BNG(NE)-APHA
      B1=(-2.*BNG(NE+1)-4.*BNG(NE)+6.*APHA)/AL(NE)
      B2=(3.*BNG(NE+1)+3.*BNG(NE)-6.*APHA)/AL(NE)**2
      PHI=BZER+B1*SL+B2*SL**2
      PHIP=B1+2.*B2*SL
      YZET=0.0
      ZZET=0.0
      DO 104 JJ=1,NOGA
      P2=BZER+B1*SL*AXG(JJ)+B2*(SL*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*SL*AWG(JJ)
104   ZZET=ZZET+SIN(P2)*SL*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      ELR(1,1)=SCTP
      ELR(2,1)=0.0
      ELR(3,1)=(P3*COS(PHI)-P4*SIN(PHI))*SCTP
      ELR(4,1)=SL*COS(PHI)*SCTP
      ELR(5,1)=-SL**2*SIN(PHI)*SCTP
      ELR(6,1)=-SL**3*SIN(PHI)*SCTP
      ELR(7,1)=SL**2*COS(PHI)*SCTP
```

```
      ELR(8,1)=SL**3*COS(PHI)*SCTP
      ELR(2,2)=SCTP
      ELR(3,2)=(P3*SIN(PHI)+P4*COS(PHI))*SCTP
      ELR(4,2)=SL*SIN(PHI)*SCTP
      ELR(5,2)=SL**2*COS(PHI)*SCTP
      ELR(6,2)=SL**3*COS(PHI)*SCTP
      ELR(7,2)=SL**2*SIN(PHI)*SCTP
      ELR(8,2)=SL**3*SIN(PHI)*SCTP
      ELR(3,3)=(P3**2+P4**2)*SCTP+SCRP
      ELR(4,3)=P3*SL*SCTP+SL*PHIP*SCRP
      ELR(5,3)=P4*SL**2*SCTP+2.*SL*SCRP
      ELR(6,3)=P4*SL**3*SCTP+3.*SL**2*SCRP
      ELR(7,3)=(P3*SCTP+PHIP*SCRP)*SL**2
      ELR(8,3)=(P3*SCTP+PHIP*SCRP)*SL**3
      ELR(4,4)=(SCTP+PHIP**2*SCRP)*SL**2
      ELR(5,4)=2.*SL**2*PHIP*SCRP
      ELR(6,4)=3.*SL**3*PHIP*SCRP
      ELR(7,4)=(SCTP+PHIP**2*SCRP)*SL**3
      ELR(8,4)=(SCTP+PHIP**2*SCRP)*SL**4
      ELR(5,5)=SL**4*SCTP+4.*SL**2*SCRP
      ELR(6,5)=SL**5*SCTP+6.*SL**3*SCRP
      ELR(7,5)=2.*SL**3*PHIP*SCRP
      ELR(8,5)=2.*SL**4*PHIP*SCRP
      ELR(6,6)=SL**6*SCTP+9.*SL**4*SCRP
      ELR(7,6)=3.*SL**4*PHIP*SCRP
      ELR(8,6)=3.*SL**5*PHIP*SCRP
      ELR(7,7)=(SCTP+PHIP**2*SCRP)*SL**4
      ELR(8,7)=(SCTP+PHIP**2*SCRP)*SL**5
      ELR(8,8)=(SCTP+PHIP**2*SCRP)*SL**6
      DO 12 I=1,7
      IP1=I+1
      DO 12 J=IP1,8
12    ELR(I,J)=ELR(J,I)
      DO 13 I=1,8
      DO 13 J=1,8
      ELRR(I,J)=0.0
      DO 13 K=1,8
13    ELRR(I,J)=ELRR(I,J)+ELR(I,K)*AA(NE,K,J)
      DO 14 I=1,8
      DO 14 J=1,8
      ELRP(I,J)=0.0
      DO 14 K=1,8
14    ELRP(I,J)=ELRP(I,J)+AA(NE,K,I)*ELRR(K,J)
      CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
10    CONTINUE
1     IF(NORU .EQ.0) GO TO 4
      READ(MREAD,3) SCTU,SCRU,(NRST(I),NREU(I),I=1,NORU)
3     FORMAT(2E15.6,8I5)
      DO 15 IQ=1,NORU
      NSTAT=NRST(IQ)
      NEND=NREU(IQ)
      DO 16 IR=1,NEND
      NE=(NSTAT-1)+IR
      IF(NE .GT. IK) NE=NE-IK
      P5=Z(NE+1)-Z(NE)
      P6=Y(NE+1)-Y(NE)
      P7=ANG(NE+1)-ANG(NE)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      BNG(NE+1)=ANG(NE+1)
```

```
      BNG(NE)=ANG(NE)
      IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(NE+1)=ANG(NE+1)-6.2831853
      IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(NE)=ANG(NE)+6.2831853
      IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(NE+1)=ANG(NE+1)+6.2831853
      IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(NE)=ANG(NE)-6.2831853
      BZER=BNG(NE)-APHA
      B1=(-2.*BNG(NE+1)-4.*BNG(NE)+6.*APHA)/AL(NE)
      B2=(3.*BNG(NE+1)+3.*BNG(NE)-6.*APHA)/AL(NE)**2
      DO 102 I=1,8
      DO 102 J=1,8
102    ELR(I,J)=0.0
      DO 103 J=1,NOGA
      ZET=AL(NE)*AXG(J)
      PHIP=B1+2.*B2*ZET
      PHI=BZER+B1*ZET+B2*ZET**2
      WET=AL(NE)*AWG(J)
      YZET=0.0
      ZZET=0.0
      DO 105 JJ=1,NOGA
      P2=BZER+B1*ZET*AXG(JJ)+B2*(ZET*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*ZET*AWG(JJ)
105   ZZET=ZZET+SIN(P2)*ZET*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      ELR(1,1)=ELR(1,1)+SCTU*WET
      ELR(3,1)=ELR(3,1)+(P3*COS(PHI)-P4*SIN(PHI))*SCTU*WET
      ELR(4,1)=ELR(4,1)+ZET*COS(PHI)*SCTU*WET
      ELR(5,1)=ELR(5,1)-ZET**2*SIN(PHI)*SCTU*WET
      ELR(6,1)=ELR(6,1)-ZET**3*SIN(PHI)*SCTU*WET
      ELR(7,1)=ELR(7,1)+ZET**2*COS(PHI)*SCTU*WET
      ELR(8,1)=ELR(8,1)+ZET**3*COS(PHI)*SCTU*WET
      ELR(2,2)=ELR(2,2)+SCTU*WET
      ELR(3,2)=ELR(3,2)+(P3*SIN(PHI)+P4*COS(PHI))*SCTU*WET
      ELR(4,2)=ELR(4,2)+ZET*SIN(PHI)*SCTU*WET
      ELR(5,2)=ELR(5,2)+ZET**2*COS(PHI)*SCTU*WET
      ELR(6,2)=ELR(6,2)+ZET**3*COS(PHI)*SCTU*WET
      ELR(7,2)=ELR(7,2)+ZET**2*SIN(PHI)*SCTU*WET
      ELR(8,2)=ELR(8,2)+ZET**3*SIN(PHI)*SCTU*WET
      ELR(3,3)=ELR(3,3)+((P3**2+P4**2)*SCTU+SCRU)*WET
      ELR(4,3)=ELR(4,3)+(P3*SCTU+PHIP*SCRU)*ZET*WET
      ELR(5,3)=ELR(5,3)+(P4*ZET**2*SCTU+2.*ZET*SCRU)*WET
      ELR(6,3)=ELR(6,3)+(P4*ZET**3*SCTU+3.*ZET**2*SCRU)*WET
      ELR(7,3)=ELR(7,3)+(P3*SCTU+PHIP*SCRU)*ZET**2*WET
      ELR(8,3)=ELR(8,3)+(P3*SCTU+PHIP*SCRU)*ZET**3*WET
      ELR(4,4)=ELR(4,4)+(SCTU+PHIP**2*SCRU)*ZET**2*WET
      ELR(5,4)=ELR(5,4)+2.*ZET**2*PHIP*SCRU*WET
      ELR(6,4)=ELR(6,4)+3.*ZET**3*PHIP*SCRU*WET
      ELR(7,4)=ELR(7,4)+(SCTU+PHIP**2*SCRU)*ZET**3*WET
      ELR(8,4)=ELR(8,4)+(SCTU+PHIP**2*SCRU)*ZET**4*WET
      ELR(5,5)=ELR(5,5)+(ZET**4*SCTU+4.*ZET**2*SCRU)*WET
      ELR(6,5)=ELR(6,5)+(ZET**5*SCTU+6.*ZET**3*SCRU)*WET
      ELR(7,5)=ELR(7,5)+2.*ZET**3*PHIP*SCRU*WET
      ELR(8,5)=ELR(8,5)+2.*ZET**4*PHIP*SCRU*WET
      ELR(6,6)=ELR(6,6)+(ZET**6*SCTU+9.*ZET**4*SCRU)*WET
      ELR(7,6)=ELR(7,6)+3.*ZET**4*PHIP*SCRU*WET
      ELR(8,6)=ELR(8,6)+3.*ZET**5*PHIP*SCRU*WET
      ELR(7,7)=ELR(7,7)+(SCTU+PHIP**2*SCRU)*ZET**4*WET
      ELR(8,7)=ELR(8,7)+(SCTU+PHIP**2*SCRU)*ZET**5*WET
      ELR(8,8)=ELR(8,8)+(SCTU+PHIP**2*SCRU)*ZET**6*WET
103   CONTINUE
```

```
      DO 5 I=1,7
      IP1=I+1
      DO 5 J=IP1,8
5     ELR(I,J)=ELR(J,I)
      DO 6 I=1,8
      DO 6 J=1,8
      ELRR(I,J)=0.0
      DO 6 K=1,8
6     ELRR(I,J)=ELRR(I,J)+ELR(I,K)*AA(NE,K,J)
      DO 7 I=1,8
      DO 7 J=1,8
      ELRP(I,J)=0.0
      DO 7 K=1,8
7     ELRP(I,J)=ELRP(I,J)+AA(NE,K,I)*ELRR(K,J)
16    CALL ASSEM(NE,IK,ELRP,SPRIN,ICOL,NI)
15    CONTINUE
4     IF(NBCOND .EQ. 0) RETURN
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,SPRIN,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,SPRIN,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,SPRIN,NI,ICOL)
91    CONTINUE
      RETURN
      END




      SUBROUTINE TSTEP(AMASS,STIFK,DENS,YOUNG,KROW,NDEX,NIRREG,DELTAT)
C     TO FIND DELTAT IF IT IS NOT SPECIFIED
      DIMENSION AMASS(1),STIFK(1),TRIAL(205),VMULT(205),VECTR(205),
     *KROW(1),NDEX(1)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 3 K=1,NI
3     TRIAL(K)=1.0
      IF(NBCOND .EQ. 0) GO TO 90
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,STIFK,NI,ICOL)
      TRIAL(JT4M3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,STIFK,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,STIFK,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) TRIAL(JT4M1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) TRIAL(JT4M2)=0.0
91    CONTINUE
90    MRANK=NI
      BONE=0.
      EPSLN=1.0E-07
2     BOLD=1.0
      DO 14 IKK=1,4
      DO 12 ILL=1,50
```

```
      DO 4 I=1,MRANK
 4    VMULT(I)=0.0
      CALL OMULT(STIFK,TRIAL,ICOL,NI,VMULT,KROW,NDEX,NIRREG)
      CALL SOLV(AMASS,VMULT,VECTR,ICOL,KROW,NDEX,NI,NIRREG)
      BNEW=-1.
      DO 6 K=1,MRANK
      IF(BNEW- ABS(VECTR(K)))60,60,6
 60   BNEW= ABS(VECTR(K))
 6    CONTINUE
      DO 7 K=1,MRANK
      IF(BNEW- ABS(VECTR(K)))7,8,7
 7    CONTINUE
 8    MROW=K
      BNEW=VECTR(K)
      DO 9 K=1,MRANK
 9    TRIAL(K)=VECTR(K)/BNEW
      IF( ABS(BNEW/BOLD-1.0)-EPSLN)15,15,10
C     ITERATION
 10   BKTH=BOLD
      BOLD=BNEW
 12   CONTINUE
      EPSLN=EPSLN*10.
 14   CONTINUE
C     NOT CONVERGING AFTER IL*IK ITERATIONS
      EPSLN=1.0
      BONE=BNEW
      GO TO 32
C     EIGEN VALUE FOUND
 15   BONE=BNEW
 32   WRITE(MWRITE,24) (TRIAL(J),J=1,NI)
 24   FORMAT(/,'    EIGEN VECTOR OF HIGHEST MODE',/,18X,'V',14X,'W',13X
     *,'PSI',12X,'CHI',/,(11X,4E15.6))
      FREQ= SQRT(YOUNG*BONE/DENS)
      FACTCL=0.8
      DELTAT=FACTCL*2./FREQ
      WRITE(MWRITE,25)FREQ
 25   FORMAT(/,'    HIGHEST NATURAL FREQUENCY (RAD/SEC) =',E17.8)
      RETURN
      END
```

5.4 JET 3D: Variable Thickness Arbitrarily Curved Ring; Houbolt's Timewise Operator

The JET 3D program consists of the following main programs and subroutines:

1. JET 3D MAIN PROGRAM
2. ASSEM
3. ASSEF
4. IDENT
5. IMPULS
6. PRINT

(items 1–6: partial ring)

7. JET 3D MAIN PROGRAM
8. ASSEM
9. ASSEF
10. IDENT
11. IMPULS
12. PRINT

(items 7–12: complete ring)

13. ELMPP
14. STRESS
15. LOADEQ
16. LOADFT
17. QREM
18. ERC
19. FAC
20. FICOL
21. MINV
22. OMULT
23. SOLV

Again, note that the subroutines in items 13 through 23 are common to each of these two groups of "control programs".

The number of memory locations required is approximately 224,000 bytes. The subroutines LOADEQ, LOADFT, and QREM (No. 15 through No. 17) are the same as those listed in Subsection 5.3. The subroutines ERC, FAC, FICOL, MINV, OMULT, and SOLV (No. 18 through No. 23) are the same as those listed in Subsection 5.2. To avoid needless repetition, only the main programs and subroutines No. 1 through No. 17 are listed in this subsection.

```
C     JET3D  MAIN PROGRAM FOR VARIABLE THICKNESS ARBITRARILY CURVED RING
C     JET3D  HOUBOLT OPERATOR
C       ***** PARTIAL RING *****
        DIMENSION AMASS(2060),AA(50,8,8),TXG(6),TWG(6),ES(6),GFL(50,3,6),
     *INUM(205),FMECH(205),HHALF(50),KROW(8),NDEX(8),
     *BMASS(2060),EPS(5),SIG(5)
        DIMENSION DDELD(205),DISUM(205),DIS(205),DISM1(205),DISM2(205),
     *FLR(205),FLN(205),FLVM(205),STIFK(2060)
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
        COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
        COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
        COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
        COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
        COMMON /ELFU/ SPRIN(2060),FQREF(205),NQR,NORP,NORU,NREL(4),
     *REX(4),NRST(4),NREU(4)
        MREAD=5
        MWRITE=6
        MPUNCH=7
        READ(MREAD,1) B,DENS,IK,NOGA,NFL,NSFL,MM,M1,M2
        IKP1=IK+1
        PIE=3.14159265
        READ(MREAD,11) (Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
 11     FORMAT(4E15.6)
        DO 111 I=1,IKP1
 111    ANG(I)=ANG(I)*PIE/180.
        READ(MREAD,2) DELTAT,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
 1      FORMAT(2E15.6/7I5)
 2      FORMAT(4E15.6/(4E15.6))
        READ(MREAD,3)(AXG(K),K=1,NOGA)
        READ(MREAD,3)(AWG(K),K=1,NOGA)
        READ(MREAD,3)(TXG(K),K=1,NFL)
        READ(MREAD,3)(TWG(K),K=1,NFL)
 3      FORMAT(4F15.10)
        NI=IKP1*4
        READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
 4      FORMAT(9I5)
        READ(MREAD,9) NQR,NORP,NORU
 9      FORMAT(3I5)
                CALL IDENT(B,DENS,NQR)
        DO 70 IR=1,IK
        DO 70 J=1,NOGA
        RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
        DO 70 K=1,NFL
        GFL(IR,J,K)=RH*TWG(K)*B/2.
 70     GZETA(IR,J,K)=RH*TXG(K)/2.
        ES(1)=SIG(1)/EPS(1)
        IF(NSFL-1)77,77,76
 76     DO 78 L=2,NSFL
 78     ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
 77     ES(NSFL+1)=0.0
        DO 79 L=1,NSFL
 79     SNO(L)=ES(1)*EPS(L)
        YOUNG=ES(1)
```

```
      DO 71 IR=1,IK
      DO 71 J=1,NOGA
      DO 71 K=1,NFL
      DO 71 L=1,NSFL
71    ASFL(IR,J,K,L)=GFL(IR,J,K)*(ES(L)-ES(L+1))/ES(1)
      DO 73 IR=1,IK
73    HHALF(IR)=(H(IR+1)+H(IR))/2./2.
      DO 15 I=1,8
15    ICOL(I)=1
      DO 16 I=3,IKP1
      IK4=I*4
      IK3=IK4-1
      IK2=IK4-2
      IK1=IK4-3
      JJ=(I-1)*4-3
      ICOL(IK1)=JJ
      ICCL(IK2)=JJ
      ICOL(IK3)=JJ
      ICOL(IK4)=JJ
16    CONTINUE
      INUM(1)=1
      DO 99 I=2,NI
99    INUM(I)=I-ICOL(I-1)+INUM(I-1)
      DO 990 I=1,NI
990   INUM(I)=INUM(I)-ICOL(I)
      NIRREG=0
      INDEX=0
      ISET=1
      DO 116 I=1,NI
      L=ICOL(I)
      IF(ICOL(I)-ISET)117,116,119
119   ISET=ICOL(I)
      GO TO 116
117   NIRREG=NIRREG+1
      IF(NIRREG-NI/2)711,711,90
711   KRCW(NIRREG)=I
      NDEX(NIRREG)=INDEX
116   INDEX=INDEX+I-L
90    CALL FICOL(NI,NI,L,ICOL)
      ISIZE=L
      WRITE(MWRITE,17) L
17    FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX=',I5)
            CALL ELMPP(AMASS,STIFK,AA,ISIZE,DENS,YOUNG,B)
      DO 23 L=1,ISIZE
      BMASS(L)=AMASS(L)
23    SPRIN(L)=0.0
      IF (NQR .EQ. 0) GO TO 22
            CALL QREM(AA,AL,AXG,AWG)
22    IF(DS.EQ.0.0) GO TO 21
      C5=1./P
      C6=1./DS/DELTAT
21    DTSQ=DELTAT**2
      C2=1./(2.*DELTAT**2)
      DO 25 IR=1,IK
      DO 25 J=1,NOGA
      RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
      C3(IR,J)=YOUNG*B*RH
25    C4(IR,J)=AL(IR)*AWG(J)
      MCRIT=0
      BIG=10.**(-10)
```

```
      IBIG=0
      IT=0
      TIME=0.0
            CALL IMPULS(DELTAT,AL)
      READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5     FORMAT(4E15.6)
      IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48    FORMAT('0   THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
      IF(TFINAL .EQ. 0.0) GO TO 49
           CALL LOADEQ(Y,Z,ANG,AL,NOGA,AXG,AWG,AA,TBEGIN,TFINAL,I[illegible])
49    APDEN=0.0
            CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
      NREADF=0
      T1=TBEGIN
      NLOAD=2
      DO 34 I=1,NI
34    FMECH(I)=0.0
      IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 30
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      CALL SOLV(AMASS,FMECH,DDELD,ICOL,KROW,NDEX,NI,NIRREG)
      GO TO 31
30    DO 32 I=1,NI
32    DDELD(I)=0.0
31    DO 33 I=1,NI
33    DISUM(I)=2.*DTSQ*DDELD(I)+6.*DELD(I)+6.*DISP(I)
      MLOAD=NLOAD
      DO 35 I=1,NI
      FLR(I)=FMECH(I)
35    FLVM(I)=0.0
      CALL DMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      DO 37 L=1,ISIZE
37    AMASS(L)=6.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      ITT=1
      TIME=ITT*DELTAT
      NLOAD=2
      DO 60 I=1,NI
      FLVA(I)=0.0
60    FMECH(I)=0.0
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 38
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
38    DO 39 I=1,NI
39    FLVM(I)=DTSQ*FMECH(I)+FLVM(I)
      CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 61 I=1,NI
      DELD(I)=DIS(I)-DISP(I)
61    DISM1(I)=DTSQ*DDELD(I)-DIS(I)+2.*DISP(I)
      DO 100 L=1,ISIZE
100   AMASS(L)=2.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
      IF(MLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
```

```
120   ITT=ITT+1
      TIME=ITT*DELTAT
45    DO 121 I=1,NI
      DISM2(I)=DISM1(I)
      DISM1(I)=DISP(I)
      DISP(I)=DIS(I)
      FLR(I)=FMECH(I)
      FLN(I)=FLVA(I)
      FLVA(I)=0.0
      FMECH(I)=0.0
      FLVM(I)=0.0
121   DISUM(I)=5.*DISP(I)-4.*DISM1(I)+DISM2(I)
      MLOAD=NLOAD
      CALL STRESS
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
122   DO 123 I=1,NI
123   FLVM(I)=(FMECH(I)-(2.*FLVA(I)-FLN(I)))*DTSQ+FLVM(I)
      IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVM(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVM(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVM(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DIS(I)-DISP(I)
      IF(MLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
42     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
41    IT=ITT-1
      TIME=IT*DELTAT
      IF(IT.EQ.1) CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,
     *KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'   LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *OUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
150   CALL EXIT
      END
```

```
      SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C     ***** PARTIAL RING *****
      DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
  202 DO 402 I=1,8
      M=NN(I)
      DO 402 J=1,8
      N=NN(J)
      IF(M-N)402,403,403
  403 CALL FICOL(M,N,L,ICOL)
      STIFM(L)=STIFM(L)+ELMAS(I,J)
  402 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C     ***** PARTIAL RING *****
      DIMENSION NN(8),FLVA(1),ELFP(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
  121 J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
  123 DO 101 I=1,8
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
  101 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IDENT(B,DENS,NQR)
C     ***** PARTIAL RING *****
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
```

```
     *,Y(51),Z(51),ANG(51),H(51)
      WRITE(MWRITE,1) B,DENS,IK,NOGA,NFL,NSFL
 1    FORMAT(' ***JET3D***  A SPATIAL FINITE ELEMENT AND HOUBOLT TEMPOR
     *AL OPERATOR PROGRAM',/,'     USED TO CALCULATE THE NONLINEAR RESPON
     *SES OF A VARIABLE THICKNESS ARBITRARILY',/,'     CURVED  PARTIAL RI
     *NG WITH THE FOLLOWING PARAMETERS  ',//,
     *'     WIDTH OF RING (IN)                  =',E15.6,/,
     *'     DENSITY (LB-SEC**2/IN**4)           =',E15.6,/,
     *'     NUMBER OF ELEMENTS                  =',I5,/,
     *'     NUMBER OF SPANWISE GAUSSIAN PTS     =',I5,/,
     *'     NUMBER OF DEPTHWISE GAUSSIAN PTS    =',I5,/,
     *'     NUMBER OF MECHANICAL SUBLAYERS      =',I5)
      IF(NBCOND .EQ. 0) GO TO 5
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
 14   CONTINUE
 15   FORMAT('   SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
 16   FORMAT('    CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
 17   FORMAT('    HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
      GO TO 18
 5    WRITE(MWRITE,13)
 13  FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
 18   IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
 20   FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
      GO TO 23
 19   WRITE(MWRITE,21)
 21   FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
 23   IKP1=IK+1
      WRITE(MWRITE,11)
      WRITE(MWRITE,12) (I,Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
 12   FORMAT(2(I5,4E15.6))
 11   FORMAT(/,' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS',3X,
     *' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS')
      RETURN
      END


      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** PARTIAL RING *****
      DIMENSION AL(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 50 I=1,NI
      DELD(I)=0.0
 50    DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
```

```
      DO 51 L=1,NSFL
      SNP(IR,J,K,L)=0.0
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'     TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'     THERE IS NO INITIAL IMPULSE   ')
6    FORMAT(/,'     IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
    * INPUT ')
      IF(NV .EQ. 0) RETURN
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 41
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
41    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      TX=0.0
      DO 65 NN=1,IS2
      NE=(IS1-1)+NN
      IF(NE .GT. IK) NE=NE-IK
65    TX=TX+AL(NE)
      PIEP=3.14159265/TX
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP
      XX=0.0
      DO 63 II=1,IS2
      I=IS1+II
      NE=I-1
      IF(NE .GT. IK) NE=NE-IK
      XX=XX+AL(NE)
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*XX)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*XX)
61    CONTINUE
60    IF(NBCOND .EQ.0) RETURN
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
```

```
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
 40   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
C     ***** PARTIAL RING *****
      DIMENSION COPY(51),COPZ(51),HHALF(50),BEPS(3),EPSI(50),EPSO(50)
      DIMENSION FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),SPRIN(1)
     *,FAILI(50),FAILO(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DATA ASTER/'*'/,BLANK/' '/
      DO 700 I=1,NI
 700  CINE(I)=0.0
      CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
      CINET=0.0
      DO 701 I=1,NI
 701  CINET=CINET+DELD(I)*CINE(I)
      CINET=CINET*C2
      IF(IT .EQ. 0) CINETO=CINET
      ELAST=0.0
      DO 702 IR=1,IK
      DO 703 J=1,NOGA
      SUM=0.0
      DO 704 K=1,NFL
      DO 704 L=1,NSFL
 704  SUM=SUM+SNS(IR,J,K,L)**2*ASFL(IR,J,K,L)
 703  ELAST=ELAST+SUM*C4(IR,J)
 702  CONTINUE
      SPDEN=0.0
      IF(NQR .EQ. 0) GO TO 31
      DO 30 I=1,NI
 30   FQREF(I)=0.0
      CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
      DO 32 I=1,NI
 32   SPDEN=SPDEN+DISP(I)*FQREF(I)
      SPDEN=SPDEN/2.
 31   ELAST=ELAST/YOUNG/2.
      CINETT=CINETO+APDEN
      PLAST=CINETT-CINET-ELAST-SPDEN
      WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
 1    FORMAT(//////,'    J=',I5,'        TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)   =',E15.6,/,
     *'           KINETIC ENERGY (IN.-LB.)   =',E15.6,/,
     *'           ELASTIC ENERGY (IN.-LB.)   =',E15.6,/,
     *'           PLASTIC WORK   (IN.-LB.)   =',E15.6)
      IF(NQR .EQ. 0) GO TO 33
      WRITE(MWRITE,34) SPDEN
```

```
34    FORMAT('   ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
33    IKP1=IK+1
      DO 11 I=1,IKP1
      COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG(I))-DISP(I*4-2)*SIN(ANG(I))
11    COPZ(I)=Z(I)+DISP(I*4-3)*SIN(ANG(I))+DISP(I*4-2)*COS(ANG(I))
      DO 601 IR=1,IK
      DO 604 I=1,3
      BEPS(I)=0.0
      DO 604 K=1,8
      INDEX=(IR-1)*4+K
604   BEPS(I)=BEPS(I)+BEP(IR,2,I,K)*DISP(INDEX)
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF(IR)*FCUR
      EPSO(IR)=FARE+HHALF(IR)*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'   I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53 I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,54)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'   STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
50    DO 21 I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,9E12.4,2X,E12.4)
```

```
      WRITE(MWRITE,22)IKP1,DISP(IKP1*4-3),DISP(IKP1*4-2),DISP(IKP1*4-1)
     *,DISP(IKP1*4),COPY(IKP1),COPZ(IKP1)
      RETURN
      END
```

```
C     JET3D  MAIN PROGRAM FOR VARIABLE THICKNESS ARBITRARILY CURVED RING
C     JET3D  HOUBOLT OPERATOR
C      ***** COMPLETE RING *****
      DIMENSION AMASS(2060),AA(50,8,8),TXG(6),TWG(6),ES(6),GFL(50,3,6),
     *INUM(205),FMECH(205),HHALF(50),KROW(8),NDEX(8),
     *BMASS(2060),EPS(5),SIG(5)
      DIMENSION DDELD(205),DISUM(205),DIS(205),DISM1(205),DISM2(205),
     *FLR(205),FLN(205),FLVM(205),STIFK(2060)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELC(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
      COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
      COMMON /FORCE/ T1,AMP1FV,AMP1FW,T2,AMP2FV,AMP2FW,SLOPEV,SLOPEW,
     *AMPFV,AMPFW,NOFT1,NOFT2,NOFT3,JELEM(4),ETA(4),RTOV(4),RTOW(4),
     *NSTF2(4),NELF2(4),RTO2V(4),RTO2W(4),NSTF3(4),NELF3(4),RTO3V(4),
     *RTO3W(4),FM1(4,8,2),FM2(2,4,8,2),FM3A(2,4,8,2),FM3B(2,4,8,2)
      COMMON /ELFU/ SPRIN(2060),FQREF(205),NQR,NORP,NORU,NREL(4),
     *REX(4),NRST(4),NREU(4)
      MREAD=5
      MWRITE=6
      MPUNCH=7
      READ(MREAD,1) B,DENS,IK,NOGA,NFL,NSFL,MM,M1,M2
      IKP1=IK+1
      PIE=3.14159265
      READ(MREAD,11) (Y(I),Z(I),ANG(I),H(I),I=1,IK)
 11   FORMAT(4E15.6)
      DO 111 I=1,IK
 111  ANG(I)=ANG(I)*PIE/180.
      Y(IKP1)=Y(1)
      Z(IKP1)=Z(1)
      H(IKP1)=H(1)
      ANG(IKP1)=ANG(1)
      READ(MREAD,2) DELTAT,CRITS,DS,P,(EPS(L),SIG(L),L=1,NSFL)
 1    FORMAT(2E15.6/7I5)
 2    FORMAT(4E15.6/(4E15.6))
      READ(MREAD,3)(AXG(K),K=1,NOGA)
      READ(MREAD,3)(AWG(K),K=1,NOGA)
      READ(MREAD,3)(TXG(K),K=1,NFL)
      READ(MREAD,3)(TWG(K),K=1,NFL)
 3    FORMAT(4F15.10)
      NI=IK*4
      READ(MREAD,4) NBCOND,(NBC(I),NODEB(I),I=1,NBCOND)
```

```
4       FORMAT(9I5)
        READ(MREAD,9) NQR,NQRP,NQRU
9       FORMAT(3I5)
              CALL IDENT(B,DENS,NQR)
        DO 70 IR=1,IK
        DO 70 J=1,NOGA
        RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
        DO 70 K=1,NFL
        GFL(IR,J,K)=RH*TWG(K)*B/2.
70      GZETA(IR,J,K)=RH*TXG(K)/2.
        ES(1)=SIG(1)/EPS(1)
        IF(NSFL-1)77,77,76
76      DO 78 L=2,NSFL
78      ES(L)=(SIG(L)-SIG(L-1))/(EPS(L)-EPS(L-1))
77      ES(NSFL+1)=0.0
        DO 79 L=1,NSFL
79      SNO(L)=ES(1)*EPS(L)
        YOUNG=ES(1)
        DO 71 IR=1,IK
        DO 71 J=1,NOGA
        DO 71 K=1,NFL
        DO 71 L=1,NSFL
71      ASFL(IR,J,K,L)=GFL(IR,J,K)*(ES(L)-ES(L+1))/ES(1)
        DO 73 IR=1,IK
73      HHALF(IR)=(H(IR+1)+H(IR))/2./2.
        DO 15 I=1,8
15      ICOL(I)=1
        IKM1=IK-1
        DO 16 I=3,IKM1
        IK4=I*4
        IK3=IK4-1
        IK2=IK4-2
        IK1=IK4-3
        JJ=(I-1)*4-3
        ICOL(IK1)=JJ
        ICOL(IK2)=JJ
        ICOL(IK3)=JJ
        ICOL(IK4)=JJ
16      CONTINUE
        ICOL(IK*4)=1
        ICOL(IK*4-1)=1
        ICOL(IK*4-2)=1
        ICOL(IK*4-3)=1
        INUM(1)=1
        DO 99 I=2,NI
99      INUM(I)=I-ICOL(I-1)+INUM(I-1)
        DO 990 I=1,NI
990     INUM(I)=INUM(I)-ICOL(I)
        NIRREG=0
        INDEX=0
        ISET=1
        DO 116 I=1,NI
        L=ICOL(I)
        IF(ICOL(I)-ISET)117,116,119
119     ISET=ICOL(I)
        GO TO 116
117     NIRREG=NIRREG+1
        IF(NIRREG-NI/2)711,711,90
711     KROW(NIRREG)=I
        NDEX(NIRREG)=INDEX
```

```
116     INDEX=INDEX+I-L
90      CALL FICOL(NI,NI,L,ICOL)
        ISIZE=L
        WRITE(MWRITE,17) L
17      FORMAT(/,'    SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX=',I5)
              CALL ELMPP(AMASS,STIFK,AA,ISIZE,DENS,YOUNG,B)
        DO 23 L=1,ISIZE
        BMASS(L)=AMASS(L)
23      SPRIN(L)=0.0
        IF (NQR .EQ. 0) GO TO 22
              CALL QREM(AA,AL,AXG,AWG)
22      IF(DS.EQ.0.0) GO TO 21
        C5=1./P
        C6=1./DS/DELTAT
21      DTSQ=DELTAT**2
        C2=1./(2.*DELTAT**2)
        DO 25 IR=1,IK
        DO 25 J=1,NOGA
        RH=H(IR)*(1.-AXG(J))+H(IR+1)*AXG(J)
        C3(IR,J)=YOUNG*B*RH
25      C4(IR,J)=AL(IR)*AWG(J)
        MCRIT=0
        BIG=10.**(-10)
        IBIG=0
        IT=0
        TIME=0.0
              CALL IMPULS(DELTAT,AL)
        READ(MREAD,5) TBEGIN,TFINAL,AMP1FV,AMP1FW
5       FORMAT(4E15.6)
        IF(TFINAL .EQ. 0.0) WRITE(MWRITE,48)
48      FORMAT('0   THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING
     * THIS RUN ')
        IF(TFINAL .EQ. 0.0) GO TO 49
             CALL LOADEQ(Y,Z,ANG,AL,NOGA,AXG,AWG,AA,TBEGIN,TFINAL)
49      APDEN=0.0
              CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
        NREADF=0
        T1=TBEGIN
        NLOAD=2
        DO 34 I=1,NI
34      FMECH(I)=0.0
        IF(TBEGIN.GT.0.0 .OR. TFINAL.EQ.0.0) GO TO 30
        NLOAD=1
              CALL LOADFT(TIME,NREADF,FMECH,AL)
        CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
        CALL SOLV(AMASS,FMECH,DDELD,ICOL,KROW,NDEX,NI,NIRREG)
        GO TO 31
30      DO 32 I=1,NI
32      DDELD(I)=0.0
31      DO 33 I=1,NI
33      DISUM(I)=2.*DTSQ*DDELD(I)+6.*DELD(I)+6.*DISP(I)
        MLOAD=NLOAD
        DO 35 I=1,NI
        FLR(I)=FMECH(I)
35      FLVM(I)=0.0
        CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
        DO 37 L=1,ISIZE
37      AMASS(L)=6.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
        CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,MWRITE,NI,NIRREG,INUM)
```

```
      ITT=1
      TIME=ITT*DELTAT
      NLOAD=2
      DO 60 I=1,NI
      FLVA(I)=0.0
60    FMECH(I)=0.0
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 38
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
38    DO 39 I=1,NI
39    FLVM(I)=DTSQ*FMECH(I)+FLVM(I)
      CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 61 I=1,NI
      DELD(I)=DIS(I)-DISP(I)
61    DISM1(I)=DTSQ*DDELD(I)-DIS(I)+2.*DISP(I)
      DO 100 L=1,ISIZE
100   AMASS(L)=2.*BMASS(L)+DTSQ*(STIFK(L)+SPRIN(L))
      CALL FAC(AMASS,ICOL,KROW,NDEX,IDET,NWRITE,NI,NIRREG,INUM)
      IF(MLOAD .EQ. 2) GO TO 120
      APD=0.0
      DO 46 I=1,NI
46     APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
120   ITT=ITT+1
      TIME=ITT*DELTAT
45    DO 121 I=1,NI
      DISM2(I)=DISM1(I)
      DISM1(I)=DISP(I)
      DISP(I)=DIS(I)
      FLR(I)=FMECH(I)
      FLN(I)=FLVA(I)
      FLVA(I)=0.0
      FMECH(I)=0.0
      FLVM(I)=0.0
121   DISUM(I)=5.*DISP(I)-4.*DISM1(I)+DISM2(I)
      DO 40 K=1,4
      DISP(IK*4+K)=DISP(K)
40    DELD(IK*4+K)=DELD(K)
      MLOAD=NLOAD
      CALL STRESS
      CALL OMULT(BMASS,DISUM,ICOL,NI,FLVM,KROW,NDEX,NIRREG)
      NLOAD=2
      IF(TIME.LT.TBEGIN .OR. TIME.GT.TFINAL) GO TO 122
      NLOAD=1
            CALL LOADFT(TIME,NREADF,FMECH,AL)
122   DO 123 I=1,NI
123   FLVM(I)=(FMECH(I)-(2.*FLVA(I)-FLN(I)))*DTSQ+FLVM(I)
      IF(NBCOND .EQ. 0) GO TO 124
      DO 125 I=1,NBCOND
      JT4=NODEB(I)*4
      FLVM(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) FLVM(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) FLVM(JT4-2)=0.0
125   CONTINUE
124   CALL SOLV(AMASS,FLVM,DIS,ICOL,KROW,NDEX,NI,NIRREG)
      DO 126 I=1,NI
126   DELD(I)=DIS(I)-DISP(I)
      IF(MLOAD .EQ. 2) GO TO 41
      APD=0.0
      DO 42 I=1,NI
```

```
42    APD=APD+FLR(I)*DELD(I)
      APDEN=APDEN+APD
41    IT=ITT-1
      TIME=IT*DELTAT
      IF(IT.EQ.1) CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,
     *KROW,NDEX,NIRREG,CINETO)
      IF(IT-M1) 130,140,150
140   M1=M1+M2
            CALL PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
130   IF(IT-MM) 120,170,150
170   IF(IBIG) 62,150,62
62    IF(ISURF-2) 64,65,65
64    WRITE(MWRITE,66) BIG,IBIG,BTIME
66    FORMAT(///,'    LARGEST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *INNER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
      GO TO 150
65    WRITE(MWRITE,67) BIG,IBIG,BTIME
67    FORMAT(///,'    LARGFST COMPUTED STRAIN =',E15.6,' OCCURS AT THE
     *CUTER SURFACE MIDSPAN OF ELEMENT =',I3,' AT TIME (SEC.) =',E15.6)
150   CALL EXIT
      END
```

```
      SUBROUTINE ASSEM(IR,IK,ELMAS,STIFM,ICOL,NI)
C     ***** COMPLETE RING *****
      DIMENSION ELMAS(8,8),NN(8),STIFM(1),ICOL(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 203,204,204
203   J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
      GO TO 202
204   NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
202   DO 402 I=1,8
      M=NN(I)
      DO 402 J=1,8
      N=NN(J)
      IF(M-N)402,403,403
403   CALL FICOL(M,N,L,ICOL)
```

```
      STIFM(L)=STIFM(L)+ELMAS(I,J)
 402  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ASSEF(IR,IK,ELFP,FLVA)
C     ***** COMPLETE RING *****
      DIMENSION NN(8),FLVA(1),ELFP(1)
      J1=IR*4
      NN(1)=J1-3
      NN(2)=J1-2
      NN(3)=J1-1
      NN(4)=J1
      IF(IR-IK) 121,122,122
 121  J2=(IR+1)*4
      NN(5)=J2-3
      NN(6)=J2-2
      NN(7)=J2-1
      NN(8)=J2
      GO TO 123
 122  NN(5)=1
      NN(6)=2
      NN(7)=3
      NN(8)=4
 123  DO 101 I=1,8
      M=NN(I)
      FLVA(M)=FLVA(M)+ELFP(I)
 101  CONTINUE
      RETURN
      END
```

)

```
      SUBROUTINE IDENT(B,DENS,NQR)
C     ***** COMPLETE RING *****
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      WRITE(MWRITE,1) B,DENS,IK,NOGA,NFL,NSFL
 1    FORMAT(' ***JET3D***  A SPATIAL FINITE ELEMENT AND HOUBOLT TEMPOR
     *AL OPERATOR PROGRAM',/,'     USED TO CALCULATE THE NONLINEAR RESPON
     *SES OF A VARIABLE THICKNESS ARBITRARILY',/,'     CURVED COMPLETE RI
     *NG WITH THE FOLLOWING PARAMETERS  ',//,
     *'     WIDTH OF RING (IN)                 =',E15.6,/,
     *'     DENSITY (LB-SEC**2/IN**4)          =',E15.6,/,
     *'     NUMBER OF ELEMENTS                 =',I5,/,
     *'     NUMBER OF SPANWISE GAUSSIAN PTS    =',I5,/,
     *'     NUMBER OF DEPTHWISE GAUSSIAN PTS   =',I5,/,
     *'     NUMBER OF MECHANICAL SUBLAYERS     =',I5)
      IF(NBCOND .EQ. 0) GO TO 5
      DO 14 I=1,NBCOND
      IF(NBC(I) .EQ. 1) WRITE(MWRITE,15) NODEB(I)
      IF(NBC(I) .EQ. 2) WRITE(MWRITE,16) NODEB(I)
      IF(NBC(I) .EQ. 3) WRITE(MWRITE,17) NODEB(I)
```

```
14    CONTINUE
15    FORMAT('    SYMMETRY DISPLACEMENT CONDITION AT NODE =',I5)
16    FORMAT('     CLAMPED DISPLACEMENT CONDITION AT NODE =',I5)
17    FORMAT('     HINGED  DISPLACEMENT CONDITION AT NODE =',I5)
      GO TO 18
5     WRITE(MWRITE,13)
13   FORMAT(/,'    THERE IS NO PRESCRIBED DISPLACEMENT CONDITION')
18    IF(NQR .EQ. 0) GO TO 19
      WRITE(MWRITE,20)
20    FORMAT(/,'    CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED
     * BY INPUT ')
      GO TO 23
19    WRITE(MWRITE,21)
21    FORMAT(/,'    THERE ARE NO ELASTIC SPRING CONSTRAINTS')
23    IKP1=IK+1
      WRITE(MWRITE,11)
      WRITE(MWRITE,12) (I,Y(I),Z(I),ANG(I),H(I),I=1,IKP1)
12    FORMAT(2(I5,4E15.6))
11    FORMAT(/,' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS',3X,
     *' NODE',7X,'Y',14X,'Z',12X,'SLOPE',8X,'THICKNESS')
      RETURN
      END




      SUBROUTINE IMPULS(DELTAT,AL)
C     ***** COMPLETE RING *****
      DIMENSION AL(50)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 50 I=1,NI
      DELD(I)=0.0
50     DISP(I)=0.0
      DO 51 IR=1,IK
      DO 51 J=1,NOGA
      BINP(IR,J)=0.0
      BIMP(IR,J)=0.0
      DO 51 K=1,NFL
      DO 51 L=1,NSFL
      SNP(IR,J,K,L)=0.0
51    SNS(IR,J,K,L)=0.0
      READ(MREAD,1) NV,IOTA,IOTB,IOTC
1     FORMAT(4I5)
      WRITE(MWRITE,2) DELTAT
2      FORMAT(/,'     TIME STEP SIZE USED IN PROGRAM (SEC) =',E15.6)
      IF(NV .EQ. 0) WRITE(MWRITE,4)
      IF(NV .GT. 0) WRITE(MWRITE,6)
4     FORMAT(/,'     THERE IS NO INITIAL IMPULSE  ')
6    FORMAT(/,'     IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY
     * INPUT ')
      IF(NV .EQ. 0) GO TO 43
      IF(IOTA .EQ.0) GO TO 10
      DO 20 IM=1,IOTA
      READ(MREAD,21) IE1,IE2,WRAD,WRAD1,ANGV1,WRAD2,ANGV2
21    FORMAT(2I5/5E15.6)
```

```
      IE2M1=IE2-1
      DO 22 II=1,IE2M1
      I=IE1+II
      IF(I .GT. IK) I=I-IK
22    DELD(I*4-2)=DELTAT*WRAD
      DELD(IE1*4-2)=DELTAT*WRAD1
      DELD(IE1*4-1)=DELTAT*ANGV1
      IE2P1=IE1+IE2
      IF(IE2P1 .GT. IK) IE2P1=IE2P1-IK
      DELD(IE2P1*4-2)=DELTAT*WRAD2
      DELD(IE2P1*4-1)=DELTAT*ANGV2
20    CONTINUE
10    IF(IOTB .EQ. 0) GO TO 41
      DO 30 IM=1,IOTB
      READ(MREAD,31) NODEV,VRAD,WRAD,ANGV
31    FORMAT(I5,3E15.6)
      DELD(NODEV*4-3)=DELTAT*VRAD
      DELD(NODEV*4-2)=DELTAT*WRAD
      DELD(NODEV*4-1)=DELTAT*ANGV
30    CONTINUE
41    IF(IOTC .EQ. 0) GO TO 60
      DO 61 IM=1,IOTC
      READ(MREAD,62) IS1,IS2,WRAD
62    FORMAT(2I5,E15.6)
      TX=0.0
      DO 65 NN=1,IS2
      NE=(IS1-1)+NN
      IF(NE .GT. IK) NE=NE-IK
65    TX=TX+AL(NE)
      PIEP=3.14159265/TX
      DELD(IS1*4-1)=WRAD*DELTAT*PIEP
      XX=0.0
      DO 63 II=1,IS2
      I=IS1+II
      NE=I-1
      IF(I .GT. IK) I=I-IK
      IF(NE .GT. IK) NE=NE-IK
      XX=XX+AL(NE)
      DELD(I*4-2)=WRAD*DELTAT*SIN(PIEP*XX)
63    DELD(I*4-1)=WRAD*DELTAT*PIEP*COS(PIEP*XX)
61    CONTINUE
60    IF(NBCOND .EQ.0) GO TO 43
      DO 40 I=1,NBCOND
      JT4=NODEB(I)*4
      DELD(JT4-3)=0.0
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) DELD(JT4-1)=0.0
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) DELD(JT4-2)=0.0
40    CONTINUE
43    DO 44 K=1,4
      DISP(IK*4+K)=DISP(K)
44    DELD(IK*4+K)=DELD(K)
      RETURN
      END


      SUBROUTINE PRINT(IT,TIME,HHALF,APDEN,SPRIN,BMASS,C2,NQR,KROW,
     *NDEX,NIRREG,CINETO)
```

```
C       ***** COMPLETE RING *****
        DIMENSION COPY(51),COPZ(51),HHALF(50),BEPS(3),EPSI(50),EPSO(50)
        DIMENSION FQREF(1),BMASS(1),KROW(1),NDEX(1),CINE(205),SPRIN(1)
     *,FAILI(50),FAILO(50)
        COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
        COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
        COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
        COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
        COMMON /SC/ MCRIT,CRITS,BIG,IBIG,BTIME,ISURF
        COMMON /TAPE/ MREAD,MWRITE,MPUNCH
        DATA ASTER/'*'/,BLANK/' '/
        DO 700 I=1,NI
  700   CINE(I)=0.0
        CALL OMULT(BMASS,DELD,ICOL,NI,CINE,KROW,NDEX,NIRREG)
        CINET=0.0
        DO 701 I=1,NI
  701   CINET=CINET+DELD(I)*CINE(I)
        CINET=CINET*C2
        IF(IT .EQ. 0) CINETO=CINET
        ELAST=0.0
        DO 702 IR=1,IK
        DO 703 J=1,NOGA
        SUM=0.0
        DO 704 K=1,NFL
        DO 704 L=1,NSFL
  704   SUM=SUM+SNS(IR,J,K,L)**2*ASFL(IR,J,K,L)
  703   ELAST=ELAST+SUM*C4(IR,J)
  702   CONTINUE
        SPDEN=0.0
        IF(NQR .EQ. 0) GO TO 31
        DO 30 I=1,NI
  30    FQREF(I)=0.0
        CALL OMULT(SPRIN,DISP,ICOL,NI,FQREF,KROW,NDEX,NIRREG)
        DO 32 I=1,NI
  32    SPDEN=SPDEN+DISP(I)*FQREF(I)
        SPDEN=SPDEN/2.
  31    ELAST=ELAST/YOUNG/2.
        CINETT=CINETO+APDEN
        PLAST=CINETT-CINET-ELAST-SPDEN
        WRITE(MWRITE,1) IT,TIME,CINETT,CINET,ELAST,PLAST
  1     FORMAT('1   J=',I5,'      TIME (SEC.) =',E15.6,/,
     *'     TOTAL ENERGY INPUT (IN.-LB.)  =',E15.6,/,
     *'          KINETIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          ELASTIC ENERGY (IN.-LB.)  =',E15.6,/,
     *'          PLASTIC WORK   (IN.-LB.)  =',E15.6)
        IF(NQR .EQ. 0) GO TO 33
        WRITE(MWRITE,34) SPDEN
  34    FORMAT('    ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =',
     *E15.6)
  33    DO 11 I=1,IK
        COPY(I)=Y(I)+DISP(I*4-3)*COS(ANG(I))-DISP(I*4-2)*SIN(ANG(I))
  11    COPZ(I)=Z(I)+DISP(I*4-3)*SIN(ANG(I))+DISP(I*4-2)*COS(ANG(I))
        DO 601 IR=1,IK
        DO 604 I=1,3
        BEPS(I)=0.0
        DO 604 K=1,8
        INDEX=(IR-1)*4+K
  604   BEPS(I)=BEPS(I)+BEP(IR,2,I,K)*DISP(INDEX)
```

```
      FARE=BEPS(1)+BEPS(2)**2/2.
      FCUR=BEPS(3)
      EPSI(IR)=FARE-HHALF(IR)*FCUR
      EPSO(IR)=FARE+HHALF(IR)*FCUR
601   CONTINUE
      DO 60 IR=1,IK
      IF(EPSI(IR) .LE. BIG) GO TO 61
      BIG=EPSI(IR)
      IBIG=IR
      ISURF=1
      BTIME=TIME
61    IF(EPSO(IR) .LE. BIG) GO TO 60
      BIG=EPSO(IR)
      IBIG=IR
      ISURF=2
      BTIME=TIME
60    CONTINUE
      WRITE(MWRITE,2)
2     FORMAT(/,'    I ',5X,'V',11X,'W',9X,'PSI',9X,'CHI',10X,'COPY',
     *8X,'COPZ',9X,'L',11X,'M',7X,'STRAIN(IN)',4X,'STRAIN(OUT)')
      IF(MCRIT .GT. 0) GO TO 50
      DO 51 I=1,IK
      FAILI(I)=BLANK
      FAILO(I)=BLANK
      IF(EPSI(I) .LT. CRITS) GO TO 52
      FAILI(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 52
      MCRIT=1
52    IF(EPSO(I) .LT. CRITS) GO TO 51
      FAILO(I)=ASTER
      IF(MCRIT .GT. 0) GO TO 51
      MCRIT=1
51    CONTINUE
      IF(MCRIT .LE. 0) GO TO 50
      DO 53 I=1,IK
53    WRITE(MWRITE,54) I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),FAILI(I),
     *EPSO(I),FAILO(I)
54    FORMAT(I5,9E12.4,A2,E12.4,A2)
      WRITE(MWRITE,55) ASTER
55    FORMAT(//,5X,A2,'    STRAIN EXCEEDS THE CRITICAL VALUE')
      RETURN
50    DO 21 I=1,IK
21    WRITE(MWRITE,22)I,DISP(I*4-3),DISP(I*4-2),DISP(I*4-1),DISP(I*4),
     *COPY(I),COPZ(I),BINP(I,2),BIMP(I,2),EPSI(I),EPSO(I)
22    FORMAT(I5,9E12.4,2X,E12.4)
      RETURN
      END
      SUBROUTINE ELMPP(AMASS,STIFK,AA,ISIZE,DENS,YOUNG,B)
C     TO FIND THE MASS MATRIX STIFFNESS MATRIX AND STRAIN NODAL
C     DISPLACEMENT TRANSFORMATION MATRICES
      DIMENSION A(8,8),AA(50,8,8),LMI(8),MMI(8),D(8,8),ELM(8,8),
     *ELMAS(8,8),AMASS(1),E(8,8),EK1(8,8),ELK(8,8),STIFK(1),
     *BE1(3,3,8),BNG(51)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
      COMMON /TAPE/ MREAD,MWRITE,MPUNCH
      DO 18 L=1,ISIZE
      STIFK(L)=0.0
18    AMASS(L)=0.0
50    DO 101 IR=1,IK
```

```
      P5=Z(IR+1)-Z(IR)
      P6=Y(IR+1)-Y(IR)
      P7=ANG(IR+1)-ANG(IR)
      APHA=ATAN(P5/P6)
      IF(P6.LT.0.0 .AND. P5.LT.0.0) APHA=APHA-3.14159265
      IF(P6.LT.0.0 .AND. P5.GE.0.0) APHA=APHA+3.14159265
      IF(P7 .EQ. 0.0) GO TO 60
      AL(IR)=P7*SQRT(P5**2+P6**2)/SIN(P7/2.)/2.
      GO TO 61
0     AL(IR)=SQRT(P5**2+P6**2)
1     BNG(IR+1)=ANG(IR+1)
      BNG(IR)=ANG(IR)
     IF(P7.GT.(4.7124).AND.APHA.LT.0.0) BNG(IR+1)=ANG(IR+1)-6.2831853
     IF(P7.GT.(4.7124).AND.APHA.GT.0.0) BNG(IR)=ANG(IR)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.GT.0.0) BNG(IR+1)=ANG(IR+1)+6.2831853
     IF(P7.LT.(-4.7124).AND.APHA.LT.0.0) BNG(IR)=ANG(IR)-6.2831853
      BZER=BNG(IR)-APHA
      B1=(-2.*BNG(IR+1)-4.*BNG(IR)+6.*APHA)/AL(IR)
      B2=(3.*BNG(IR+1)+3.*BNG(IR)-6.*APHA)/AL(IR)**2
      DO 102 I=1,8
      DO 102 J=1,8
      A(I,J)=0.0
      E(I,J)=0.0
02    D(I,J)=0.0
      A(1,1)= COS(BNG(IR)-APHA)
      A(1,2)= SIN(BNG(IR)-APHA)
      A(2,1)=-SIN(BNG(IR)-APHA)
      A(2,2)= COS(BNG(IR)-APHA)
      A(3,3)=1.
      A(5,1)=COS(BNG(IR+1)-APHA)
      A(5,2)=SIN(BNG(IR+1)-APHA)
      A(5,3)=P6*SIN(BNG(IR+1))-P5*COS(BNG(IR+1))
      A(6,1)=-SIN(BNG(IR+1)-APHA)
      A(6,2)=COS(BNG(IR+1)-APHA)
      A(6,3)=P6*COS(BNG(IR+1))+P5*SIN(BNG(IR+1))
      A(7,3)=1.
      A(4,4)=1.
      A(5,4)=AL(IR)
      A(5,7)=AL(IR)**2
      A(5,8)=AL(IR)**3
      A(6,5)=AL(IR)**2
      A(6,6)=AL(IR)**3
      P8=B1+2.*B2*AL(IR)
      A(7,4)=AL(IR)*P8
      A(7,5)=2.*AL(IR)
      A(7,6)=3.*AL(IR)**2
      A(7,7)=AL(IR)**2*P8
      A(7,8)=AL(IR)**3*P8
      A(8,4)=1.
      A(8,5)=-AL(IR)**2*P8
      A(8,6)=-AL(IR)**3*P8
      A(8,7)=2.*AL(IR)
      A(8,8)=3.*AL(IR)**2
      CALL MINV(A,8,DET,LMI,MMI)
      DO 52 I=1,8
      DO 52 J=1,8
2     AA(IR,I,J)=A(I,J)
      DO 103 J=1,NOGA
      ZET=AL(IR)*AXG(J)
      RH=H(IR+1)*AXG(J)+H(IR)*(1.-AXG(J))
```

```
      RI=RH**3/12.
      PHIP=B1+2.*B2*ZET
      PHI=BZER+B1*ZET+B2*ZET**2
      WET=AL(IR)*AWG(J)
      YZET=0.0
      ZZET=0.0
      DO 104 JJ=1,NOGA
      P2=BZER+B1*ZET*AXG(JJ)+B2*(ZET*AXG(JJ))**2+APHA
      YZET=YZET+COS(P2)*ZET*AWG(JJ)
104   ZZET=ZZET+SIN(P2)*ZET*AWG(JJ)
      P3=YZET*SIN(PHI+APHA)-ZZET*COS(PHI+APHA)
      P4=YZET*COS(PHI+APHA)+ZZET*SIN(PHI+APHA)
      D(1,1)=D(1,1)+RH*WET
      D(2,2)=D(2,2)+RH*WET
      D(3,1)=D(3,1)+(P3*COS(PHI)-P4*SIN(PHI))*RH*WET
      D(3,2)=D(3,2)+(P3*SIN(PHI)+P4*COS(PHI))*RH*WET
      D(3,3)=D(3,3)+(P3**2*RH+P4**2*RH+RI)*WET
      D(4,1)=D(4,1)+ZET*COS(PHI)*RH*WET
      D(4,2)=D(4,2)+ZET*SIN(PHI)*RH*WET
      D(4,3)=D(4,3)+(P3*ZET*RH+ZET*PHIP*RI)*WET
      D(4,4)=D(4,4)+(RH+PHIP**2*RI)*ZET**2*WET
       D(5,1)=D(5,1)-ZET**2*SIN(PHI)*RH*WET
      D(6,1)=D(6,1)-ZET**3*SIN(PHI)*RH*WET
      D(7,1)=D(7,1)+ZET**2*COS(PHI)*RH*WET
      D(8,1)=D(8,1)+ZET**3*COS(PHI)*RH*WET
      D(5,3)=D(5,3)+(P4*ZET**2*RH+2.*ZET*RI)*WET
      D(6,3)=D(6,3)+(P4*ZET**3*RH+3.*ZET**2*RI)*WET
      D(7,3)=D(7,3)+(P3*RH+PHIP*RI)*ZET**2*WET
      D(8,3)=D(8,3)+(P3*RH+PHIP*RI)*ZET**3*WET
      D(5,4)=D(5,4)+2.*ZET**2*PHIP*RI*WET
      D(6,4)=D(6,4)+3.*ZET**3*PHIP*RI*WET
      D(7,4)=D(7,4)+(RH+PHIP**2*RI)*ZET**3*WET
      D(8,4)=D(8,4)+(RH+PHIP**2*RI)*ZET**4*WET
      D(5,5)=D(5,5)+(ZET**4*RH+4.*ZET**2*RI)*WET
      D(6,5)=D(6,5)+(ZET**5*RH+6.*ZET**3*RI)*WET
      D(7,5)=D(7,5)+2.*ZET**3*PHIP*RI*WET
      D(8,5)=D(8,5)+2.*ZET**4*PHIP*RI*WET
      D(6,6)=D(6,6)+(ZET**6*RH+9.*ZET**4*RI)*WET
      D(7,6)=D(7,6)+3.*ZET**4*PHIP*RI*WET
      D(8,6)=D(8,6)+3.*ZET**5*PHIP*RI*WET
      D(7,7)=D(7,7)+(RH+PHIP**2*RI)*ZET**4*WET
      D(8,7)=D(8,7)+(RH+PHIP**2*RI)*ZET**5*WET
      D(8,8)=D(8,8)+(RH+PHIP**2*RI)*ZET**6*WET
      DO 201 M=1,3
      DO 201 N=1,8
201   BE1(J,M,N)=0.0
      BE1(J,1,4)=1.
      BE1(J,1,5)=-ZET**2*PHIP
      BE1(J,1,6)=-ZET**3*PHIP
      BE1(J,1,7)=2.*ZET
      BE1(J,1,8)=3.*ZET**2
      BE1(J,2,3)=1.
      BE1(J,2,4)=ZET*PHIP
      BE1(J,2,5)=2.*ZET
      BE1(J,2,6)=3.*ZET**2
      BE1(J,2,7)=ZET**2*PHIP
      BE1(J,2,8)=ZET**3*PHIP
      BE1(J,3,4)=-PHIP-ZET*2.*B2
      BE1(J,3,5)=-2.
      BE1(J,3,6)=-6.*ZET
      BE1(J,3,7)=-2.*ZET*PHIP-ZET**2*2.*B2
```

```
      BE1(J,3,8)=-3.*ZET**2*PHIP-ZET**3*2.*B2
      DO 202 M=1,3
      DO 202 N=1,8
      BEP(IR,J,M,N)=0.0
      DO 202 K=1,8
202   BEP(IR,J,M,N)=BEP(IR,J,M,N)+BE1(J,M,K)*A(K,N)
      T1=PHIP+ZET*2.*B2
      T2=2.*ZET*PHIP+ZET**2*2.*B2
      T3=3.*ZET**2*PHIP+ZET**3*2.*B2
      E(4,4)=E(4,4)+(RH+T1**2*RI)*WET
      E(5,4)=E(5,4)+(-ZET**2*PHIP*RH+2.*T1*RI)*WET
      E(6,4)=E(6,4)+(-ZET**3*PHIP*RH+6.*ZET*T1*RI)*WET
      E(7,4)=E(7,4)+(2.*ZET*RH+T2*T1*RI)*WET
      E(8,4)=E(8,4)+(3.*ZET**2*RH+T3*T1*RI)*WET
      E(5,5)=E(5,5)+(ZET**4*PHIP**2*RH+4.*RI)*WET
      E(6,5)=E(6,5)+(ZET**5*PHIP**2*RH+12.*ZET*RI)*WET
      E(7,5)=E(7,5)+(-2.*ZET**3*PHIP*RH+2.*T2*RI)*WET
      E(8,5)=E(8,5)+(-3.*ZET**4*PHIP*RH+2.*T3*RI)*WET
      E(6,6)=E(6,6)+(ZET**6*PHIP**2*RH+36.*ZET**2*RI)*WET
      E(7,6)=E(7,6)+(-2.*ZET**4*PHIP*RH+6.*ZET*T2*RI)*WET
      E(8,6)=E(8,6)+(-3.*ZET**5*PHIP*RH+6.*ZET*T3*RI)*WET
      E(7,7)=E(7,7)+(4.*ZET**2*RH+T2**2*RI)*WET
      E(8,7)=E(8,7)+(6.*ZET**3*RH+T2*T3*RI)*WET
      E(8,8)=E(8,8)+(9.*ZET**4*RH+T3**2*RI)*WET
103   CONTINUE
      D(5,2)=D(7,1)
      D(6,2)=D(8,1)
      D(7,2)=-D(5,1)
      D(8,2)=-D(6,1)
      CCM=DENS*B
      CCK=YOUNG*B
      DO 19 I=1,8
      DO 19 J=1,I
      D(I,J)=D(I,J)*CCM
19    E(I,J)=E(I,J)*CCK
      DO 105 I=1,7
      IP1=I+1
      DO 105 J=IP1,8
      E(I,J)=E(J,I)
105   D(I,J)=D(J,I)
      DO 106 I=1,8
      DO 106 J=1,8
     EK1(I,J)=0.0
      ELM(I,J)=0.0
      DO 106 K=1,8
      EK1(I,J)=EK1(I,J)+A(K,I)*E(K,J)
106   ELM(I,J)=ELM(I,J)+A(K,I)*D(K,J)
      DO 107 I=1,8
      DO 107 J=1,8
      ELK(I,J)=0.0
      ELMAS(I,J)=0.0
      DO 107 K=1,8
      ELK(I,J)=ELK(I,J)+EK1(I,K)*A(K,J)
107   ELMAS(I,J)=ELMAS(I,J)+ELM(I,K)*A(K,J)
      CALL ASSEM(IR,IK,ELMAS,AMASS,ICOL,NI)
      CALL ASSEM(IR,IK,ELK,STIFK,ICOL,NI)
101   CONTINUE
      IF(NBCOND .EQ.0) RETURN
      DO 91 I=1,NBCOND
      JT4=NODEB(I)*4
```

```
      JT4M3=JT4-3
      JT4M2=JT4-2
      JT4M1=JT4-1
      CALL ERC(JT4M3,AMASS,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,AMASS,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,AMASS,NI,ICOL)
      CALL ERC(JT4M3,STIFK,NI,ICOL)
      IF(NBC(I).EQ.1 .OR. NBC(I).EQ.2) CALL ERC(JT4M1,STIFK,NI,ICOL)
      IF(NBC(I).EQ.2 .OR. NBC(I).EQ.3) CALL ERC(JT4M2,STIFK,NI,ICOL)
 91   CONTINUE
      RETURN
      END




      SUBROUTINE STRESS
C     TO EVALUATE GENERALIZED NODAL LOAD VECTOR DUE TO LARGE DEFLECTION
C     AND ELASTIC-PLASTIC STRAIN
      DIMENSION ELFP(8),BEPS(3),CEPS(3,3),BINPW(3),BIMPW(3),HWB(3,3),
     *PN(8),PM(8),HNL(8),BINPP(3),BIMPP(3)
      COMMON /FG/ IK,NOGA,NFL,NSFL,NI,ICOL(205),NBCOND,NBC(4),NODEB(4)
     *,Y(51),Z(51),ANG(51),H(51)
      COMMON /HM/ YOUNG,DS,C5,C6,ASFL(50,3,6,5),GZETA(50,3,6),SNO(5)
      COMMON /VQ/ FLVA(205),DISP(205),DELD(205),SNS(50,3,6,5),
     *BINP(50,3),BIMP(50,3),SNP(50,3,6,5)
      COMMON /BA/ BEP(50,3,3,8),AL(50),AXG(3),AWG(3),C3(50,3),C4(50,3)
      DO 502 IR=1,IK
      DO 503 J=1,NOGA
      BINP(IR,J)=0.
      BIMP(IR,J)=0.
      BINPP(J)=0.0
      BIMPP(J)=0.0
 202  DO 402 I=1,3
      BEPS(I)=0.
      DO 402 K=1,8
      INDEX=(IR-1)*4+K
 402  BEPS(I)=BEPS(I)+BEP(IR,J,I,K)*DELD(INDEX)
      CEPS(J,1)=0.0
      CEPS(J,2)=0.0
      DO 403 K=1,8
      INDEX=(IR-1)*4+K
      CEPS(J,1)=CEPS(J,1)+BEP(IR,J,1,K)*DISP(INDEX)
 403  CEPS(J,2)=CEPS(J,2)+BEP(IR,J,2,K)*DISP(INDEX)
 205  FARE=BEPS(1)+CEPS(J,2)*BEPS(2)-BEPS(2)**2/2.
      FCUR=BEPS(3)
      DO 151 K=1,NFL
      BFNP=0.
      BFNPP=0.0
      BEPX=FARE+GZETA(IR,J,K)*FCUR
      IF(DS.GT. 0.0) RFACTR=1.+(C6*ABS(BEPX))**C5
      DO 35 L=1,NSFL
      DESNP=0.0
      SNS(IR,J,K,L)=SNS(IR,J,K,L)+YOUNG*BEPX
      IF(DS.EQ. 0.0) GO TO 255
      IF(SNS(IR,J,K,L)-SNO(L))30,301,91
 91   SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)-SNY)301,301,20
 20   DESNP=SNS(IR,J,K,L)-SNY
      SNS(IR,J,K,L)=SNY
```

```
      GO TO 301
30    IF(SNS(IR,J,K,L)+SNO(L))92,301,301
92    SNY=SNO(L)*RFACTR
      IF(SNS(IR,J,K,L)+SNY)40,301,301
40    DESNP=SNS(IR,J,K,L)+SNY
      SNS(IR,J,K,L)=-SNY
      GO TO 301
255   IF(SNS(IR,J,K,L)-SNO(L)) 18,301,17
17    DESNP=SNS(IR,J,K,L)-SNO(L)
      SNS(IR,J,K,L)=SNO(L)
      GO TO 301
18    IF(SNS(IR,J,K,L)+SNO(L)) 19, 301,301
19    DESNP=SNS(IR,J,K,L)+SNO(L)
      SNS(IR,J,K,L)=-SNO(L)
301   BFNP=BFNP+SNS(IR,J,K,L)*ASFL(IR,J,K,L)
      SNP(IR,J,K,L)=SNP(IR,J,K,L)+DESNP
      BFNPP=BFNPP+SNP(IR,J,K,L)*ASFL(IR,J,K,L)
35    CONTINUE
      BINP(IR,J)=BINP(IR,J)+BFNP
      BIMP(IR,J)=BIMP(IR,J)+BFNP*GZETA(IR,J,K)
      BINPP(J)=BINPP(J)+BFNPP
      BIMPP(J)=BIMPP(J)+BFNPP*GZETA(IR,J,K)
151   CONTINUE
503   CONTINUE
107   DO 101 J=1,NOGA
       BINPW(J)=(C3(IR,J)*CEPS(J,2)**2/2.-BINPP(J))*C4(IR,J)
      BIMPW(J)=-BIMPP(J)*C4(IR,J)
       HWB(J,2)=(C3(IR,J)*(CEPS(J,1)+CEPS(J,2)**2/2.)-BINPP(J))*
     *CEPS(J,2)*C4(IR,J)
101    CONTINUE
      DO 102 I=1,8
      PN(I)=0.
      PM(I)=0.
      HNL(I)=0.0
      DO 102 J=1,NOGA
      PN(I)=PN(I)+BEP(IR,J,1,I)*BINPW(J)
      PM(I)=PM(I)+BEP(IR,J,3,I)*BIMPW(J)
102   HNL(I)=HNL(I)+BEP(IR,J,2,I)*HWB(J,2)
200   DO 105 I=1,8
105   ELFP(I)=PN(I)+PM(I)+HNL(I)
502   CALL ASSEF(IR,IK,ELFP,FLVA)
      RETURN
      END
```

SECTION 6

ILLUSTRATIVE EXAMPLES

The following three examples are presented to assist the user in checking the adaptation of JET 3 to his computer facility.

6.1 A Uniform Thickness Circular Complete Ring Example

The geometry of the structure as shown in Fig. 7a, is a free circular ring, 0.124-in. thick, 1.195-in. wide, and 2.937-in. mean radius. The ring is subjected to severe impulsive loading over a peripheral sector of 120 degrees of its exterior. Taking account of the symmetry of the impulsive loading and geometry, only half of the ring is analyzed with the symmetry-prescribed-displacement conditions imposed at the centerline midplane. Eighteen uniform finite elements are used to model the half ring.

The ring material is considered to be elastic, linear-strain-hardening, and strain rate sensitive (EL-SH-SR). Its uniaxial stress-strain curve is approximated by the following coordinates (ε,σ) = (0 in/in, 0 psi); (0.00408, 42800); (1, 121200). The values $D = 6500\ sec^{-1}$ and $p = 4$ are used in the strain rate formula. For illustrative purpose only, ε_{cr} is assumed to be 0.04. The mass density is taken to be $0.25 \times 10^{-3}\ (lb\text{-}sec^2)/in^4$.

Let the JET 3A program calculate the incremental time interval, Δt, and 400 cycles of structural response; printout is desired at 50 cycles, and every 50 cycles thereafter.

6.1.1 Input Data

The values to be punched on the data cards are as follows:

			Format
Card 1			5E15.6
R	= 0.293700 E+01		
B	= 0.119500 E+01		
H	= 0.124000 E+00		
DENS	= 0.250000 E-03		
EXANG	= 0.180000 E+03	(subtended angle of the analyzed ring)	

		Format
Card 2		7I5
IK	= 18	
NOGA	= 3	
NFL	= 4	
NSFL	= 2	
MM	= 400	
M1	= 50	
M2	= 50	
Card 3		5E15.6
DELTAT	= 0.0 (to be calculated by the program)	
THETA	= 0.0 (first node is on the +Z axis)	
CRITS	= 0.400000 E-01	
DS	= 0.650000 E+04 } strain-rate constants	
P	= 0.400000 E+01 } strain-rate constants	
Card 4		4E15.6
EPS(1)	= 0.408000 E-02	
SIG(1)	= 0.428000 E+05	
EPS(2)	= 0.100000 E+01	
SIG(2)	= 0.121200 E+06	
Card 5		4F15.10
AXG(1)	= -0.7745966692	
AXG(2)	= 0.0	
AXG(3)	= 0.7745966692	
Card 6		4F15.10
AWG(1)	= 0.5555555555	
AWG(2)	= 0.8888888888	
AWG(3)	= 0.5555555555	
Card 7		4F15.10
TXG(1)	= -0.8611363115	
TXG(2)	= -0.3399810435	
TXG(3)	= 0.3399810435	
TXG(4)	= 0.8611363115	

Card 8 4F15.10

TWG(1) = 0.3478548451

TWG(2) = 0.6521451548

TWG(3) = 0.6521451548

TWG(4) = 0.3478548451

Card 9 9I5

NBCOND = 2 (two prescribed displacement conditions are to be imposed)

NBC(1) = 1
NODEB(1) = 1 } symmetry condition at node 1

NBC(2) = 1
NODEB(2) = 19 } symmetry condition at node 19

Card 10 3I5

NQR = 0 (no prescribed elastic restraints)

Cards 10a and 10b are not required since NQR=0

Card 11 4I5

NV = 1
IOTA = 1
IOTB = 0
IOTC = 0 } one local uniform initial normal velocity distribution

Card 12a 2I5

IE1 = 1
IE2 = 6 } first element and number of elements over which the local uniform initial normal velocity is to be prescribed

Card 12aa 5E15.6

WRAD = -0.685300 E+04

WRAD1 = -0.685300 E+04

ANGV1 = 0.0

WRAD2 = -0.342700 E+04
ANGV2 = 0.137060 E+05 } smooth the discontinuous initial velocity function

Card 13 and Card 14 are not used since IOTB=0 and IOTC=0, respectively.

Format

Card 15 4E15.6

TBEGIN = 0.0 } no forcing function is to be prescribed
TFINAL = 0.0 }

The input data deck for this example problem should appear as follows:

```
 0.293700E+01    0.119500E+01    0.124000E+00    0.250000E-03    0.180000E+03
 18    3    4     2   400   50   50
 0.0             0.0             0.400000E-01    0.650000E+04    0.400000E+01
 0.408000E-02    0.428000E+05    0.100000E+01    0.121200E+06
-0.7745966692    0.0             0.7745966692
 0.5555555555    0.8888888888    0.5555555555
-0.8611363115   -0.3399810435    0.3399810435    0.8611363115
 0.3478548451    0.6521451548    0.6521451548    0.3478548451
  2    1    1     1   19
  0
  1    1    0     0
  1    6
-0.685300E+04   -0.685300E+04    0.0            -0.342700E+04    0.137060E+05
 0.0             0.0
```

6.1.2 Solution Output for Example 1

The solution output for this example is as follows:

JET3A** A SPATIAL FINITE ELEMENT AND TEMPORAL CENTRAL DIFFERENCE PROGRAM
USED TO CALCULATE THE NONLINEAR RESPONSES OF A UNIFORM THICKNESS CIRCULAR
PARTIAL RING WITH THE FOLLOWING PARAMETERS

```
MEAN RADIUS OF RING (IN.)            =   0.293700E 01
WIDTH OF RING (IN.)                  =   0.119500E 01
THICKNESS OF RING (IN.)              =   0.124000E 00
DENSITY (LB-SEC**2/IN**4)            =   0.250000E-03
SUBTENDED ANGLE (DEGREE)             =   0.180000E 03
NUMBER OF ELEMENTS                   =   18
NUMBER OF SPANWISE GAUSSIAN PTS      =    3
NUMBER OF DEPTHWISE GAUSSIAN PTS     =    4
NUMBER OF MECHANICAL SUBLAYERS       =    2
SYMMETRY DISPLACEMENT CONDITION AT NODE =    1
SYMMETRY DISPLACEMENT CONDITION AT NODE =   19
```

THERE ARE NO ELASTIC SPRING CONSTRAINTS

SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX= 478

ELEMENT MASS MATRIX / (DENS*B*H)

0.190567D 00	0.258246D-03	0.443980D-03	0.137657D-01	0.658168D-01	0.528009D-02	-0.312910D-03	-0.813494D-02
0.258246D-03	0.193529D 00	0.138919D-01	-0.414821D-03	-0.528009D-02	0.628103D-01	-0.800565D-02	0.305614D-03
0.443980D-03	0.138919D-01	0.137036D-02	-0.301910D-07	-0.312910D-03	0.800565D-02	-0.983987D-03	-0.188040D-05
0.137657D-01	-0.414821D-03	-0.301910D-07	0.128297D-02	0.813494D-02	0.305614D-03	0.188040D-05	-0.962230D-03
0.658168D-01	-0.528009D-02	-0.312910D-03	0.813494D-02	0.190567D 00	-0.258246D-03	0.443980D-03	-0.137657D-01
0.528009D-02	0.628103D-01	0.800565D-02	0.305614D-03	-0.258246D-03	0.193529D 00	-0.138919D-01	-0.414821D-03
-0.312910D-03	-0.800565D-02	-0.983987D-03	0.188040D-05	0.443980D-03	-0.138919D-01	0.137036D-02	0.301910D-07
-0.813494D-02	0.305614D-03	-0.188040D-05	-0.962230D-03	-0.137657D-01	-0.414821D-03	0.301910D-07	0.128297D-02

ELEMENT STIFFNESS MATRIX / (YOUNG*B*H)

0.233005D 01	-0.193816D 00	-0.148494D-01	0.100089D 00	-0.232831D 01	-0.213738D 00	0.199686D-01	0.994332D-01
-0.193816D 00	0.131686D 00	0.307793D-01	-0.498121D-02	0.213738D 00	-0.960298D-01	0.277332D-01	-0.124747D-01
-0.148494D-01	0.307793D-01	0.101473D-01	0.217189D-03	0.199686D-01	-0.277332D-01	0.488773D-02	-0.170829D-02
0.100089D 00	-0.498121D-02	0.217189D-03	0.683572D-01	-0.994332D-01	-0.124747D-01	0.170829D-02	-0.170893D-01
-0.232831D 01	0.213738D 00	0.199686D-01	-0.994332D-01	0.233005D 01	0.193816D 00	-0.148494D-01	-0.100089D 00
-0.213738D 00	-0.960298D-01	-0.277332D-01	-0.124747D-01	0.193816D 00	0.131686D 00	-0.307793D-01	-0.498121D-02
0.199686D-01	0.277332D-01	0.488773D-02	0.170829D-02	-0.148494D-01	-0.307793D-01	0.101473D-01	-0.217189D-03
0.994332D-01	-0.124747D-01	-0.170829D-02	-0.170893D-01	-0.100089D 00	-0.498121D-02	-0.217189D-03	0.683572D-01

EIGEN VECTOR OF HIGHEST MODE

V	W	PSI	CHI
0.0	-0.29226859D-05	0.0	0.81258545D 00
0.97109752D-04	-0.28782912D-05	-0.11807250D-03	0.81400910D 00
0.19126853D-03	-0.27464574D-05	-0.23255703D-03	0.81823676D 00
0.27961512D-03	-0.25311940D-05	-0.33997472D-03	0.82513999D 00
0.35946506D-03	-0.22390468D-05	-0.43706165D-03	0.83450899D 00
0.42839224D-03	-0.18788977D-05	-0.52086798D-03	0.84605910D 00
0.48430260D-03	-0.14616936D-05	-0.58884760D-03	0.85943933D 00
0.52549766D-03	-0.10001122D-05	-0.63893538D-03	0.87424315D 00
0.55072609D-03	-0.50817718D-06	-0.66960984D-03	0.89002074D 00
0.55922158D-03	-0.83189849D-09	-0.67993924D-03	0.90629273D 00
0.55072609D-03	0.50651338D-06	-0.66960984D-03	0.92256472D 00
0.52549766D-03	0.99844841D-06	-0.63893538D-03	0.93834231D 00
0.48430260D-03	0.14600298D-05	-0.58884760D-03	0.95314612D 00
0.42839224D-03	0.18772339D-05	-0.52086798D-03	0.96652636D 00
0.35946506D-03	0.22373830D-05	-0.43706165D-03	0.97807646D 00
0.27961512D-03	0.25295302D-05	-0.33997472D-03	0.98744547D 00
0.19126853D-03	0.27447936D-05	-0.23255703D-03	0.99434869D 00
0.97109752D-04	0.28766274D-05	-0.11807250D-03	0.99857636D 00
0.0	0.29210221D-05	0.0	0.10000000D 01

HIGHEST NATURAL FREQUENCY (RAD/SEC) = 0.25883311D 07

TIME STEP SIZE USED IN PROGRAM (SEC) = 0.618159E-06

IMPULSE LOADINGS HAVE BEEN SPECIFIED AS DESCRIBED BY INPUT

THERE IS NO TIME DEPENDENT FORCE DISTRIBUTION DURING THIS RUN

J= 0 TIME (SEC.) = 0.0
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.257443E 04
ELASTIC ENERGY (IN.-LB.) = 0.0
PLASTIC WORK (IN.-LB.) = 0.0

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	0.0	0.0	0.0	0.0	0.2937E 01	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.5100E 00	0.2892E 01	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.1005E 01	0.2760E 01	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.1468E 01	0.2544E 01	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.1888E 01	0.2250E 01	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.2250E 01	0.1888E 01	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.2544E 01	0.1469E 01	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.2760E 01	0.1005E 01	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.2892E 01	0.5100E 00	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.2937E 01	0.6524E-05	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.2892E 01	-0.5100E 00	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.2760E 01	-0.1005E 01	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.2544E 01	-0.1468E 01	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.2250E 01	-0.1888E 01	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.1888E 01	-0.2250E 01	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.1469E 01	-0.2544E 01	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.1005E 01	-0.2760E 01	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.5100E 00	-0.2892E 01	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1025E-04	-0.2937E 01				

J= 1 TIME (SEC.) = 0.618159E-06
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.256498E 04
ELASTIC ENERGY (IN.-LB.) = 0.596245E 01
PLASTIC WORK (IN.-LB.) = 0.348970E 01

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.4236D-02	0.0	0.0	0.0	0.2933E 01	-0.3363E 04	-0.4903E 00	-0.2148E-02	-0.2179E-02
2	0.0	-0.4236D-02	0.0	0.0	0.5093E 00	0.2888E 01	-0.3363E 04	-0.4903E 00	-0.2148E-02	-0.2179E-02
3	0.0	-0.4236D-02	0.0	0.0	0.1003E 01	0.2756E 01	-0.3363E 04	-0.4903E 00	-0.2148E-02	-0.2179E-02
4	0.0	-0.4236D-02	0.0	0.0	0.1466E 01	0.2540E 01	-0.3363E 04	-0.4903E 00	-0.2148E-02	-0.2179E-02
5	0.0	-0.4236D-02	0.0	0.0	0.1885E 01	0.2247E 01	-0.3363E 04	-0.4903E 00	-0.2148E-02	-0.2179E-02
6	0.0	-0.4236D-02	0.0	0.0	0.2247E 01	0.1885E 01	-0.2797E 04	-0.3329E 02	-0.7631E-03	-0.2836E-02
7	0.0	-0.2118D-02	0.8472D-02	0.0	0.2542E 01	0.1467E 01	-0.5407E 03	0.3280E 02	-0.1369E-02	0.6731E-03
8	0.0	0.0	0.0	0.0	0.2760E 01	0.1005E 01	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.2892E 01	0.5100E 00	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.2937E 01	0.6524E-05	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.2892E 01	-0.5100E 00	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.2760E 01	-0.1005E 01	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.2544E 01	-0.1468E 01	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.2250E 01	-0.1888E 01	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.1888E 01	-0.2250E 01	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.1469E 01	-0.2544E 01	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.1005E 01	-0.2760E 01	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.5100E 00	-0.2892E 01	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1025E-04	-0.2937E 01				

J= 50 TIME (SEC.) = 0.309079E-04

TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04

KINETIC ENERGY (IN.-LB.) = 0.126536E 04

ELASTIC ENERGY (IN.-LB.) = 0.161289E 03

PLASTIC WORK (IN.-LB.) = 0.114778E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.1674D 00	0.0	-0.5376D-01	0.0	0.2770E 01	-0.8297E 04	-0.8113E 01	-0.5638E-01	-0.5631E-01
2	0.8602D-03	-0.1675D 00	-0.4830D-03	-0.5280D-01	0.4818E 00	0.2727E 01	-0.9526E 04	0.8400E 01	-0.5478E-01	-0.5419E-01
3	0.2824D-02	-0.1677D 00	-0.3151D-02	-0.4845D-01	0.9498E 00	0.2601E 01	-0.8924E 04	0.1739E 01	-0.4636E-01	-0.4729E-01
4	0.8443D-02	-0.1681D 00	0.6102D-03	-0.4198D-01	0.1392E 01	0.2394E 01	-0.8261E 04	0.2823E 02	-0.4055E-01	-0.2845E-01
5	0.1978D-01	-0.1725D 00	-0.4938D-01	-0.3108D-01	0.1792E 01	0.2105E 01	-0.7150E 04	-0.1215E 03	-0.2868E-02	-0.3524E-01
6	0.3892D-01	-0.1855D 00	0.8540D-01	-0.3892D-01	0.2133E 01	0.1739E 01	-0.5630E 04	-0.1523E 03	0.6110E-02	-0.3198E-01
7	0.4324D-01	-0.7344D-01	0.2430D 00	-0.3673D-01	0.2502E 01	0.1394E 01	-0.5494E 04	0.1954E 03	-0.3318E-01	0.9486E-02
8	0.3257D-01	0.2049D-01	0.6634D-01	-0.1581D-01	0.2790E 01	0.9809E 00	-0.4483E 04	0.1703E 03	-0.1857E-01	0.5597E-02
9	0.2402D-01	0.2438D-01	-0.3352D-01	-0.3265D-02	0.2921E 01	0.4906E 00	-0.4073E 04	-0.3581E 02	-0.1403E-02	-0.3968E-02
10	0.1923D-01	0.1241D-01	-0.2290D-01	-0.3234D-02	0.2949E 01	-0.1922E-01	-0.4186E 04	-0.5678E 02	-0.8602E-03	-0.4609E-02
11	0.1605D-01	0.8350D-02	-0.7369D-02	-0.2783D-02	0.2898E 01	-0.5273E 00	-0.4397E 04	0.1743E 01	-0.2883E-02	-0.2774E-02
12	0.1321D-01	0.7674D-02	-0.7829D-02	-0.2549D-02	0.2763E 01	-0.1020E 01	-0.4539E 04	0.3290E 01	-0.3023E-02	-0.2818E-02
13	0.1068D-01	0.4636D-02	-0.8706D-02	-0.2433D-02	0.2542E 01	-0.1480E 01	-0.4895E 04	-0.1706E 02	-0.2618E-02	-0.3680E-02
14	0.8475D-02	0.3516D-02	-0.4345D-02	-0.2725D-02	0.2247E 01	-0.1897E 01	-0.4968E 04	0.9722E 00	-0.3226E-02	-0.3166E-02
15	0.6400D-02	0.1829D-02	-0.4612D-02	-0.3146D-02	0.1884E 01	-0.2255E 01	-0.4958E 04	-0.1813E 01	-0.3133E-02	-0.3246E-02
16	0.4503D-02	0.1186D-02	-0.4147D-02	-0.3191D-02	0.1465E 01	-0.2547E 01	-0.5114E 04	-0.1246E 02	-0.2902E-02	-0.3678E-02
17	0.2708D-02	0.4394D-03	-0.9432D-03	-0.3208D-02	0.1002E 01	-0.2761E 01	-0.4355E 04	0.1466E 01	-0.2847E-02	-0.2756E-02
18	0.1196D-02	0.8124D-04	-0.1314D-02	-0.2679D-02	0.5089E 00	-0.2893E 01	-0.3418E 04	-0.5017E 01	-0.2042E-02	-0.2355E-02
19	0.0	0.7154D-04	0.0	-0.2446D-02	0.1025E-04	-0.2937E 01				

J= 100 TIME (SEC.) = 0.618159E-04

TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04

KINETIC ENERGY (IN.-LB.) = 0.111864E 04

ELASTIC ENERGY (IN.-LB.) = 0.967907E 02

PLASTIC WORK (IN.-LB.) = 0.135900E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.2507D 00	0.0	-0.4930D-01	0.0	0.2686E 01	0.5243E 04	0.1220E 02	-0.5491E-01	-0.5449E-01
2	0.1687D-01	-0.2519D 00	-0.2108D-02	-0.4795D-01	0.4829E 00	0.2641E 01	0.4661E 04	0.8986E 01	-0.5179E-01	-0.4821E-01
3	0.3596D-01	-0.2510D 00	-0.1725D-01	-0.4146D-01	0.9525E 00	0.2512E 01	0.3706E 04	0.1647E 03	-0.4402E-01	-0.3304E-01
4	0.6021D-01	-0.2609D 00	-0.6265D-01	-0.3792D-01	0.1390E 01	0.2287E 01	0.3197E 04	0.6942E 02	-0.3953E-01	-0.1770E-01
5	0.9061D-01	-0.3041D 00	-0.1528D 00	-0.3743D-01	0.1762E 01	0.1959E 01	0.1614E 04	-0.2692E 03	0.2441E-01	-0.5837E-01
6	0.1326D 00	-0.3207D 00	0.1908D 00	-0.4606D-01	0.2089E 01	0.1580E 01	-0.2456E 03	-0.2475E 03	0.2158E-01	-0.4069E-01
7	0.1272D 00	-0.1040D 00	0.4476D 00	-0.1064D 00	0.2517E 01	0.1306E 01	-0.1589E 04	0.2603E 03	-0.5038E-01	0.2840E-01
8	0.8961D-01	0.8611D-01	0.1208D 00	-0.2053D-01	0.2871E 01	0.9498E 00	-0.1734E 04	0.2595E 03	-0.2816E-01	0.1790E-01
9	0.6833D-01	0.9583D-01	-0.6943D-01	-0.3667D-02	0.2999E 01	0.4594E 00	-0.1569E 04	0.1663E 02	-0.1424E-02	-0.7239E-03
10	0.5196D-01	0.6767D-01	-0.7235D-01	-0.3941D-02	0.3005E 01	-0.5195E-01	-0.1363E 04	-0.1157E 03	0.2790E-02	-0.4627E-02
11	0.4087D-01	0.4639D-01	-0.4164D-01	-0.1480D-02	0.2931E 01	-0.5583E 00	-0.6998E 03	-0.9910E 02	0.2635E-02	-0.3535E-02
12	0.3318D-01	0.3896D-01	-0.1610D-01	-0.1463D-03	0.2785E 01	-0.1049E 01	0.3076E 03	-0.2097E 02	0.8506E-03	-0.4547E-03
13	0.2656D-01	0.3801D-01	-0.1070D-01	0.4428D-03	0.2563E 01	-0.1511E 01	0.1310E 04	0.2803E 02	-0.2975E-04	0.1715E-02
14	0.2049D-01	0.3478D-01	-0.1792D-01	0.7390D-03	0.2263E 01	-0.1926E 01	0.1820E 04	-0.2881E 02	0.2068E-02	0.2740E-03
15	0.1543D-01	0.2999D-01	-0.1049D-01	0.1489D-02	0.1895E 01	-0.2283E 01	0.2590E 04	-0.1649E 02	0.2180E-02	0.1153E-02
16	0.1121D-01	0.2817D-01	-0.6244D-02	0.1741D-02	0.1473E 01	-0.2574E 01	0.3145E 04	-0.5402E 00	0.2040E-02	0.2006E-02
17	0.7356D-02	0.2724D-01	-0.6090D-02	0.1803D-02	0.1007E 01	-0.2788E 01	0.3541E 04	-0.1055E 02	0.2669E-02	0.1594E-02
18	0.3804D-02	0.2517D-01	-0.1613D-02	0.1454D-02	0.5106E 00	-0.2918E 01	0.3101E 04	0.4102E 01	0.1432E-02	0.1045E-02
19	0.0	0.2531D-01	0.0	0.5975D-03	0.1034E-04	-0.2962E 01				

J= 150 TIME (SEC.) = 0.927238E-04
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.105222E 04
ELASTIC ENERGY (IN.-LB.) = 0.756474E 02
PLASTIC WORK (IN.-LB.) = 0.144656E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.3377D 00	0.0	-0.5270D-01	0.0	0.2599E 01	-0.2580E 03	0.5773E 01	-0.5825E-01	-0.5823E-01
2	0.2987D-01	-0.3339D 00	-0.4530D-03	-0.5152D-01	0.4814E 00	0.2558E 01	-0.1041E 04	0.2067E 03	-0.6363E-01	-0.4403E-01
3	0.6147D-01	-0.3443D 00	-0.8186D-01	-0.4767D-01	0.9445E 00	0.2415E 01	-0.9055E 03	0.6356E 02	-0.4512E-01	-0.3476E-01
4	0.1012D 00	-0.3871D 00	-0.1248D 00	-0.4606D-01	0.1363E 01	0.2158E 01	-0.1097E 04	-0.2310E 03	-0.2995E-01	-0.3185E-01
5	0.1525D 00	-0.4297D 00	-0.1169D 00	-0.3295D-01	0.1728E 01	0.1823E 01	-0.1337E 04	-0.2093E 03	0.2963E-01	-0.6154E-01
6	0.2138D 00	-0.3986D 00	0.2623D 00	-0.6362D-01	0.2082E 01	0.1468E 01	-0.1044E 04	-0.6852E 02	0.2116E-01	-0.3765E-01
7	0.2062D 00	-0.1372D 00	0.5047D 00	-0.1331D 00	0.2528E 01	0.1221E 01	-0.6801E 03	0.2598E 02	-0.4372E-01	0.2286E-01
8	0.1550D 00	0.1079D 00	0.2278D 00	-0.3736D-01	0.2914E 01	0.8957E 00	-0.4524E 03	0.1825E 03	-0.3273E-01	0.3642E-01
9	0.1260D 00	0.1634D 00	-0.5725D-01	-0.1874D-02	0.3075E 01	0.4143E 00	-0.6846E 03	0.2091E 03	-0.7168E-02	0.6565E-02
10	0.9702D-01	0.1350D 00	-0.1141D 00	-0.7057D-02	0.3072E 01	-0.9701E-01	-0.3118E 03	-0.4041E 02	0.1837E-02	-0.1923E-02
11	0.7405D-01	0.9247D-01	-0.9864D-01	-0.3718D-02	0.2971E 01	-0.5990E 00	0.3820E 03	-0.1547E 03	0.6460E-02	-0.5188E-02
12	0.5944D-01	0.6666D-01	-0.5041D-01	-0.6956D-03	0.2802E 01	-0.1083E 01	0.4263E 03	-0.9728E 02	0.3488E-02	-0.2836E-02
13	0.4861D-01	0.5759D-01	-0.2423D-01	0.8976D-04	0.2569E 01	-0.1539E 01	0.5963E 03	-0.3877E 02	0.1590E-02	-0.8231E-03
14	0.3885D-01	0.5633D-01	-0.1425D-01	0.4797D-03	0.2268E 01	-0.1954E 01	0.4639E 03	0.2496E 02	-0.4785E-03	0.1076E-02
15	0.2934D-01	0.5336D-01	-0.2070D-01	0.4630D-03	0.1900E 01	-0.2310E 01	0.1085E 04	-0.8364E 01	0.9583E-03	0.4376E-03
16	0.2084D-01	0.4717D-01	-0.1855D-01	0.8596D-03	0.1474E 01	-0.2595E 01	0.1674E 04	-0.3116E 02	0.2047E-02	0.1065E-03
17	0.1353D-01	0.4271D-01	-0.1052D-01	0.1021D-02	0.1006E 01	-0.2805E 01	0.2185E 04	-0.2780E 02	0.2333E-02	0.1845E-03
18	0.6830D-02	0.4112D-01	-0.1604D-02	0.6758D-03	0.5104E 00	-0.2934E 01	0.2371E 04	0.4156E 01	0.9601E-03	0.5768E-03
19	0.0	0.4101D-01	0.0	0.2718D-03	0.1039E-04	-0.2978E 01				

J= 200 TIME (SEC.) = 0.123632E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.997464E 03
ELASTIC ENERGY (IN.-LB.) = 0.104127E 03
PLASTIC WORK (IN.-LB.) = 0.147284E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.3943D 00	0.0	-0.5177D-01	0.0	0.2543E 01	0.1788E 03	0.2396E 03	-0.6924E-01	-0.4622E-01
2	0.4094D-01	-0.4218D 00	-0.9567D-01	-0.5569D-01	0.4771E 00	0.2470E 01	0.2362E 03	-0.2054E 02	-0.5581E-01	-0.5013E-01
3	0.8915D-01	-0.4669D 00	-0.1195D 00	-0.5064D-01	0.9286E 00	0.2291E 01	0.6417E 03	-0.1459E 03	-0.3754E-01	-0.4042E-01
4	0.1506D 00	-0.5049D 00	-0.1075D 00	-0.4325D-01	0.1346E 01	0.2031E 01	0.3768E 03	-0.1677E 03	-0.3000E-01	-0.3007E-01
5	0.2221D 00	-0.5292D 00	-0.1072D 00	-0.3248D-01	0.1718E 01	0.1702E 01	-0.1497E 03	-0.2423E 03	0.3304E-01	-0.6421E-01
6	0.2987D 00	-0.4754D 00	0.2974D 00	-0.7114D-01	0.2078E 01	0.1353E 01	-0.3465E 03	-0.2251E 03	0.2657E-01	-0.4226E-01
7	0.2864D 00	-0.1687D 00	0.5810D 00	-0.1753D 00	0.2541E 01	0.1136E 01	-0.4978E 03	0.1691E 03	-0.4806E-01	0.2743E-01
8	0.2216D 00	0.1211D 00	0.2669D 00	-0.4644D-01	0.2949E 01	0.8377E 00	-0.6520E 03	0.2110E 03	-0.3445E-01	0.3748E-01
9	0.1866D 00	0.2021D 00	-0.2951D-01	-0.1229D-02	0.3124E 01	0.3613E 00	-0.9139E 03	0.1755E 03	-0.1117E-01	0.7412E-02
10	0.1491D 00	0.1948D 00	-0.1064D 00	-0.6466D-02	0.3132E 01	-0.1491E 00	-0.1015E 04	0.1520E 03	-0.5215E-02	0.3884E-02
11	0.1139D 00	0.1514D 00	-0.1442D 00	-0.1019D-01	0.3022E 01	-0.6485E 00	-0.1244E 04	-0.4258E 02	0.2435E-02	-0.3902E-02
12	0.8713D-01	0.9878D-01	-0.1180D 00	-0.7667D-02	0.2823E 01	-0.1120E 01	-0.1564E 04	-0.2193E 03	0.6778E-02	-0.9644E-02
13	0.7039D-01	0.7008D-01	-0.5005D-01	-0.2134D-02	0.2569E 01	-0.1564E 01	-0.1615E 04	-0.1290E 03	0.2978E-02	-0.5056E-02
14	0.5792D-01	0.6602D-01	-0.1677D-01	-0.1552D-02	0.2263E 01	-0.1975E 01	-0.2507E 04	0.6686E 01	-0.1821E-02	-0.1405E-02
15	0.4538D-01	0.6678D-01	-0.1849D-01	-0.2194D-02	0.1896E 01	-0.2330E 01	-0.3195E 04	0.2316E 02	-0.2776E-02	-0.1334E-02
16	0.3281D-01	0.6257D-01	-0.2444D-01	-0.2800D-02	0.1471E 01	-0.2614E 01	-0.3761E 04	-0.1350E 02	-0.1999E-02	-0.2840E-02
17	0.2113D-01	0.5501D-01	-0.2096D-01	-0.2844D-02	0.1003E 01	-0.2819E 01	-0.4466E 04	-0.3143E 02	-0.1784E-02	-0.4317E-02
18	0.1042D-01	0.4958D-01	-0.1047D-01	-0.3610D-02	0.5084E 00	-0.2943E 01	-0.4835E 04	-0.3029E 02	-0.2603E-02	-0.5131E-02
19	0.0	0.4717D-01	0.0	-0.4532D-02	0.1041E-04	-0.2984E 01				

J= 250 TIME (SEC.) = 0.154540E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.942427E 03
ELASTIC ENERGY (IN.-LB.) = 0.114932E 03
PLASTIC WORK (IN.-LB.) = 0.151707E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.4774D 00	0.0	-0.4969D-01	0.0	0.2460E 01	-0.7593E 03	0.2336E 03	-0.7301E-01	-0.4399E-01
2	0.5506D-01	-0.5137D 00	-0.1206D 00	-0.5903D-01	0.4750E 00	0.2377E 01	-0.1001E 04	0.2882E 02	-0.5814E-01	-0.4939E-01
3	0.1179D 00	-0.5707D 00	-0.1572D 00	-0.5635D-01	0.9202E 00	0.2183E 01	-0.6196E 03	-0.1881E 03	-0.3609E-01	-0.4470E-01
4	0.1958D 00	-0.6189D 00	-0.1217D 00	-0.4539D-01	0.1329E 01	0.1910E 01	-0.2724E 03	-0.2604E 03	-0.2511E-01	-0.3619E-01
5	0.2866D 00	-0.6270D 00	-0.7568D-01	-0.3004D-01	0.1704E 01	0.1585E 01	-0.2564E 03	-0.2578E 03	0.3469E-01	-0.6610E-01
6	0.3764D 00	-0.5392D 00	0.3439D 00	-0.8607D-01	0.2079E 01	0.1253E 01	0.2820E 02	-0.1961E 03	0.2643E-01	-0.4229E-01
7	0.3599D 00	-0.1957D 00	0.6268D 00	-0.2018D 00	0.2554E 01	0.1059E 01	0.5969E 03	0.9510E 02	-0.4505E-01	0.2584E-01
8	0.2831D 00	0.1337D 00	0.3314D 00	-0.6514D-01	0.2982E 01	0.7843E 00	0.1503E 04	0.2260E 03	-0.3795E-01	0.4281E-01*
9	0.2391D 00	0.2526D 00	-0.1319D-02	0.9784D-03	0.3183E 01	0.3184E 00	0.2075E 04	0.2511E 03	-0.1347E-01	0.1541E-01
10	0.1928D 00	0.2556D 00	-0.1208D 00	-0.6001D-02	0.3193E 01	-0.1928E 00	0.2971E 04	0.1394E 03	-0.2324E-02	0.6203E-02
11	0.1473D 00	0.2113D 00	-0.1562D 00	-0.9499D-02	0.3075E 01	-0.6918E 00	0.3473E 04	0.1314E 02	0.3735E-02	0.8672E-03
12	0.1105D 00	0.1556D 00	-0.1443D 00	-0.8646D-02	0.2868E 01	-0.1162E 01	0.3611E 04	-0.8234E 02	0.6964E-02	-0.3345E-02
13	0.8467D-01	0.1081D 00	-0.1017D 00	-0.2701D-02	0.2595E 01	-0.1596E 01	0.3904E 04	-0.1289E 03	0.1064E-01	-0.3859E-02
14	0.6849D-01	0.8486D-01	-0.4161D-01	0.2145D-02	0.2271E 01	-0.1995E 01	0.3671E 04	-0.1305E 03	0.6964E-02	-0.1940E-02
15	0.5501D-01	0.8571D-01	-0.4737D-02	0.1998D-02	0.1901E 01	-0.2351E 01	0.3342E 04	0.2710E 02	0.1307E-02	0.2994E-02
16	0.4050D-01	0.9158D-01	-0.1170D-01	0.1733D-02	0.1479E 01	-0.2643E 01	0.2825E 04	0.6905E 02	-0.3321E-03	0.3967E-02
17	0.2561D-01	0.8596D-01	-0.2949D-01	0.1108D-02	0.1010E 01	-0.2849E 01	0.2594E 04	-0.2282E 02	0.2490E-02	0.4928E-03
18	0.1211D-01	0.7512D-01	-0.2121D-01	0.7327D-03	0.5111E 00	-0.2968E 01	0.2643E 04	-0.7197E 02	0.3505E-02	-0.1618E-02
19	0.0	0.6984D-01	0.0	0.6912D-03	0.1049E-04	-0.3007E 01				

* STRAIN EXCEEDS THE CRITICAL VALUE

J= 300 TIME (SEC.) = 0.185448E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.916673E 03
ELASTIC ENERGY (IN.-LB.) = 0.980654E 02
PLASTIC WORK (IN.-LB.) = 0.155969E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.5780D 00	0.0	-0.4961D-01	0.0	0.2359E 01	-0.3347E 03	0.1883E 03	-0.7184E-01	-0.4326E-01
2	0.7293D-01	-0.6114D 00	-0.1187D 00	-0.5829D-01	0.4757E 00	0.2278E 01	-0.4709E 03	0.8667E 02	-0.5960E-01	-0.4724E-01
3	0.1525D 00	-0.6658D 00	-0.1702D 00	-0.5811D-01	0.9200E 00	0.2082E 01	-0.2779E 03	-0.1041E 03	-0.3833E-01	-0.4193E-01
4	0.2454D 00	-0.7200D 00	-0.1555D 00	-0.4951D-01	0.1321E 01	0.1797E 01	-0.2569E 03	-0.2485E 03	-0.1242E-01	-0.4196E-01
5	0.3549D 00	-0.7199D 00	-0.3297D-01	-0.2305D-01	0.1697E 01	0.1470E 01	-0.1046E 02	-0.2125E 03	0.3651E-01	-0.6560E-01
6	0.4556D 00	-0.5905D 00	0.3924D 00	-0.1055D 00	0.2090E 01	0.1159E 01	-0.7489E 02	-0.9272E 02	0.2314E-01	-0.3914E-01
7	0.4360D 00	-0.2166D 00	0.6485D 00	-0.2158D 00	0.2574E 01	0.9826E 00	-0.2852E 03	0.8910E 02	-0.4543E-01	0.2508E-01
8	0.3548D 00	0.1364D 00	0.3547D 00	-0.7393D-01	0.3009E 01	0.7178E 00	-0.4652E 03	0.2023E 03	-0.3861E-01	0.4146E-01
9	0.3057D 00	0.2803D 00	0.2472D-01	0.1348D-03	0.3221E 01	0.2576E 00	-0.5590E 03	0.2209E 03	-0.1873E-01	0.1685E-01
10	0.2522D 00	0.3009D 00	-0.1225D 00	-0.8137D-02	0.3238E 01	-0.2522E 00	-0.1117E 04	0.1880E 03	-0.6925E-02	0.5289E-02
11	0.1962D 00	0.2611D 00	-0.1731D 00	-0.1526D-01	0.3115E 01	-0.7485E 00	-0.1744E 04	0.6590E 02	-0.1264E-02	-0.8461E-03
12	0.1472D 00	0.2005D 00	-0.1749D 00	-0.1690D-01	0.2898E 01	-0.1211E 01	-0.2077E 04	-0.7440E 02	0.3057E-02	-0.6757E-02
13	0.1103D 00	0.1421D 00	-0.1343D 00	-0.1016D-01	0.2611E 01	-0.1635E 01	-0.2388E 04	-0.1175E 03	0.6306E-02	-0.7696E-02
14	0.8579D-01	0.1055D 00	-0.7630D-01	-0.3868D-02	0.2276E 01	-0.2021E 01	-0.2819E 04	-0.1205E 03	0.2800E-02	-0.6088E-02
15	0.6732D-01	0.9017D-01	-0.3951D-01	-0.2521D-02	0.1894E 01	-0.2362E 01	-0.3301E 04	-0.1144E 03	0.1437E-02	-0.5684E-02
16	0.5073D-01	0.8776D-01	-0.1005D-01	-0.2237D-02	0.1468E 01	-0.2645E 01	-0.3455E 04	-0.8360E 01	-0.1962E-02	-0.2483E-02
17	0.3386D-01	0.9198D-01	-0.7889D-02	-0.2333D-02	0.1004E 01	-0.2858E 01	-0.3439E 04	0.4693E 02	-0.3562E-02	-0.1217E-02
18	0.1662D-01	0.8912D-01	-0.1758D-01	-0.3138D-02	0.5091E 00	-0.2983E 01	-0.3439E 04	-0.5787E 02	-0.8469E-03	-0.5091E-02
19	0.0	0.8381D-01	0.0	-0.3498D-02	0.1054E-04	-0.3021E 01				

J= 350 TIME (SEC.) = 0.216356E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.899933E 03
ELASTIC ENERGY (IN.-LB.) = 0.103451E 03
PLASTIC WORK (IN.-LB.) = 0.157104E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.6829D 00	0.0	-0.4946D-01	0.0	0.2254E 01	-0.5116E 03	0.2076E 03	-0.7255E-01	-0.4277E-01
2	0.9106D-01	-0.7169D 00	-0.1237D 00	-0.5888D-01	0.4752E 00	0.2171E 01	-0.8276E 03	0.3051E 02	-0.5808E-01	-0.4922E-01
3	0.1887D 00	-0.7656D 00	-0.1608D 00	-0.5672D-01	0.9200E 00	0.1976E 01	-0.5110E 03	-0.9866E 02	-0.3865E-01	-0.4191E-01
4	0.2988D 00	-0.8061D 00	-0.1474D 00	-0.4879D-01	0.1324E 01	0.1696E 01	-0.4475E 03	-0.1856E 03	-0.1396E-01	-0.4176E-01
5	0.4220D 00	-0.7946D 00	-0.3211D-01	-0.2415D-01	0.1700E 01	0.1370E 01	-0.5691E 03	-0.2694E 03	0.3878E-01	-0.7041E-01
6	0.5326D 00	-0.6463D 00	0.4228D 00	-0.1166D 00	0.2097E 01	0.1064E 01	-0.6647E 03	-0.1531E 03	0.2464E-01	-0.4140E-01
7	0.5068D 00	-0.2378D 00	0.6941D 00	-0.2472D 00	0.2591E 01	0.9107E 00	-0.2375E 03	0.1766E 03	-0.4812E-01	0.2784E-01
8	0.4158D 00	0.1446D 00	0.3776D 00	-0.8217D-01	0.3038E 01	0.6633E 00	-0.1252E 03	0.2168E 03	-0.3884E-01	0.4214E-01
9	0.3619D 00	0.3081D 00	0.4399D-01	-0.4510D-03	0.3259E 01	0.2071E 00	-0.2107E 03	0.2105E 03	-0.1888E-01	0.1692E-01
10	0.3022D 00	0.3494D 00	-0.1041D 00	-0.6069D-02	0.3286E 01	-0.3022E 00	-0.3113E 03	0.2198E 03	-0.9966E-02	0.8970E-02
11	0.2370D 00	0.3197D 00	-0.1825D 00	-0.1630D-01	0.3166E 01	-0.7989E 00	-0.8361E 01	0.1004E 03	-0.1221E-02	0.1344E-02
12	0.1770D 00	0.2576D 00	-0.1932D 00	-0.1872D-01	0.2941E 01	-0.1259E 01	0.5265E 03	-0.2530E 02	0.3204E-02	-0.3554E-02
13	0.1294D 00	0.1907D 00	-0.1653D 00	-0.1310D-01	0.2644E 01	-0.1676E 01	0.1192E 04	-0.1171E 03	0.8595E-02	-0.5378E-02
14	0.9674D-01	0.1398D 00	-0.1074D 00	-0.4419D-02	0.2295E 01	-0.2052E 01	0.1859E 04	-0.1467E 03	0.6625E-02	-0.3895E-02
15	0.7389D-01	0.1121D 00	-0.6384D-01	-0.9994D-03	0.1903E 01	-0.2383E 01	0.2298E 04	-0.1205E 03	0.5401E-02	-0.2660E-02
16	0.5574D-01	0.9944D-01	-0.3046D-01	0.1104D-02	0.1470E 01	-0.2657E 01	0.2617E 04	-0.1367E 03	0.5938E-02	-0.2571E-02
17	0.3925D-01	0.1010D 00	0.4773D-02	0.1677D-02	0.1002E 01	-0.2868E 01	0.2648E 04	-0.7715E 02	0.4216E-02	-0.1164E-02
18	0.2107D-01	0.1161D 00	0.2705D-01	0.5752D-03	0.5094E 00	-0.3010E 01	0.2313E 04	0.1153E 03	-0.2537E-02	0.4000E-02
19	0.0	0.1258D 00	0.0	0.4762D-03	0.1069E-04	-0.3063E 01				

J= 400 TIME (SEC.) = 0.247263E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.257443E 04
KINETIC ENERGY (IN.-LB.) = 0.887424E 03
ELASTIC ENERGY (IN.-LB.) = 0.984258E 02
PLASTIC WORK (IN.-LB.) = 0.158858E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	-0.7956D 00	0.0	-0.4924D-01	0.0	0.2141E 01	0.4494E 03	0.1300E 03	-0.6952E-01	-0.4457E-01
2	0.1111D 00	-0.8213D 00	-0.1037D 00	-0.5623D-01	0.4768E 00	0.2064E 01	0.6061E 03	0.8102E 02	-0.5873E-01	-0.4673E-01
3	0.2272D 00	-0.8572D 00	-0.1537D 00	-0.5513D-01	0.9248E 00	0.1877E 01	0.4692E 03	-0.9054E 02	-0.3827E-01	-0.4103E-01
4	0.3530D 00	-0.8877D 00	-0.1424D 00	-0.4762D-01	0.1330E 01	0.1598E 01	-0.7249E 02	-0.2304E 03	-0.1232E-01	-0.4291E-01
5	0.4898D 00	-0.8597D 00	-0.1559D-01	-0.2283D-01	0.1711E 01	0.1276E 01	-0.1663E 03	-0.2179E 03	0.3978E-01	-0.7003E-01
6	0.6086D 00	-0.6879D 00	0.4420D 00	-0.1254D 00	0.2114E 01	0.9794E 00	-0.4279E 03	-0.1478E 03	0.2463E-01	-0.4108E-01
7	0.5833D 00	-0.2581D 00	0.7120D 00	-0.2595D 00	0.2612E 01	0.8343E 00	-0.6191E 03	0.1250E 03	-0.4676E-01	0.2598E-01
8	0.4859D 00	0.1503D 00	0.4085D 00	-0.9453D-01	0.3067E 01	0.5994E 00	-0.6640E 03	0.2355E 03	-0.4131E-01	0.4431E-01
9	0.4259D 00	0.3380D 00	0.5581D-01	-0.1820D-02	0.3299E 01	0.1493E 00	-0.7354E 03	0.2326E 03	-0.2087E-01	0.1915E-01
10	0.3596D 00	0.3900D 00	-0.1097D 00	-0.7227D-02	0.3327E 01	-0.3596E 00	-0.9031E 03	0.1862E 03	-0.9937E-02	0.8986E-02
11	0.2863D 00	0.3669D 00	-0.1880D 00	-0.1771D-01	0.3204E 01	-0.8556E 00	-0.1101E 04	0.1100E 03	-0.2507E-02	0.1582E-02
12	0.2166D 00	0.3089D 00	-0.2050D 00	-0.2188D-01	0.2976E 01	-0.1314E 01	-0.1044E 04	0.2851E 02	0.5185E-03	-0.2889E-02
13	0.1579D 00	0.2382D 00	-0.1910D 00	-0.1890D-01	0.2671E 01	-0.1724E 01	-0.7952E 03	-0.5337E 02	0.5334E-02	-0.4674E-02
14	0.1147D 00	0.1741D 00	-0.1495D 00	-0.1097D-01	0.2310E 01	-0.2088E 01	-0.2659E 03	-0.1593E 03	0.5953E-02	-0.5787E-02
15	0.8463D-01	0.1267D 00	-0.1009D 00	-0.4972D-02	0.1904E 01	-0.2401E 01	0.3862E 02	-0.2255E 03	0.9066E-02	-0.8497E-02
16	0.6376D-01	0.1063D 00	-0.2818D-01	0.3223D-03	0.1466E 01	-0.2667E 01	0.2830E 03	-0.1438E 03	0.5649E-02	-0.4731E-02
17	0.4499D-01	0.1144D 00	0.1479D-01	0.2493D-03	0.1001E 01	-0.2883E 01	0.5114E 03	0.1748E 01	0.3858E-03	-0.8237E-04
18	0.2361D-01	0.1295D 00	0.1674D-01	-0.7519D-03	0.5093E 00	-0.3024E 01	0.5211E 03	0.7195E 02	-0.2405E-02	0.1644E-02
19	0.0	0.1359D 00	0.0	-0.6665D-03	0.1072E-04	-0.3073E 01				

LARGEST COMPUTED STRAIN = 0.443120E-01 OCCURS AT THE OUTER SURFACE MIDSPAN OF ELEMENT = 8 AT TIME (SEC.) = 0.247263E-03

6.2 A Uniform Thickness Circular Complete Ring Example+

In this example, a free circular ring 7.3375-in. midsurface radius, 0.125-in. thick, 1.0-in. long is acted upon by a timewise triangularly-shaped normal direction forcing function lasting 400 μsec with a peak value of 2500 pounds per inch at t = 200 μsec. The forces are assumed to be distributed over three equally separated peripheral sectors (as shown in Fig. 7b); each amplitude is defined by the shape of a half-sine wave over a 30° segment of the ring. The normalized values of the three sine-shaped forcing functions with respect to the nominal amplitude are 0.8, 0.9, and 1.0, respectively.

The stress-strain curve is approximated by the following stress-strain coordinates (ε,σ) = (0 in/in, 0 psi); (0.00425, 42000); (0.03, 50000); and (0.14, 65000). Strain-rate effects are considered to be negligible, and the mass density is taken to be $0.25 \times 10^{-3} (\text{lb-sec}^2)/\text{in}^4$.

The number of finite elements to be used to describe the complete ring is 36.

Let the JET 3B program be employed to calculate the transient response of the ring. For the time increment, Δt = 3 μsec is chosen, which has been shown (by numerical experimentation) to be suitable to provide an acceptably accurate solution. Three hundred computational cycles (.0009 sec) of structural response are to be computed; printout is desired at 10 cycles and every 10 cycles thereafter.

6.2.1 Input Data

The values to be punched on the data cards are as follows:

			Format
Card 1			5E15.6
R	= 0.733750 E+01		
B	= 0.100000 E+01		
H	= 0.125000 E+00		
DENS	= 0.250000 E-03		
EXANG	= 0.360000 E+03	(complete ring; 360°)	

+The ε_{cr} and the "maximum strain inspection and statement" features have been omitted.

			Format
Card 2			7I5
IK	= 36		
NOGA	= 3		
NFL	= 4		
NSFL	= 3		
MM	= 300		
M1	= 10		
M2	= 10		
Card 3			5E15.6
DELTAT	= 0.300000 E-05		
THETA	= 0.0	(first node is on the +Z axis)	
CRITS	= 0.100000 E+01		
DS	= 0.0	(strain-rate effects are neglected)	
Card 4			4E15.6
EPS(1)	= 0.425000 E-02		
SIG(1)	= 0.420000 E+05		
EPS(2)	= 0.300000 E-01		
SIG(2)	= 0.500000 E+05		
Card 4a			4E15.6
EPS(3)	= 0.140000 E+00		
SIG(3)	= 0.650000 E+05		
Card 5			4F15.10
AXG(1)	= -0.7745966692		
AXG(2)	= 0.0		
AXG(3)	= 0.774596692		
Card 6			4F15.10
AWG(1)	= 0.5555555555		
AWG(2)	= 0.8888888888		
AWG(3)	= 0.5555555555		

Format

Card 7 4F15.10

TXG(1) = -0.8611363115

TXG(2) = -0.3399810435

TXG(3) = 0.3399810435

TXG(4) = 0.8611363115

Card 8 4F15.10

TWG(1) = 0.3478548451

TWG(2) = 0.6521451548

TWG(3) = 0.6521451548

TWG(4) = 0.3478548451

Card 9 9I5

NBCOND = 0 (no prescribed displacement conditions)

Card 10

NQR = 0 (no prescribed elastic restraints)

Cards 10a and 10b are not required since NQR=0.

Card 11 4I5

NV = 0 (no initial velocity distributions)

Cards 12, 13, and 14 are not used since NV=0.

Card 15 4E15.6

TBEGIN = 0.0

TFINAL = 0.400000 E-03

AMP1FV = 0.0

AMP1FW = 0.0

} total forcing function lasts 400 μsec; forcing function has zero amplitude at t=0

Card 16 3I5

NOFT1 = 0

NOFT2 = 0

NOFT3 = 3 (three local sine-shaped force distributions)

Cards 17 and 18 are not required since NOFT1=0 and NOFT2=0, respectively.

			Format
Card 19			2I5,2E15.6
NSTF3(1)	= 1	(first element and number of elements over which the first sine-shaped force distribution is to be prescribed)	
NELF3(1)	= 3		
RTO3V(1)	= 0.0		
RTO3W(1)	= 0.800000 E+00		
Card 19a			2I5,2E15.6
NSTF3(2)	= 13		
NELF3(2)	= 3		
RTO3V(2)	= 0.0		
RTO3W(2)	= 0.900000 E+00		
Card 19b			2I5,2E15.6
NSTF3(3)	= 25		
NELF3(3)	= 3		
RTO3V(3)	= 0.0	(no circumferential force component)	
RTO3W(3)	= 0.100000 E+01		
Card 20			3E15.6
T2	= 0.200000 E-03		
AMP2FV	= 0.0		
AMP2FW	= 0.2500000 E+04		
Card 20a			3E15.6
T2	= 0.400000 E-03		
AMP2FV	= 0.0		
AMP2FW	= 0.0		

The total input data deck for this example problem should appear as follows:

```
 0.733750E+01    0.100000E+01    0.125000E+00    0.250000E-03    0.360000E+03
 36      3     4   3   300    10    10
 0.300000E-05    0.0             0.100000E+01    0.0
 0.425000E-02    0.420000E+05    0.300000E-01    0.500000E+05
 0.140000E+00    0.650000E+05
-0.7745966692    0.0             0.7745966692
 0.5555555555    0.8888888888    0.5555555555
-0.8611363115   -0.3399810435    0.3399810435    0.8611363115
 0.3478548451    0.6521451548    0.6521451548    0.3478548451
  0
  0
  0
 0.0             0.400000E-03    0.0             0.0
  0      0     3
  1      3    0.0             0.800000E+00
 13      3    0.0             0.900000E+00
 25      3    0.0             0.100000E+01
 0.200000E-03    0.0             0.250000E+04
 0.400010E-03    0.0             0.0
```

6.2.2 Solution Output for Example 2

For illustrative purposes and in the interest of conciseness, only the solution output for the following printout cycles 0, 1, 10, 20, 30, 40, 50, 100, 200, 290, and 300 is presented:

JET3B* A SPATIAL FINITE ELEMENT AND HOUBOLT TEMPORAL OPERATOR PROGRAM
USED TO CALCULATE THE NONLINEAR RESPONSES OF A UNIFORM THICKNESS CIRCULAR
COMPLETE RING WITH THE FOLLOWING PARAMETERS

MEAN RADIUS OF RING (IN.) = 0.733750E 01
WIDTH OF RING (IN.) = 0.100000E 01
THICKNESS OF RING (IN.) = 0.125000E 00
DENSITY (LB-SEC**2/IN**4) = 0.250000E-03
NUMBER OF ELEMENTS = 36
NUMBER OF SPANWISE GAUSSIAN PTS = 3
NUMBER OF DEPTHWISE GAUSSIAN PTS = 4
NUMBER OF MECHANICAL SUBLAYERS = 3

THERE IS NO PRESCRIBED DISPLACEMENT CONDITION

THERE ARE NO ELASTIC SPRING CONSTRAINTS

SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX = 1464

ELEMENT MASS MATRIX

0.148772E-04	0.183759E-07	0.902335E-07	0.268475E-05	0.513699E-05	0.423868E-06	-0.617810E-07	-0.158624E-05
0.183758E-07	0.150900E-04	0.276271E-05	-0.816229E-07	-0.423870E-06	0.492106E-05	-0.150797E-05	0.666776E-07
0.902332E-07	0.276271E-05	0.655658E-06	0.949100E-09	-0.617811E-07	0.150797E-05	-0.446945E-06	0.933088E-09
0.268475E-05	-0.816232E-07	0.949104E-09	0.625096E-06	0.158624E-05	0.666778E-07	-0.933159E-09	-0.468822E-06
0.513699E-05	-0.423869E-06	-0.517809E-07	0.158624E-05	0.148772E-04	-0.183761E-07	0.902332E-07	-0.268475E-05
0.423869E-06	0.492106E-05	0.150797E-05	0.666774E-07	-0.183763E-07	0.150900E-04	-0.276271E-05	-0.816229E-07
-0.617812E-07	-0.150797E-05	-0.446945E-06	-0.933138E-09	0.902330E-07	-0.276271E-05	0.655660E-06	-0.949064E-09
-0.158624E-05	0.666778E-07	0.933085E-09	-0.468822E-06	-0.268475E-05	-0.816231E-07	-0.949050E-09	0.625096E-06

ELEMENT STIFFNESS MATRIX

0.115171E 07	-0.999434E 05	-0.209838E 05	0.123546E 06	-0.115157E 07	-0.101568E 06	0.220265E 05	0.122890E 06
-0.999434E 05	0.180972E 05	0.784013E 04	-0.702979E 04	0.101568E 06	-0.467230E 03	0.407723E 04	-0.145306E 05
-0.209838E 05	0.784013E 04	0.548271E 04	0.106699E 03	0.220264E 05	-0.407723E 04	0.216760E 04	-0.470840E 04
0.123546E 06	-0.702977E 04	0.106695E 03	0.210933E 06	-0.122890E 06	-0.145306E 05	0.470841E 04	-0.527334E 05
-0.115157E 07	0.101568E 06	0.220264E 05	-0.122890E 06	0.115171E 07	0.999438E 05	-0.209839E 05	-0.123546E 06
-0.101568E 06	-0.467223E 03	-0.407723E 04	-0.145306E 05	0.999438E 05	0.180972E 05	-0.784014E 04	-0.702982E 04
0.220265E 05	0.407723E 04	0.216760E 04	0.470841E 04	-0.209839E 05	-0.784015E 04	0.548271E 04	-0.106684E 03
0.122890E 06	-0.145305E 05	-0.470840E 04	-0.527334E 05	-0.123546E 06	-0.702980E 04	-0.106682E 03	0.210933E 06

TIME STEP SIZE USED IN PROGRAM (SEC) = 0.300000E-05

THERE IS NO INITIAL IMPULSE

STARTING TIME OF FORCING FUNCTION (SEC) = 0.0
STOPPING TIME OF FORCING FUNCTION (SEC) = 0.400000E-03

```
J=     0       TIME (SEC.) =    0.0
TOTAL ENERGY INPUT (IN.-LB.)  =    0.0
    KINETIC ENERGY (IN.-LB.)  =    0.0
    ELASTIC ENERGY (IN.-LB.)  =    0.0
    PLASTIC WORK   (IN.-LB.)  =    0.0
```

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	0.0	0.0	0.0	0.0	0.7337E 01	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.1274E 01	0.7226E 01	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.2510E 01	0.6895E 01	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.3669E 01	0.6354E 01	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.4716E 01	0.5621E 01	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.5621E 01	0.4716E 01	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.6354E 01	0.3669E 01	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.6895E 01	0.2510E 01	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.7226E 01	0.1274E 01	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.7337E 01	0.2304E-05	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.7226E 01	-0.1274E 01	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.6895E 01	-0.2510E 01	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.6354E 01	-0.3669E 01	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.5621E 01	-0.4716E 01	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.4716E 01	-0.5621E 01	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.3669E 01	-0.6354E 01	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.2510E 01	-0.6895E 01	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.1274E 01	-0.7226E 01	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.4608E-05	-0.7337E 01	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	-0.1274E 01	-0.7226E 01	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	-0.2510E 01	-0.6895E 01	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	-0.3669E 01	-0.6354E 01	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	-0.4716E 01	-0.5621E 01	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	-0.5621E 01	-0.4716E 01	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	-0.6354E 01	-0.3669E 01	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	-0.6895E 01	-0.2510E 01	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	-0.7226E 01	-0.1274E 01	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	-0.7337E 01	-0.6910E-05	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	-0.7226E 01	0.1274E 01	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	-0.6895E 01	0.2510E 01	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	-0.6354E 01	0.3669E 01	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	-0.5621E 01	0.4716E 01	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	-0.4716E 01	0.5621E 01	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	-0.3669E 01	0.6354E 01	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	-0.2510E 01	0.6895E 01	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	-0.1274E 01	0.7226E 01	0.0	0.0	0.0	0.0

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J=      1        TIME (SEC.) =     0.300000E-05
TOTAL ENERGY INPUT (IN.-LB.)  =     0.183841E-02
     KINETIC ENERGY (IN.-LB.)  =     0.106849E-02
     ELASTIC ENERGY (IN.-LB.)  =     0.150600E-06
     PLASTIC WORK   (IN.-LB.)  =     0.769773E-03
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3542E-08	0.7281E-07	0.4638E-06	0.1482E-07	0.3542E-08	0.7337E 01	0.1110E 00	0.8464E-04	0.8653E-07	0.9311E-07
2	0.3645E-08	0.1160E-05	0.3971E-06	0.1363E-06	0.1274E 01	0.7226E 01	0.2197E 00	0.9994E-03	0.1390E-06	0.2167E-06
3	-0.3645E-08	0.1160E-05	-0.3971E-06	0.1363E-06	0.2510E 01	0.6895E 01	0.1110E 00	0.8465E-04	0.8653E-07	0.9311E-07
4	-0.3542E-08	0.7281E-07	-0.4533E-06	0.1482E-07	0.3669E 01	0.6354E 01	0.1145E-02	-0.4805E-03	0.1960E-07	-0.1774E-07
5	0.1591E-09	0.9971E-08	-0.8109E-07	-0.7782E-09	0.4716E 01	0.5621E 01	0.7909E-04	-0.7954E-04	0.3155E-08	-0.3027E-08
6	0.7373E-10	0.2135E-08	-0.1764E-07	-0.4646E-09	0.5621E 01	0.4716E 01	0.7890E-04	-0.1728E-04	0.7354E-09	-0.6077E-09
7	0.2305E-10	0.4750E-09	-0.3839E-08	-0.1650E-09	0.6354E 01	0.3669E 01	0.3415E-04	-0.3998E-05	0.1830E-09	-0.1277E-09
8	0.4712E-11	0.1289E-09	-0.6438E-09	-0.6323E-10	0.6895E 01	0.2510E 01	0.2087E-04	-0.1773E-05	0.8578E-10	-0.5199E-10
9	-0.5788E-11	0.1390E-09	0.7743E-09	-0.6759E-10	0.7226E 01	0.1274E 01	0.3767E-04	-0.4449E-05	0.2034E-09	-0.1424E-09
10	-0.2606E-10	0.5331E-09	0.4330E-08	-0.1847E-09	0.7337E 01	0.2304E-05	0.8854E-04	-0.1943E-04	0.8268E-09	-0.6834E-09
11	-0.8298E-10	0.2401E-08	0.1985E-07	-0.5224E-09	0.7226E 01	-0.1274E 01	0.8886E-04	-0.8949E-04	0.3549E-08	-0.3405E-08
12	-0.1790E-09	0.1122E-07	0.9123E-07	-0.8752E-09	0.6895E 01	-0.2510E 01	0.1288E-02	-0.5405E-03	0.2205E-07	-0.1996E-07
13	0.3984E-08	0.8191E-07	0.5217E-06	0.1667E-07	0.6354E 01	-0.3669E 01	0.1248E 00	0.9523E-04	0.9735E-07	0.1048E-06
14	0.4101E-08	0.1305E-05	0.4463E-06	0.1534E-06	0.5621E 01	-0.4716E 01	0.2471E 00	0.1124E-02	0.1564E-06	0.2437E-06
15	-0.4101E-08	0.1305E-05	-0.4468E-06	0.1534E-06	0.4716E 01	-0.5621E 01	0.1248E 00	0.9522E-04	0.9735E-07	0.1048E-06
16	-0.3984E-08	0.8191E-07	-0.5217E-06	0.1667E-07	0.3669E 01	-0.6354E 01	0.1288E-02	-0.5405E-03	0.2205E-07	-0.1996E-07
17	0.1790E-09	0.1122E-07	-0.9123E-07	-0.8755E-09	0.2510E 01	-0.6895E 01	0.8898E-04	-0.8949E-04	0.3549E-08	-0.3405E-08
18	0.8295E-10	0.2401E-08	-0.1984E-07	-0.5227E-09	0.1274E 01	-0.7226E 01	0.8875E-04	-0.1944E-04	0.8273E-09	-0.6836E-09
19	0.2594E-10	0.5343E-09	-0.4320E-08	-0.1856E-09	0.4608E-05	-0.7337E 01	0.3838E-04	-0.4495E-05	0.2057E-09	-0.1436E-09
20	0.5329E-11	0.1447E-09	-0.7272E-09	-0.7093E-10	-0.1274E 01	-0.7226E 01	0.2332E-04	-0.1981E-05	0.9587E-10	-0.5811E-10
21	-0.6405E-11	0.1548E-09	0.8577E-09	-0.7528E-10	-0.2510E 01	-0.6895E 01	0.4189E-04	-0.4946E-05	0.2261E-09	-0.1583E-09
22	-0.2895E-10	0.5923E-09	0.4811E-08	-0.2052E-09	-0.3669E 01	-0.6354E 01	0.9839E-04	-0.2159E-04	0.9187E-09	-0.7594E-09
23	-0.9220E-10	0.2668E-08	0.2205E-07	-0.5805E-09	-0.4716E 01	-0.5621E 01	0.9873E-04	-0.9943E-04	0.3943E-08	-0.3784E-08
24	-0.1989E-09	0.1246E-07	0.1014E-06	-0.9724E-09	-0.5621E 01	-0.4716E 01	0.1431E-02	-0.6006E-03	0.2450E-07	-0.2218E-07
25	0.4427E-08	0.9101E-07	0.5797E-06	0.1852E-07	-0.6354E 01	-0.3669E 01	0.1387E 00	0.1058E-03	0.1082E-06	0.1164E-06
26	0.4556E-08	0.1450E-05	0.4964E-06	0.1704E-06	-0.6895E 01	-0.2510E 01	0.2746E 00	0.1249E-02	0.1737E-06	0.2708E-06
27	-0.4556E-08	0.1450E-05	-0.4964E-06	0.1704E-06	-0.7226E 01	-0.1274E 01	0.1387E 00	0.1058E-03	0.1082E-06	0.1164E-06
28	-0.4427E-08	0.9101E-07	-0.5797E-06	0.1852E-07	-0.7337E 01	-0.6915E-05	0.1431E-02	-0.6006E-03	0.2450E-07	-0.2218E-07
29	0.1989E-09	0.1246E-07	-0.1014E-06	-0.9726E-09	-0.7226E 01	0.1274E 01	0.9878E-04	-0.9942E-04	0.3943E-08	-0.3783E-08
30	0.9222E-10	0.2668E-08	-0.2205E-07	-0.5804E-09	-0.6895E 01	0.2510E 01	0.9831E-04	-0.2159E-04	0.9184E-09	-0.7592E-09
31	0.2901E-10	0.5917E-09	-0.4815E-08	-0.2048E-09	-0.6354E 01	0.3669E 01	0.4155E-04	-0.4923E-05	0.2249E-09	-0.1577E-09
32	0.6634E-11	0.1519E-09	-0.8812E-09	-0.7361E-10	-0.5621E 01	0.4716E 01	0.2209E-04	-0.1877E-05	0.9082E-10	-0.5505E-10
33	-0.4482E-11	0.1318E-09	0.6203E-09	-0.6490E-10	-0.4716E 01	0.5621E 01	0.3450E-04	-0.4021E-05	0.1842E-09	-0.1283E-09
34	-0.2299E-10	0.4756E-09	0.3834E-08	-0.1654E-09	-0.3669E 01	0.6354E 01	0.7898E-04	-0.1729E-04	0.7357E-09	-0.6078E-09
35	-0.7372E-10	0.2135E-08	0.1754E-07	-0.4647E-09	-0.2510E 01	0.6895E 01	0.7907E-04	-0.7954E-04	0.3155E-08	-0.3027E-08
36	-0.1591E-09	0.9971E-08	0.8109E-07	-0.7781E-09	-0.1274E 01	0.7226E 01	0.1144E-02	-0.4805E-03	0.1960E-07	-0.1774E-07

J= 10 TIME (SEC.) = 0.300000E-04
TOTAL ENERGY INPUT (IN.-LB.) = 0.261563E 01
KINETIC ENERGY (IN.-LB.) = 0.223608E 01
ELASTIC ENERGY (IN.-LB.) = 0.670031E-01
PLASTIC WORK (IN.-LB.) = 0.312547E 00

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.7764E-04	0.8130E-04	0.4847E-03	0.5494E-04	0.7764E-04	0.7338E 01	0.8065E 02	0.1786E-01	0.6460E-04	0.6599E-04
2	0.5535E-04	0.1120E-02	0.4705E-03	0.7393E-04	0.1274E 01	0.7227E 01	0.1027E 03	0.1181E 01	0.3725E-04	0.1290E-03
3	-0.5535E-04	0.1120E-02	-0.4705E-03	0.7393E-04	0.2510E 01	0.6896E 01	0.8065E 02	0.1787E-01	0.6460E-04	0.6599E-04
4	-0.7764E-04	0.8129E-04	-0.4847E-03	0.5494E-04	0.3669E 01	0.6355E 01	0.4334E 02	-0.5984E 00	0.5834E-04	0.1183E-04
5	-0.2944E-04	0.2138E-05	-0.7883E-05	0.2248E-04	0.4716E 01	0.5621E 01	0.1922E 02	-0.1981E-01	0.1633E-04	0.1479E-04
6	-0.9173E-05	-0.1592E-05	0.7907E-05	0.8833E-05	0.5621E 01	0.4716E 01	0.6339E 01	0.7527E-02	0.4839E-05	0.5424E-05
7	-0.2256E-05	-0.4361E-06	0.1872E-05	0.2661E-05	0.6354E 01	0.3669E 01	0.1652E 01	0.2031E-02	0.1259E-05	0.1416E-05
8	-0.3686E-06	-0.8033E-07	0.2318E-06	0.7431E-06	0.6895E 01	0.2510E 01	0.6736E 00	0.6029E-03	0.5219E-06	0.5687E-06
9	0.4350E-06	-0.8839E-07	-0.2620E-06	0.8051E-06	0.7226E 01	0.1274E 01	0.1845E 01	0.2282E-02	0.1405E-05	0.1582E-05
10	0.2541E-05	-0.4906E-06	-0.2104E-05	0.2989E-05	0.7337E 01	-0.2376E-06	0.7130E 01	0.8469E-02	0.5443E-05	0.6101E-05
11	0.1032E-04	-0.1791E-05	-0.8894E-05	0.9937E-05	0.7226E 01	-0.1274E 01	0.2163E 02	-0.2229E-01	0.1837E-04	0.1664E-04
12	0.3312E-04	0.2405E-05	0.8871E-05	0.2529E-04	0.6895E 01	-0.2510E 01	0.4877E 02	-0.6732E 00	0.6564E-04	0.1332E-04
13	0.8736E-04	0.9147E-04	0.5454E-03	0.6182E-04	0.6354E 01	-0.3669E 01	0.9078E 02	0.2009E-01	0.7271E-04	0.7427E-04
14	0.6226E-04	0.1260E-02	0.5294E-03	0.8318E-04	0.5622E 01	-0.4717E 01	0.1156E 03	0.1329E 01	0.4192E-04	0.1452E-03
15	-0.6226E-04	0.1260E-02	-0.5293E-03	0.8318E-04	0.4717E 01	-0.5622E 01	0.9078E 02	0.2012E-01	0.7271E-04	0.7427E-04
16	-0.8736E-04	0.9146E-04	-0.5453E-03	0.6182E-04	0.3669E 01	-0.6354E 01	0.4877E 02	-0.6732E 00	0.6564E-04	0.1332E-04
17	-0.3312E-04	0.2404E-05	-0.8868E-05	0.2529E-04	0.2510E 01	-0.6895E 01	0.2163E 02	-0.2228E-01	0.1837E-04	0.1664E-04
18	-0.1032E-04	-0.1791E-05	0.8895E-05	0.9938E-05	0.1274E 01	-0.7226E 01	0.7132E 01	0.8467E-02	0.5444E-05	0.6103E-05
19	-0.2539E-05	-0.4906E-06	0.2106E-05	0.2993E-05	0.7146E-05	-0.7337E 01	0.1858E 01	0.2285E-02	0.1415E-05	0.1593E-05
20	-0.4159E-06	-0.9026E-07	0.2609E-06	0.8341E-06	-0.1274E 01	-0.7226E 01	0.7529E 00	0.6738E-03	0.5833E-06	0.6357E-06
21	0.4822E-06	-0.9831E-07	-0.2910E-06	0.8962E-06	-0.2510E 01	-0.6895E 01	0.2051E 01	0.2535E-02	0.1562E-05	0.1759E-05
22	0.2824E-05	-0.5451E-06	-0.2338E-05	0.3321E-05	-0.3669E 01	-0.6354E 01	0.7923E 01	0.9410E-02	0.6048E-05	0.6780E-05
23	0.1147E-04	-0.1990E-05	-0.9883E-05	0.1104E-04	-0.4716E 01	-0.5621E 01	0.2403E 02	-0.2476E-01	0.2042E-04	0.1849E-04
24	0.3681E-04	0.2671E-05	0.9852E-05	0.2810E-04	-0.5621E 01	-0.4716E 01	0.5420E 02	-0.7481E 00	0.7294E-04	0.1481E-04
25	0.9708E-04	0.1016E-03	0.5060E-03	0.6869E-04	-0.6355E 01	-0.3669E 01	0.1009E 03	0.2231E-01	0.8082E-04	0.8256E-04
26	0.6917E-04	0.1400E-02	0.5382E-03	0.9243E-04	-0.6896E 01	-0.2510E 01	0.1284E 03	0.1476E 01	0.4660E-04	0.1613E-03
27	-0.6917E-04	0.1400E-02	-0.5981E-03	0.9243E-04	-0.7227E 01	-0.1274E 01	0.1009E 03	0.2237E-01	0.8082E-04	0.8256E-04
28	-0.9708E-04	0.1016E-03	-0.6059E-03	0.6869E-04	-0.7338E 01	-0.1040E-03	0.5420E 02	-0.7480E 00	0.7294E-04	0.1481E-04
29	-0.3681E-04	0.2571E-05	-0.9850E-05	0.2810E-04	-0.7226E 01	0.1274E 01	0.2403E 02	-0.2476E-01	0.2042E-04	0.1849E-04
30	-0.1147E-04	-0.1990E-05	0.9883E-05	0.1104E-04	-0.6895E 01	0.2510E 01	0.7922E 01	0.9411E-02	0.6048E-05	0.6779E-05
31	-0.2825E-05	-0.5451E-06	0.2337E-05	0.3319E-05	-0.6354E 01	0.3669E 01	0.2044E 01	0.2534E-02	0.1557E-05	0.1754E-05
32	-0.4918E-06	-0.9737E-07	0.2915E-06	0.8816E-06	-0.5621E 01	0.4716E 01	0.7132E 00	0.6383E-03	0.5526E-06	0.6022E-06
33	0.3590E-06	-0.8127E-07	-0.2313E-06	0.7576E-06	-0.4716E 01	0.5621E 01	0.1659E 01	0.2033E-02	0.1264E-05	0.1422E-05
34	0.2255E-05	-0.4361E-06	-0.1873E-05	0.2663E-05	-0.3669E 01	0.6354E 01	0.6340E 01	0.7526E-02	0.4840E-05	0.5425E-05
35	0.9173E-05	-0.1592E-05	-0.7907E-05	0.8833E-05	-0.2510E 01	0.6895E 01	0.1922E 02	-0.1981E-01	0.1633E-04	0.1479E-04
36	0.2944E-04	0.2137E-05	0.7382E-05	0.2248E-04	-0.1274E 01	0.7226E 01	0.4334E 02	-0.5984E 00	0.5834E-04	0.1183E-04

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J=   20      TIME (SEC.) =    0.600000E-04
TOTAL ENERGY INPUT (IN.-LB.)  =    0.341053E 02
    KINETIC ENERGY (IN.-LB.)  =    0.294962E 02
    ELASTIC ENERGY (IN.-LB.)  =    0.227319E 01
    PLASTIC WORK   (IN.-LB.)  =    0.233591E 01
```

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.1022E-02	0.6945E-03	0.3974E-02	0.3014E-03	0.1022E-02	0.7338E 01	0.3876E 03	-0.6377E 00	0.3385E-03	0.2890E-03
2	0.6081E-03	0.8481E-02	0.4482E-02	0.3111E-03	0.1276E 01	0.7234E 01	0.4356E 03	0.1125E 02	-0.8435E-04	0.7896E-03
3	-0.6082E-03	0.8481E-02	-0.4481E-02	0.3111E-03	0.2512E 01	0.6903E 01	0.3875E 03	-0.6374E 00	0.3385E-03	0.2889E-03
4	-0.1022E-02	0.6944E-03	-0.3974E-02	0.3013E-03	0.3668E 01	0.6356E 01	0.2966E 03	-0.5702E 01	0.4616E-03	0.1852E-04
5	-0.6614E-03	-0.2705E-03	0.5712E-03	0.1989E-03	0.4716E 01	0.5621E 01	0.2253E 03	0.6118E 00	0.1586E-03	0.2062E-03
6	-0.4040E-03	-0.1198E-03	0.8372E-04	0.1576E-03	0.5620E 01	0.4717E 01	0.1699E 03	0.4929E-01	0.1356E-03	0.1394E-03
7	-0.2116E-03	-0.5832E-04	0.4433E-04	0.1220E-03	0.6354E 01	0.3669E 01	0.1378E 03	0.3394E-01	0.1103E-03	0.1129E-03
8	-0.5947E-04	-0.3804E-04	0.1715E-04	0.1057E-03	0.6895E 01	0.2510E 01	0.1298E 03	0.5150E-01	0.1031E-03	0.1071E-03
9	0.8249E-04	-0.3995E-04	-0.2401E-04	0.1093E-03	0.7226E 01	0.1274E 01	0.1467E 03	0.3466E-01	0.1174E-03	0.1201E-03
10	0.2445E-03	-0.6461E-04	-0.5174E-04	0.1326E-03	0.7337E 01	-0.2422E-03	0.1875E 03	0.5394E-01	0.1497E-03	0.1539E-03
11	0.4570E-03	-0.1345E-03	-0.9484E-04	0.1757E-03	0.7226E 01	-0.1275E 01	0.2525E 03	0.6880E 00	0.1776E-03	0.2311E-03
12	0.7456E-03	-0.3045E-03	-0.5430E-03	0.2235E-03	0.6894E 01	-0.2510E 01	0.3340E 03	-0.6415E 01	0.5196E-03	0.2108E-04
13	0.1151E-02	0.7820E-03	0.4471E-02	0.3388E-03	0.6355E 01	-0.3670E 01	0.4372E 03	-0.7168E 00	0.3818E-03	0.3261E-03
14	0.6838E-03	0.9539E-02	0.5041E-02	0.3497E-03	0.5628E 01	-0.4723E 01	0.4911E 03	0.1265E 02	-0.9397E-04	0.8891E-03
15	-0.6837E-03	0.9539E-02	-0.5040E-02	0.3497E-03	0.4723E 01	-0.5628E 01	0.4373E 03	-0.7164E 00	0.3819E-03	0.3262E-03
16	-0.1151E-02	0.7819E-03	-0.4470E-02	0.3389E-03	0.3670E 01	-0.6355E 01	0.3344E 03	-0.6414E 01	0.5199E-03	0.2144E-04
17	-0.7449E-03	-0.3046E-03	0.5428E-03	0.2241E-03	0.2510E 01	-0.6894E 01	0.2538E 03	0.6885E 00	0.1787E-03	0.2322E-03
18	-0.4550E-03	-0.1348E-03	0.9426E-04	0.1774E-03	0.1275E 01	-0.7226E 01	0.1911E 03	0.5535E-01	0.1525E-03	0.1568E-03
19	-0.2386E-03	-0.6557E-04	0.5002E-04	0.1370E-03	0.2432E-03	-0.7337E 01	0.1547E 03	0.3802E-01	0.1237E-03	0.1267E-03
20	-0.6785E-04	-0.4264E-04	0.1959E-04	0.1184E-03	-0.1274E 01	-0.7226E 01	0.1451E 03	0.5759E-01	0.1152E-03	0.1197E-03
21	0.9089E-04	-0.4455E-04	-0.2645E-04	0.1220E-03	-0.2510E 01	-0.6895E 01	0.1635E 03	0.3874E-01	0.1309E-03	0.1339E-03
22	0.2715E-03	-0.7187E-04	-0.5745E-04	0.1477E-03	-0.3669E 01	-0.6354E 01	0.2088E 03	0.5997E-01	0.1667E-03	0.1714E-03
23	0.5081E-03	-0.1495E-03	-0.1054E-03	0.1955E-03	-0.4717E 01	-0.5620E 01	0.2810E 03	0.7648E 00	0.1978E-03	0.2572E-03
24	0.8292E-03	-0.3387E-03	-0.7147E-03	0.2488E-03	-0.5621E 01	-0.4716E 01	0.3719E 03	-0.7128E 01	0.5781E-03	0.2413E-04
25	0.1280E-02	0.8696E-03	0.4967E-02	0.3764E-03	-0.6356E 01	-0.3668E 01	0.4874E 03	-0.7958E 00	0.4255E-03	0.3636E-03
26	0.7592E-03	0.1060E-01	0.5600E-02	0.3882E-03	-0.6905E 01	-0.2512E 01	0.5468E 03	0.1405E 02	-0.1034E-03	0.9887E-03
27	-0.7592E-03	0.1060E-01	-0.5599E-02	0.3882E-03	-0.7236E 01	-0.1277E 01	0.4873E 03	-0.7952E 00	0.4254E-03	0.3636E-03
28	-0.1280E-02	0.8695E-03	-0.4967E-02	0.3763E-03	-0.7338E 01	-0.1287E-02	0.3717E 03	-0.7127E 01	0.5779E-03	0.2398E-04
29	-0.8295E-03	-0.3386E-03	0.7147E-03	0.2485E-03	-0.7226E 01	0.1273E 01	0.2804E 03	0.7645E 00	0.1973E-03	0.2567E-03
30	-0.5091E-03	-0.1494E-03	0.1057E-03	0.1946E-03	-0.6895E 01	0.2509E 01	0.2070E 03	0.5928E-01	0.1653E-03	0.1699E-03
31	-0.2745E-03	-0.7139E-04	0.5830E-04	0.1455E-03	-0.6355E 01	0.3668E 01	0.1595E 03	0.3706E-01	0.1277E-03	0.1306E-03
32	-0.9820E-04	-0.4320E-04	0.2865E-04	0.1174E-03	-0.5621E 01	0.4716E 01	0.1374E 03	0.5454E-01	0.1091E-03	0.1134E-03
33	0.5215E-04	-0.3939E-04	-0.1495E-04	0.1103E-03	-0.4716E 01	0.5621E 01	0.1418E 03	0.3562E-01	0.1134E-03	0.1162E-03
34	0.2086E-03	-0.5880E-04	-0.4347E-04	0.1242E-03	-0.3669E 01	0.6355E 01	0.1716E 03	0.4997E-01	0.1370E-03	0.1409E-03
35	0.4029E-03	-0.1199E-03	-0.8341E-04	0.1585E-03	-0.2509E 01	0.6895E 01	0.2259E 03	0.6122E 00	0.1591E-03	0.2067E-03
36	0.6611E-03	-0.2706E-03	-0.5712E-03	0.1992E-03	-0.1273E 01	0.7226E 01	0.2968E 03	-0.5702E 01	0.4618E-03	0.1867E-04

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J=   30       TIME (SEC.) =    0.900000E-04
TOTAL ENERGY INPUT (IN.-LB.)  =     0.154399E 03
    KINETIC ENERGY (IN.-LB.)  =     0.128093E 03
    ELASTIC ENERGY (IN.-LB.)  =     0.185107E 02
    PLASTIC WORK   (IN.-LB.)  =     0.779515E 01
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3965E-02	0.2350E-02	0.1312E-01	0.7118E-03	0.3965E-02	0.7340E 01	0.9348E 03	-0.2772E 01	0.8645E-03	0.6490E-03
2	0.2175E-02	0.2706E-01	0.1532E-01	0.6188E-03	0.1281E 01	0.7252E 01	0.9886E 03	0.3844E 02	-0.6934E-03	0.2294E-02
3	-0.2183E-02	0.2706E-01	-0.1532E-01	0.6171E-03	0.2517E 01	0.6921E 01	0.9305E 03	-0.2772E 01	0.8610E-03	0.6455E-03
4	-0.3978E-02	0.2352E-02	-0.1311E-01	0.7065E-03	0.3666E 01	0.6358E 01	0.8013E 03	-0.1920E 02	0.1395E-02	-0.9748E-04
5	-0.2875E-02	-0.2192E-02	0.2195E-02	0.5876E-03	0.4713E 01	0.5621E 01	0.7155E 03	0.2473E 01	0.4831E-03	0.6753E-03
6	-0.1895E-02	-0.1003E-02	0.2242E-03	0.5461E-03	0.5619E 01	0.4717E 01	0.6551E 03	-0.1994E 00	0.5380E-03	0.5225E-03
7	-0.1048E-02	-0.8591E-03	0.3833E-03	0.5135E-03	0.6353E 01	0.3669E 01	0.6242E 03	0.3898E 00	0.4902E-03	0.5205E-03
8	-0.2651E-03	-0.7350E-03	0.7246E-04	0.5018E-03	0.6894E 01	0.2510E 01	0.6207E 03	0.2625E 00	0.4923E-03	0.5127E-03
9	0.5081E-03	-0.7566E-03	-0.1359E-03	0.5098E-03	0.7225E 01	0.1274E 01	0.6439E 03	0.4180E 00	0.5050E-03	0.5375E-03
10	0.1319E-02	-0.9252E-03	-0.4701E-03	0.5373E-03	0.7337E 01	-0.1317E-02	0.6953E 03	-0.2400E 00	0.5722E-03	0.5535E-03
11	0.2223E-02	-0.1107E-02	-0.2786E-03	0.5866E-03	0.7225E 01	-0.1276E 01	0.7780E 03	0.2762E 01	0.5225E-03	0.7371E-03
12	0.3295E-02	-0.2458E-02	-0.2479E-02	0.6437E-03	0.6892E 01	-0.2512E 01	0.8872E 03	-0.2160E 02	0.1557E-02	-0.1211E-03
13	0.4516E-02	0.2561E-02	0.1474E-01	0.7776E-03	0.6355E 01	-0.3674E 01	0.1043E 04	-0.3105E 01	0.9648E-03	0.7235E-03
14	0.2461E-02	0.3042E-01	0.1721E-01	0.6771E-03	0.5643E 01	-0.4738E 01	0.1111E 04	0.4319E 02	-0.7791E-03	0.2577E-02
15	-0.2445E-02	0.3042E-01	-0.1721E-01	0.6835E-03	0.4738E 01	-0.5643E 01	0.1052E 04	-0.3102E 01	0.9718E-03	0.7307E-03
16	-0.4490E-02	0.2656E-02	-0.1475E-01	0.7883E-03	0.3674E 01	-0.6355E 01	0.9055E 03	-0.2159E 02	0.1572E-02	-0.1059E-03
17	-0.3249E-02	-0.2469E-02	0.2466E-02	0.6628E-03	0.2512E 01	-0.6892E 01	0.8073E 03	0.2773E 01	0.5458E-03	0.7613E-03
18	-0.2144E-02	-0.1129E-02	0.2567E-03	0.6153E-03	0.1276E 01	-0.7225E 01	0.7374E 03	-0.2228E 00	0.6056E-03	0.5883E-03
19	-0.1191E-02	-0.9555E-03	0.4345E-03	0.5773E-03	0.1196E-02	-0.7337E 01	0.7011E 03	0.4384E 00	0.5505E-03	0.5846E-03
20	-0.3113E-03	-0.8237E-03	0.8491E-04	0.5631E-03	-0.1274E 01	-0.7225E 01	0.6959E 03	0.2939E 00	0.5519E-03	0.5748E-03
21	0.5552E-03	-0.8454E-03	-0.1495E-03	0.5712E-03	-0.2510E 01	-0.6894E 01	0.7211E 03	0.4667E 00	0.5656E-03	0.6019E-03
22	0.1463E-02	-0.1033E-02	-0.5216E-03	0.6015E-03	-0.3669E 01	-0.6353E 01	0.7782E 03	-0.2629E 00	0.6402E-03	0.6198E-03
23	0.2474E-02	-0.1234E-02	-0.3119E-03	0.6564E-03	-0.4718E 01	-0.5618E 01	0.8709E 03	0.3059E 01	0.5861E-03	0.8239E-03
24	0.3672E-02	-0.2737E-02	-0.2750E-02	0.7198E-03	-0.5621E 01	-0.4712E 01	0.9929E 03	-0.2398E 02	0.1736E-02	-0.1281E-03
25	0.5033E-02	0.2965E-02	0.1637E-01	0.8587E-03	-0.6360E 01	-0.3666E 01	0.1166E 04	-0.3432E 01	0.1077E-02	0.8105E-03
26	0.2722E-02	0.3378E-01	0.1910E-01	0.7387E-03	-0.6928E 01	-0.2519E 01	0.1234E 04	0.4792E 02	-0.8629E-03	0.2861E-02
27	-0.2730E-02	0.3378E-01	-0.1909E-01	0.7371E-03	-0.7259E 01	-0.1283E 01	0.1162E 04	-0.3431E 01	0.1074E-02	0.8071E-03
28	-0.5045E-02	0.2968E-02	-0.1637E-01	0.8533E-03	-0.7340E 01	-0.5052E-02	0.9837E 03	-0.2399E 02	0.1728E-02	-0.1357E-03
29	-0.3695E-02	-0.2731E-02	0.2756E-02	0.7102E-03	-0.7224E 01	0.1270E 01	0.8562E 03	0.3054E 01	0.5745E-03	0.8118E-03
30	-0.2513E-02	-0.1223E-02	0.3228E-03	0.6421E-03	-0.6895E 01	0.2507E 01	0.7572E 03	-0.2713E 00	0.6235E-03	0.6024E-03
31	-0.1527E-02	-0.1013E-02	0.5393E-03	0.5816E-03	-0.6354E 01	0.3667E 01	0.6925E 03	0.4565E 00	0.5429E-03	0.5783E-03
32	-0.6534E-03	-0.8119E-03	0.1754E-03	0.5446E-03	-0.5621E 01	0.4715E 01	0.6584E 03	0.2782E 00	0.5222E-03	0.5438E-03
33	0.1666E-03	-0.7686E-03	-0.4652E-04	0.5285E-03	-0.4716E 01	0.5620E 01	0.6529E 03	0.4001E 00	0.5130E-03	0.5441E-03
34	0.9844E-03	-0.8788E-03	-0.3555E-03	0.5335E-03	-0.3667E 01	0.6354E 01	0.6762E 03	-0.1909E 00	0.5548E-03	0.5400E-03
35	0.1855E-02	-0.1013E-02	-0.2132E-03	0.5605E-03	-0.2507E 01	0.6895E 01	0.7301E 03	0.2480E 01	0.4947E-03	0.6874E-03
36	0.2852E-02	-0.2197E-02	-0.2189E-02	0.5972E-03	-0.1271E 01	0.7224E 01	0.8104E 03	-0.1920E 02	0.1402E-02	-0.8997E-04

J= 40 TIME (SEC.) = 0.120000E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.440884E 03
KINETIC ENERGY (IN.-LB.) = 0.346104E 03
ELASTIC ENERGY (IN.-LB.) = 0.751859E 02
PLASTIC WORK (IN.-LB.) = 0.195941E 02

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.9787E-02	0.5519E-02	0.3088E-01	0.1169E-02	0.9787E-02	0.7343E 01	0.1881E 04	-0.3367E 01	0.1654E-02	0.1392E-02
2	0.4948E-02	0.5997E-01	0.3353E-01	0.8996E-03	0.1289E 01	0.7284E 01	0.1908E 04	0.8264E 02	-0.1701E-02	0.4835E-02
3	-0.5072E-02	0.5998E-01	-0.3348E-01	0.8960E-03	0.2525E 01	0.6953E 01	0.1869E 04	-0.3349E 01	0.1643E-02	0.1383E-02
4	-0.9927E-02	0.5549E-02	-0.3085E-01	0.1155E-02	0.3663E 01	0.6364E 01	0.1656E 04	-0.4357E 02	0.3034E-02	-0.3525E-03
5	-0.7411E-02	-0.8216E-02	0.3897E-02	0.1232E-02	0.4705E 01	0.5619E 01	0.1496E 04	0.2927E 01	0.1097E-02	0.1325E-02
6	-0.4805E-02	-0.4528E-02	0.1555E-02	0.1128E-02	0.5614E 01	0.4717E 01	0.1373E 04	0.1104E 01	0.1068E-02	0.1154E-02
7	-0.2627E-02	-0.4287E-02	0.6858E-03	0.1081E-02	0.6349E 01	0.3669E 01	0.1306E 04	0.7939E 00	0.1027E-02	0.1088E-02
8	-0.5614E-03	-0.3904E-02	0.5271E-04	0.1047E-02	0.6891E 01	0.2509E 01	0.1297E 04	0.4447E 00	0.1033E-02	0.1068E-02
9	0.1472E-02	-0.3979E-02	-0.3017E-03	0.1061E-02	0.7222E 01	0.1272E 01	0.1340E 04	0.8061E 00	0.1053E-02	0.1116E-02
10	0.3600E-02	-0.4540E-02	-0.9445E-03	0.1122E-02	0.7333E 01	-0.3598E-02	0.1441E 04	0.1209E 01	0.1120E-02	0.1214E-02
11	0.5903E-02	-0.4914E-02	-0.1908E-02	0.1195E-02	0.7220E 01	-0.1279E 01	0.1602E 04	0.3162E 01	0.1174E-02	0.1420E-02
12	0.8724E-02	-0.9127E-02	-0.4427E-02	0.1326E-02	0.6883E 01	-0.2515E 01	0.1799E 04	-0.4896E 02	0.3359E-02	-0.4460E-03
13	0.1145E-01	0.6388E-02	0.3452E-01	0.1230E-02	0.6354E 01	-0.3682E 01	0.2034E 04	-0.3690E 01	0.1790E-02	0.1503E-02
14	0.5770E-02	0.6740E-01	0.3752E-01	0.8881E-03	0.5669E 01	-0.4764E 01	0.2050E 04	0.8668E 02	-0.1889E-02	0.5437E-02
15	-0.5522E-02	0.6737E-01	-0.3759E-01	0.8964E-03	0.4764E 01	-0.5669E 01	0.2059E 04	-0.3701E 01	0.1810E-02	0.1523E-02
16	-0.1117E-01	0.6325E-02	-0.3458E-01	0.1228E-02	0.3682E 01	-0.6354E 01	0.1849E 04	-0.4891E 02	0.3397E-02	-0.4037E-03
17	-0.8380E-02	-0.9245E-02	0.4321E-02	0.1377E-02	0.2514E 01	-0.6883E 01	0.1677E 04	0.3179E 01	0.1234E-02	0.1481E-02
18	-0.5454E-02	-0.5105E-02	0.1789E-02	0.1266E-02	0.1279E 01	-0.7220E 01	0.1543E 04	0.1264E 01	0.1200E-02	0.1298E-02
19	-0.3005E-02	-0.4820E-02	0.7813E-03	0.1216E-02	0.3009E-02	-0.7333E 01	0.1470E 04	0.8855E 00	0.1155E-02	0.1224E-02
20	-0.6823E-03	-0.4381E-02	0.7525E-04	0.1178E-02	-0.1273E 01	-0.7222E 01	0.1459E 04	0.5047E 00	0.1162E-02	0.1201E-02
21	0.1602E-02	-0.4457E-02	-0.3270E-03	0.1192E-02	-0.2510E 01	-0.6890E 01	0.1504E 04	0.8968E 00	0.1183E-02	0.1253E-02
22	0.3989E-02	-0.5076E-02	-0.1042E-02	0.1258E-02	-0.3670E 01	-0.6348E 01	0.1613E 04	0.1375E 01	0.1253E-02	0.1359E-02
23	0.6566E-02	-0.5497E-02	-0.2137E-02	0.1334E-02	-0.4718E 01	-0.5612E 01	0.1786E 04	0.3380E 01	0.1315E-02	0.1577E-02
24	0.9711E-02	-0.1016E-01	-0.4830E-02	0.1471E-02	-0.5619E 01	-0.4702E 01	0.1988E 04	-0.5432E 02	0.3720E-02	-0.5014E-03
25	0.1270E-01	0.7183E-02	0.3849E-01	0.1252E-02	-0.6367E 01	-0.3661E 01	0.2193E 04	-0.4112E 01	0.1935E-02	0.1616E-02
26	0.6186E-02	0.7474E-01	0.4171E-01	0.9006E-03	-0.6967E 01	-0.2529E 01	0.2264E 04	0.9005E 02	-0.2015E-02	0.6119E-02
27	-0.6310E-02	0.7476E-01	-0.4155E-01	0.8961E-03	-0.7299E 01	-0.1293E 01	0.2182E 04	-0.4095E 01	0.1925E-02	0.1607E-02
28	-0.1284E-01	0.7211E-02	-0.3845E-01	0.1237E-02	-0.7345E 01	-0.1285E-01	0.1964E 04	-0.5434E 02	0.3701E-02	-0.5222E-03
29	-0.9882E-02	-0.1010E-01	0.4885E-02	0.1446E-02	-0.7218E 01	0.1263E 01	0.1749E 04	0.3377E 01	0.1285E-02	0.1547E-02
30	-0.6789E-02	-0.5402E-02	0.2195E-02	0.1299E-02	-0.6892E 01	0.2501E 01	0.1563E 04	0.1346E 01	0.1213E-02	0.1317E-02
31	-0.4285E-02	-0.4936E-02	0.1123E-02	0.1212E-02	-0.6352E 01	0.3663E 01	0.1440E 04	0.8576E 00	0.1132E-02	0.1199E-02
32	-0.1995E-02	-0.4257E-02	0.4391E-03	0.1134E-02	-0.5619E 01	0.4712E 01	0.1379E 04	0.4751E 00	0.1098E-02	0.1135E-02
33	0.1648E-03	-0.4106E-02	0.6034E-04	0.1107E-02	-0.4714E 01	0.5618E 01	0.1372E 04	0.8340E 00	0.1078E-02	0.1143E-02
34	0.2328E-02	-0.4428E-02	-0.6047E-03	0.1129E-02	-0.3665E 01	0.6352E 01	0.1424E 04	0.1132E 01	0.1109E-02	0.1197E-02
35	0.4580E-02	-0.4623E-02	-0.1506E-02	0.1164E-02	-0.2504E 01	0.6892E 01	0.1534E 04	0.2934E 01	0.1127E-02	0.1355E-02
36	0.7238E-02	-0.8276E-02	-0.3844E-02	0.1257E-02	-0.1266E 01	0.7219E 01	0.1681E 04	-0.4354E 02	0.3053E-02	-0.3311E-03

```
J=    50        TIME (SEC.) =     0.150000E-03
TOTAL ENERGY INPUT (IN.-LB.)  =     0.965792E 03
    KINETIC ENERGY (IN.-LB.)  =     0.733454E 03
    ELASTIC ENERGY (IN.-LB.)  =     0.161446E 03
    PLASTIC WORK    (IN.-LB.) =     0.708926E 02
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.1956E-01	0.1104E-01	0.6036E-01	0.1027E-02	0.1956E-01	0.7349E 01	0.2733E 04	0.6017E 00	0.2189E-02	0.2236E-02
2	0.8758E-02	0.1073E 00	0.5979E-01	0.7200E-03	0.1301E 01	0.7330E 01	0.2719E 04	0.9918E 02	-0.2698E-02	0.8958E-02
3	-0.9269E-02	0.1074E 00	-0.5963E-01	0.7182E-03	0.2538E 01	0.6999E 01	0.2715E 04	0.6442E 00	0.2173E-02	0.2223E-02
4	-0.2010E-01	0.1117E-01	-0.5025E-01	0.1010E-02	0.3657E 01	0.6374E 01	0.2544E 04	-0.7329E 02	0.5253E-02	-0.9417E-03
5	-0.1572E-01	-0.2140E-01	0.3321E-02	0.1911E-02	0.4691E 01	0.5615E 01	0.2379E 04	-0.2458E 01	0.2021E-02	0.1830E-02
6	-0.1017E-01	-0.1415E-01	0.5283E-02	0.1784E-02	0.5603E 01	0.4715E 01	0.2261E 04	0.5737E 01	0.1607E-02	0.2053E-02
7	-0.5563E-02	-0.1282E-01	0.7125E-03	0.1806E-02	0.6341E 01	0.3667E 01	0.2212E 04	0.2859E-01	0.1790E-02	0.1792E-02
8	-0.1061E-02	-0.1234E-01	0.5399E-03	0.1784E-02	0.6883E 01	0.2506E 01	0.2205E 04	0.2556E 01	0.1686E-02	0.1884E-02
9	0.3370E-02	-0.1254E-01	-0.1348E-02	0.1790E-02	0.7214E 01	0.1269E 01	0.2233E 04	-0.8563E-01	0.1811E-02	0.1804E-02
10	0.7965E-02	-0.1342E-01	-0.1279E-02	0.1832E-02	0.7324E 01	-0.7962E-02	0.2315E 04	0.6486E 01	0.1622E-02	0.2126E-02
11	0.1276E-01	-0.1522E-01	-0.6447E-02	0.1832E-02	0.7209E 01	-0.1284E 01	0.2494E 04	-0.3424E 01	0.2152E-02	0.1886E-02
12	0.1869E-01	-0.2341E-01	-0.3714E-02	0.1993E-02	0.6867E 01	-0.2519E 01	0.2722E 04	-0.7650E 02	0.5855E-02	-0.1069E-02
13	0.2336E-01	0.1315E-01	0.6735E-01	0.8556E-03	0.6354E 01	-0.3696E 01	0.2808E 04	0.5074E-01	0.2271E-02	0.2275E-02
14	0.1053E-01	0.1208E 00	0.6717E-01	0.6108E-03	0.5707E 01	-0.4802E 01	0.2979E 04	0.9400E 02	-0.2669E-02	0.1047E-01
15	-0.9512E-02	0.1207E 00	-0.6745E-01	0.6150E-03	0.4801E 01	-0.5707E 01	0.2842E 04	-0.2879E-01	0.2302E-02	0.2300E-02
16	-0.2229E-01	0.1289E-01	-0.6757E-01	0.9016E-03	0.3695E 01	-0.6354E 01	0.2793E 04	-0.7561E 02	0.5914E-02	-0.9925E-03
17	-0.1749E-01	-0.2384E-01	0.3325E-02	0.2065E-02	0.2518E 01	-0.6867E 01	0.2599E 04	-0.3440E 01	0.2237E-02	0.1970E-02
18	-0.1135E-01	-0.1593E-01	0.5071E-02	0.1932E-02	0.1283E 01	-0.7208E 01	0.2455E 04	0.6597E 01	0.1731E-02	0.2244E-02
19	-0.6259E-02	-0.1439E-01	0.8146E-03	0.1960E-02	0.6264E-02	-0.7323E 01	0.2406E 04	0.1289E-01	0.1947E-02	0.1948E-02
20	-0.1287E-02	-0.1385E-01	0.8045E-03	0.1942E-02	-0.1270E 01	-0.7213E 01	0.2400E 04	0.2836E 01	0.1833E-02	0.2053E-02
21	0.3606E-02	-0.1405E-01	-0.1455E-02	0.1945E-02	-0.2508E 01	-0.6881E 01	0.2423E 04	-0.1182E 00	0.1966E-02	0.1957E-02
22	0.8669E-02	-0.1500E-01	-0.1362E-02	0.1988E-02	-0.3669E 01	-0.6337E 01	0.2517E 04	0.7389E 01	0.1751E-02	0.2325E-02
23	0.1395E-01	-0.1702E-01	-0.7250E-02	0.1985E-02	-0.4716E 01	-0.5599E 01	0.2721E 04	-0.4503E 01	0.2377E-02	0.2027E-02
24	0.2048E-01	-0.2580E-01	-0.3555E-02	0.2131E-02	-0.5614E 01	-0.4684E 01	0.2906E 04	-0.7941E 02	0.6441E-02	-0.1177E-02
25	0.2552E-01	0.1486E-01	0.7454E-01	0.8663E-03	-0.6380E 01	-0.3654E 01	0.2969E 04	-0.8116E 00	0.2435E-02	0.2372E-02
26	0.1073E-01	0.1341E 00	0.7500E-01	0.5595E-03	-0.7025E 01	-0.2545E 01	0.3286E 04	0.8740E 02	-0.2568E-02	0.1206E-01
27	-0.1124E-01	0.1342E 00	-0.7484E-01	0.5604E-03	-0.7356E 01	-0.1309E 01	0.2953E 04	-0.7651E 00	0.2420E-02	0.2361E-02
28	-0.2605E-01	0.1498E-01	-0.7441E-01	0.8363E-03	-0.7352E 01	-0.2606E-01	0.2870E 04	-0.7985E 02	0.6410E-02	-0.1215E-02
29	-0.2108E-01	-0.2558E-01	0.3851E-02	0.2098E-02	-0.7204E 01	0.1249E 01	0.2669E 04	-0.4492E 01	0.2335E-02	0.1986E-02
30	-0.1465E-01	-0.1667E-01	0.7437E-02	0.1935E-02	-0.6884E 01	0.2490E 01	0.2448E 04	0.7334E 01	0.1697E-02	0.2267E-02
31	-0.9516E-02	-0.1452E-01	0.1594E-02	0.1924E-02	-0.6347E 01	0.3653E 01	0.2335E 04	-0.1667E 00	0.1897E-02	0.1884E-02
32	-0.4643E-02	-0.1341E-01	0.1727E-02	0.1868E-02	-0.5614E 01	0.4704E 01	0.2299E 04	0.2692E 01	0.1756E-02	0.1965E-02
33	0.1587E-04	-0.1300E-01	-0.4193E-03	0.1857E-02	-0.4708E 01	0.5611E 01	0.2298E 04	0.7500E-01	0.1857E-02	0.1863E-02
34	0.4705E-02	-0.1330E-01	-0.4789E-03	0.1869E-02	-0.3658E 01	0.6345E 01	0.2332E 04	0.5792E 01	0.1662E-02	0.2113E-02
35	0.9459E-02	-0.1451E-01	-0.5094E-02	0.1835E-02	-0.2496E 01	0.6885E 01	0.2432E 04	-0.2467E 01	0.2064E-02	0.1873E-02
36	0.1512E-01	-0.2163E-01	-0.3124E-02	0.1944E-02	-0.1256E 01	0.7207E 01	0.2580E 04	-0.7284E 02	0.5285E-02	-0.9030E-03

J= 100 TIME (SEC.) = 0.300000E-03

TOTAL ENERGY INPUT (IN.-LB.) = 0.539263E 04

KINETIC ENERGY (IN.-LB.) = 0.436344E 04

ELASTIC ENERGY (IN.-LB.) = 0.275030E 03

PLASTIC WORK (IN.-LB.) = 0.754161E 03

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.1303E 00	0.7667E-01	0.2840E 00	-0.3352E-01	0.1303E 00	0.7414E 01	0.2628E 04	0.7351E 02	-0.1199E-02	0.6315E-02
2	0.3687E-01	0.4520E 00	0.2057E 00	-0.1091E-01	0.1389E 01	0.7665E 01	0.2351E 04	0.1166E 03	-0.8636E-02	0.3142E-01
3	-0.4483E-01	0.4528E 00	-0.2033E 00	-0.1076E-01	0.2622E 01	0.7336E 01	0.2489E 04	0.7256E 02	-0.1301E-02	0.6222E-02
4	-0.1379E 00	0.7910E-01	-0.2622E 00	-0.3338E-01	0.3589E 01	0.6492E 01	0.2775E 04	-0.5570E 02	0.1524E-01	-0.2582E-02
5	-0.1422E 00	-0.1950E 00	-0.9913E-01	0.1120E-02	0.4482E 01	0.5563E 01	0.2916E 04	-0.8541E 02	0.8970E-02	-0.2022E-02
6	-0.9723E-01	-0.2562E 00	0.1372E-01	0.2123E-02	0.5362E 01	0.4626E 01	0.3051E 04	-0.1407E 02	0.3016E-02	0.1923E-02
7	-0.5092E-01	-0.2393E 00	0.2494E-01	0.2099E-02	0.6122E 01	0.3593E 01	0.3092E 04	0.2063E 02	0.1701E-02	0.3304E-02
8	-0.7878E-02	-0.2221E 00	0.8503E-02	0.2445E-02	0.6684E 01	0.2441E 01	0.3109E 04	0.3141E 02	0.1296E-02	0.3737E-02
9	0.3392E-01	-0.2247E 00	-0.1653E-01	0.2342E-02	0.7011E 01	0.1202E 01	0.3090E 04	0.1938E 02	0.1749E-02	0.3255E-02
10	0.7769E-01	-0.2473E 00	-0.3197E-01	0.1906E-02	0.7090E 01	-0.7769E-01	0.3041E 04	-0.1663E 02	0.3108E-02	0.1816E-02
11	0.1255E 00	-0.2675E 00	-0.1872E-01	0.2137E-02	0.6941E 01	-0.1351E 01	0.2972E 04	-0.8191E 02	0.1030E-01	-0.2174E-02
12	0.1726E 00	-0.1990E 00	0.1093E 00	0.1287E-02	0.6649E 01	-0.2604E 01	0.2890E 04	-0.4250E 02	0.1778E-01	-0.1722E-02
13	0.1639E 00	0.1034E 00	0.3096E 00	-0.3960E-01	0.6362E 01	-0.3862E 01	0.2642E 04	0.7305E 02	-0.1416E-02	0.7210E-02
14	0.5372E-01	0.5158E 00	0.2196E 00	-0.1088E-01	0.5981E 01	-0.5089E 01	0.2573E 04	0.1231E 03	-0.8158E-02	0.3522E-01
15	-0.3791E-01	0.5141E 00	-0.2239E 00	-0.1164E-01	0.5076E 01	-0.5990E 01	0.2836E 04	0.7078E 02	-0.1184E-02	0.7460E-02
16	-0.1488E 00	0.9882E-01	-0.3141E 00	-0.3996E-01	0.3847E 01	-0.6366E 01	0.3225E 04	-0.3543E 02	0.1876E-01	-0.8083E-03
17	-0.1563E 00	-0.2047E 00	-0.1131E 00	0.1379E-02	0.2586E 01	-0.6649E 01	0.3366E 04	-0.7487E 02	0.1067E-01	-0.1685E-02
18	-0.1075E 00	-0.2770E 00	0.1374E-01	0.2688E-02	0.1332E 01	-0.6935E 01	0.3408E 04	-0.1383E 02	0.3296E-02	0.2221E-02
19	-0.5704E-01	-0.2611E 00	0.2476E-01	0.2502E-02	0.5704E-01	-0.7076E 01	0.3516E 04	0.1624E 02	0.2203E-02	0.3507E-02
20	-0.9826E-02	-0.2424E 00	0.1133E-01	0.2787E-02	-0.1222E 01	-0.6989E 01	0.3580E 04	0.3786E 02	0.1420E-02	0.4386E-02
21	0.3592E-01	-0.2453E 00	-0.1904E-01	0.2658E-02	-0.2459E 01	-0.6652E 01	0.3493E 04	0.1428E 02	0.2203E-02	0.3541E-02
22	0.8384E-01	-0.2588E 00	-0.3276E-01	0.2249E-02	-0.3607E 01	-0.6080E 01	0.3398E 04	-0.1807E 02	0.3453E-02	0.2049E-02
23	0.1358E 00	-0.2879E 00	-0.1835E-01	0.2709E-02	-0.4635E 01	-0.5313E 01	0.3392E 04	-0.6809E 02	0.1252E-01	-0.1322E-02
24	0.1871E 00	-0.2077E 00	0.1238E 00	0.2142E-02	-0.5582E 01	-0.4440E 01	0.3255E 04	-0.1939E 02	0.2125E-01	0.1234E-03
25	0.1748E 00	0.1242E 00	0.3409E 00	-0.4663E-01	-0.6549E 01	-0.3579E 01	0.2920E 04	0.6772E 02	-0.1265E-02	0.8449E-02
26	0.4677E-01	0.5751E 00	0.2394E 00	-0.1236E-01	-0.7451E 01	-0.2662E 01	0.2629E 04	0.1271E 03	-0.7652E-02	0.3896E-01
27	-0.5462E-01	0.5762E 00	-0.2371E 00	-0.1179E-01	-0.7784E 01	-0.1428E 01	0.2859E 04	0.6903E 02	-0.1360E-02	0.8354E-02
28	-0.1823E 00	0.1262E 00	-0.3387E 00	-0.4613E-01	-0.7464E 01	-0.1823E 00	0.3162E 04	-0.2480E 02	0.2073E-01	-0.3688E-03
29	-0.1951E 00	-0.2048E 00	-0.1219E 00	0.2077E-02	-0.7058E 01	0.1046E 01	0.3269E 04	-0.7209E 02	0.1217E-01	-0.1712E-02
30	-0.1447E 00	-0.2833E 00	0.2066E-01	0.2518E-02	-0.6678E 01	0.2277E 01	0.3212E 04	-0.1964E 02	0.3364E-02	0.1837E-02
31	-0.9409E-01	-0.2620E 00	0.3631E-01	0.1925E-02	-0.6175E 01	0.3456E 01	0.3253E 04	0.1553E 02	0.1965E-02	0.3383E-02
32	-0.4792E-01	-0.2365E 00	0.2176E-01	0.2382E-02	-0.5471E 01	0.4528E 01	0.3298E 04	0.3471E 02	0.1321E-02	0.4018E-02
33	-0.4210E-02	-0.2310E 00	-0.5902E-02	0.2619E-02	-0.4571E 01	0.5441E 01	0.3288E 04	0.1940E 02	0.1908E-02	0.3416E-02
34	0.4051E-01	-0.2464E 00	-0.2136E-01	0.2373E-02	-0.3510E 01	0.6161E 01	0.3270E 04	-0.1230E 02	0.3125E-02	0.2170E-02
35	0.8815E-01	-0.2610E 00	-0.1155E-01	0.2367E-02	-0.2337E 01	0.6680E 01	0.3183E 04	-0.8163E 02	0.9246E-02	-0.1734E-02
36	0.1340E 00	-0.1980E 00	0.1012E 00	0.1003E-02	-0.1108E 01	0.7054E 01	0.3021E 04	-0.5396E 02	0.1565E-01	-0.2147E-02

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J=  200        TIME (SEC.) =     0.600000E-03
TOTAL ENERGY INPUT (IN.-LB.)  =    0.608204E 04
    KINETIC ENERGY (IN.-LB.)  =    0.448068E 04
    ELASTIC ENERGY (IN.-LB.)  =    0.262432E 03
    PLASTIC WORK   (IN.-LB.)  =    0.133892E 04
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3461E 00	0.1845E 00	0.5703E 00	-0.1585E 00	0.3461E 00	0.7522E 01	0.4224E 03	0.1368E 03	-0.8096E-02	0.9077E-02
2	0.7075E-01	0.8959E 00	0.3919E 00	-0.6786E-01	0.1499E 01	0.8096E 01	0.3512E 03	0.1902E 03	-0.3014E-01	0.4489E-01
3	-0.1222E 00	0.9023E 00	-0.3735E 00	-0.6097E-01	0.2703E 01	0.7785E 01	0.3733E 03	0.1396E 03	-0.8495E-02	0.9366E-02
4	-0.3901E 00	0.2015E 00	-0.5589E 00	-0.1523E 00	0.3432E 01	0.6724E 01	0.6516E 03	-0.7058E 01	0.1163E-01	-0.2411E-02
5	-0.5141E 00	-0.5170E 00	-0.4151E 00	-0.8296E-01	0.3990E 01	0.5555E 01	0.4717E 03	-0.1477E 03	0.1233E-01	-0.1021E-01
6	-0.4385E 00	-0.9948E 00	-0.1833E 00	-0.1465E-01	0.4577E 01	0.4413E 01	0.6031E 03	-0.1338E 03	0.8529E-02	-0.7673E-02
7	-0.2518E 00	-0.1159E 01	-0.1728E-01	0.9961E-04	0.5225E 01	0.3307E 01	0.7826E 03	-0.1550E 02	0.1236E-02	0.3118E-04
8	-0.4535E-01	-0.1191E 01	-0.4897E-02	0.4134E-03	0.5760E 01	0.2145E 01	0.7203E 03	0.1938E 02	-0.4379E-03	0.1943E-02
9	0.1643E 00	-0.1204E 01	-0.2929E-01	-0.1275E-03	0.6069E 01	0.9033E 00	0.7284E 03	-0.2641E 02	0.1616E-02	-0.4364E-03
10	0.3741E 00	-0.1189E 01	-0.8223E-02	-0.2688E-04	0.6148E 01	-0.3741E 00	0.4428E 03	-0.1492E 03	0.1023E-01	-0.9609E-02
11	0.5664E 00	-0.1017E 01	0.1957E 00	-0.1578E-01	0.6126E 01	-0.1655E 01	0.2745E 03	-0.1444E 03	0.1348E-01	-0.1064E-01
12	0.6333E 00	-0.4894E 00	0.4431E 00	-0.9396E-01	0.6219E 01	-0.2937E 01	0.6183E 03	0.9891E 01	0.1390E-01	-0.1526E-02
13	0.4797E 00	0.2894E 00	0.6013E 00	-0.1753E 00	0.6365E 01	-0.4229E 01	0.2857E 03	0.1416E 03	-0.8966E-02	0.1026E-01
14	0.1634E 00	0.1054E 01	0.4014E 00	-0.6835E-01	0.6323E 01	-0.5519E 01	0.3094E 03	0.1930E 03	-0.3228E-01	0.4971E-01
15	-0.6027E-01	0.1040E 01	-0.4349E 00	-0.8230E-01	0.5431E 01	-0.6379E 01	0.4297E 03	0.1329E 03	-0.8102E-02	0.9862E-02
16	-0.3922E 00	0.2553E 00	-0.6220E 00	-0.1868E 00	0.4136E 01	-0.6379E 01	0.7951E 03	0.7405E 01	0.1513E-01	-0.1111E-02
17	-0.5486E 00	-0.5276E 00	-0.4555E 00	-0.9873E-01	0.2845E 01	-0.6212E 01	0.5796E 03	-0.1411E 03	0.1356E-01	-0.1001E-01
18	-0.4802E 00	-0.1058E 01	-0.2137E 00	-0.1956E-01	0.1563E 01	-0.6101E 01	0.7384E 03	-0.1369E 03	0.9255E-02	-0.8098E-02
19	-0.2817E 00	-0.1259E 01	-0.3536E-01	-0.2767E-03	0.2817E 00	-0.6078E 01	0.8841E 03	-0.3099E 02	0.1907E-02	-0.4595E-03
20	-0.5577E-01	-0.1312E 01	-0.1105E-01	0.4070E-03	-0.9915E 00	-0.5944E 01	0.8155E 03	0.3441E 01	0.2700E-03	0.1375E-02
21	0.1752E 00	-0.1323E 01	-0.2236E-01	0.1668E-03	-0.2222E 01	-0.5592E 01	0.8371E 03	-0.4475E 02	0.2347E-02	-0.9026E-03
22	0.4048E 00	-0.1287E 01	0.1099E-01	0.2532E-03	-0.3376E 01	-0.5037E 01	0.6559E 03	-0.1515E 03	0.1088E-01	-0.9743E-02
23	0.6083E 00	-0.1075E 01	0.2230E 00	-0.2085E-01	-0.4492E 01	-0.4407E 01	0.4369E 03	-0.1401E 03	0.1528E-01	-0.9544E-02
24	0.6682E 00	-0.4977E 00	0.4775E 00	-0.1072E 00	-0.5669E 01	-0.3885E 01	0.6825E 03	0.2010E 02	0.1764E-01	-0.4248E-03
25	0.4818E 00	0.3431E 00	0.6629E 00	-0.2113E 00	-0.6892E 01	-0.3423E 01	0.2846E 03	0.1375E 03	-0.8839E-02	0.1109E-01
26	0.1005E 00	0.1187E 01	0.4550E 00	-0.8813E-01	-0.8045E 01	-0.2821E 01	0.1499E 03	0.1941E 03	-0.3403E-01	0.5360E-01
27	-0.1522E 00	0.1193E 01	-0.4385E 00	-0.8076E-01	-0.8375E 01	-0.1631E 01	0.2047E 03	0.1419E 03	-0.9241E-02	0.1124E-01
28	-0.5256E 00	0.3577E 00	-0.6521E 00	-0.2045E 00	-0.7695E 01	-0.5256E 00	0.5779E 03	0.1955E 02	0.1692E-01	-0.7368E-03
29	-0.7091E 00	-0.4790E 00	-0.4710E 00	-0.1045E 00	-0.6877E 01	0.4927E 00	0.2489E 03	-0.1383E 03	0.1486E-01	-0.1007E-01
30	-0.6501E 00	-0.1055E 01	-0.2152E 00	-0.1893E-01	-0.6126E 01	0.1538E 01	0.4883E 03	-0.1552E 03	0.1134E-01	-0.1067E-01
31	-0.4497E 00	-0.1253E 01	0.1100E-01	0.6616E-05	-0.5495E 01	0.2653E 01	0.7879E 03	-0.4214E 02	0.2211E-02	-0.8530E-03
32	-0.2285E 00	-0.1270E 01	0.4244E-01	-0.5743E-03	-0.4795E 01	0.3725E 01	0.7950E 03	0.1257E 02	-0.9009E-04	0.1687E-02
33	-0.8800E-02	-0.1245E 01	0.2424E-01	0.2133E-03	-0.3923E 01	0.4661E 01	0.8624E 03	-0.1712E 02	0.1363E-02	0.3309E-04
34	0.2053E 00	-0.1195E 01	0.3791E-01	-0.3359E-03	-0.2893E 01	0.5422E 01	0.7191E 03	-0.1285E 03	0.8054E-02	-0.6988E-02
35	0.3954E 00	-0.1017E 01	0.1925E 00	-0.1624E-01	-0.1790E 01	0.6074E 01	0.5888E 03	-0.1454E 03	0.1238E-01	-0.9977E-02
36	0.4721E 00	-0.5381E 00	0.4220E 00	-0.8578E-01	-0.7158E 00	0.6778E 01	0.6932E 03	-0.1119E 02	0.1211E-01	-0.2370E-02

J= 290 TIME (SEC.) = 0.870000E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.608204E 04
KINETIC ENERGY (IN.-LB.) = 0.413724E 04
ELASTIC ENERGY (IN.-LB.) = 0.393283E 03
PLASTIC WORK (IN.-LB.) = 0.155151E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.4559E 00	0.1433E 00	0.7058E 00	-0.2344E 00	0.4559E 00	0.7481E 01	-0.5285E 04	0.6772E 01	-0.1353E-01	0.3213E-02
2	0.7018E-01	0.1034E 01	0.5308E 00	-0.1275E 00	0.1523E 01	0.8232E 01	-0.4520E 03	0.1860E 03	-0.4527E-01	0.5420E-01
3	-0.1782E 00	0.1052E 01	-0.4824E 00	-0.1093E 00	0.2702E 01	0.7944E 01	0.1329E 04	0.1236E 03	-0.7953E-02	0.1037E-01
4	-0.5451E 00	0.1812E 00	-0.5731E 00	-0.2257E 00	0.3287E 01	0.6784E 01	0.1525E 04	0.6437E 01	0.1182E-01	-0.1180E-02
5	-0.7327E 00	-0.7190E 00	-0.5398E 00	-0.1446E 00	0.3693E 01	0.5541E 01	0.3941E 03	-0.2709E 02	0.7830E-02	-0.5698E-02
6	-0.6855E 00	-0.1457E 01	-0.4012E 00	-0.7957E-01	0.4064E 01	0.4305E 01	-0.4827E 02	-0.9556E 02	0.6795E-02	-0.6837E-02
7	-0.4500E 00	-0.1967E 01	-0.2509E 00	-0.3460E-01	0.4426E 01	0.3075E 01	-0.1298E 03	-0.1386E 03	0.6926E-02	-0.7158E-02
8	-0.1028E 00	-0.2258E 01	-0.1164E 00	-0.6731E-02	0.4729E 01	0.1830E 01	-0.2519E 03	-0.1547E 03	0.8930E-02	-0.9545E-02
9	0.2960E 00	-0.2278E 01	0.7339E-01	-0.2828E-02	0.5034E 01	0.5872E 00	-0.4392E 02	-0.1421E 03	0.7606E-02	-0.7718E-02
10	0.6546E 00	-0.1991E 01	0.2307E 00	-0.2769E-01	0.5347E 01	-0.6546E 00	0.4825E 03	-0.9514E 02	0.8468E-02	-0.7611E-02
11	0.9015E 00	-0.1470E 01	0.3953E 00	-0.7860E-01	0.5622E 01	-0.1907E 01	0.2773E 04	-0.2768E 02	0.1156E-01	-0.4198E-02
12	0.9407E 00	-0.6802E 00	0.5579E 00	-0.1591E 00	0.5934E 01	-0.3161E 01	0.5484E 04	-0.8108E 01	0.2029E-01	0.2422E-03
13	0.6998E 00	0.3168E 00	0.7645E 00	-0.2934E 00	0.6279E 01	-0.4433E 01	0.5236E 04	0.1068E 02	-0.9320E-02	0.1708E-01
14	0.2566E 00	0.1273E 01	0.4910E 00	-0.1134E 00	0.6431E 01	-0.5731E 01	-0.2705E 03	0.1866E 03	-0.4676E-01	0.5959E-01
15	-0.3616E-01	0.1234E 01	-0.5917E 00	-0.1571E 00	0.5537E 01	-0.6543E 01	-0.5314E 04	0.8590E 01	-0.1651E-01	0.4727E-02
16	-0.5199E 00	0.2389E 00	-0.8131E 00	-0.3089E 00	0.4238E 01	-0.6301E 01	-0.5048E 04	-0.8734E 01	0.1175E-01	-0.9841E-02
17	-0.7685E 00	-0.7597E 00	-0.5914E 00	-0.1627E 00	0.2972E 01	-0.5918E 01	-0.3483E 04	-0.1592E 02	0.5697E-02	-0.8460E-02
18	-0.7357E 00	-0.1562E 01	-0.4467E 00	-0.9402E-01	0.1727E 01	-0.5560E 01	-0.6111E 03	-0.8990E 02	0.6411E-02	-0.7398E-02
19	-0.4940E 00	-0.2136E 01	-0.3047E 00	-0.4553E-01	0.4940E 00	-0.5202E 01	0.2746E 03	-0.1457E 03	0.8537E-02	-0.7773E-02
20	-0.1213E 00	-0.2485E 01	-0.1374E 00	-0.8105E-02	-0.7230E 00	-0.4799E 01	0.3853E 03	-0.1673E 03	0.1207E-01	-0.1090E-01
21	0.3166E 00	-0.2494E 01	0.9860E-01	-0.3735E-02	-0.1954E 01	-0.4443E 01	0.5733E 03	-0.1481E 03	0.9325E-02	-0.8066E-02
22	0.7002E 00	-0.2151E 01	0.2771E 00	-0.3908E-01	-0.3200E 01	-0.4142E 01	0.1386E 04	-0.7068E 02	0.8550E-02	-0.6073E-02
23	0.9520E 00	-0.1565E 01	0.4276E 00	-0.9226E-01	-0.4440E 01	-0.3810E 01	0.4239E 04	-0.2274E 02	0.1424E-01	-0.2310E-02
24	0.9815E 00	-0.7211E 00	0.5975E 00	-0.1815E 00	-0.5699E 01	-0.3501E 01	0.5596E 04	-0.1164E 02	0.2755E-01	-0.1227E-02
25	0.6715E 00	0.3770E 00	0.8947E 00	-0.4029E 00	-0.7017E 01	-0.3276E 01	0.5276E 04	0.1243E 02	-0.1044E-01	0.2028E-01
26	0.1103E 00	0.1448E 01	0.5770E 00	-0.1575E 00	-0.8293E 01	-0.2901E 01	0.3706E 03	0.1943E 03	-0.4788E-01	0.6228E-01
27	-0.2205E 00	0.1463E 01	-0.5444E 00	-0.1281E 00	-0.8629E 01	-0.1745E 01	-0.5332E 04	0.1395E 02	-0.2361E-01	0.1088E-01
28	-0.7604E 00	0.4127E 00	-0.9011E 00	-0.3809E 00	-0.7750E 01	-0.7604E 00	-0.5080E 04	-0.1194E 02	0.1489E-01	-0.1463E-01
29	-0.1065E 01	-0.6815E 00	-0.5973E 00	-0.1644E 00	-0.6740E 01	0.1070E 00	-0.3168E 04	-0.3964E 02	0.8561E-02	-0.9436E-02
30	-0.1032E 01	-0.1517E 01	-0.4131E 00	-0.7936E-01	-0.5823E 01	0.1021E 01	-0.5696E 03	-0.7867E 02	0.7891E-02	-0.8659E-02
31	-0.7776E 00	-0.2078E 01	-0.2429E 00	-0.2894E-01	-0.4944E 01	0.1956E 01	0.8927E 02	-0.1491E 03	0.8643E-02	-0.8381E-02
32	-0.4015E 00	-0.2389E 01	-0.5319E-01	-0.1729E-02	-0.4049E 01	0.2873E 01	-0.1823E 02	-0.1617E 03	0.1029E-01	-0.1034E-01
33	0.1595E-01	-0.2373E 01	0.1438E 00	-0.9735E-02	-0.3179E 01	0.3813E 01	-0.9885E 02	-0.1410E 03	0.7206E-02	-0.7392E-02
34	0.3708E 00	-0.2046E 01	0.2935E 00	-0.4274E-01	-0.2325E 01	0.4768E 01	-0.8287E 03	-0.9652E 02	0.5679E-02	-0.7051E-02
35	0.6062E 00	-0.1513E 01	0.4243E 00	-0.8570E-01	-0.1423E 01	0.5681E 01	-0.3104E 04	-0.3275E 02	0.5140E-02	-0.8643E-02
36	0.6506E 00	-0.7645E 00	0.5652E 00	-0.1497E 00	-0.5007E 00	0.6586E 01	-0.5118E 04	-0.5559E 01	0.6021E-02	-0.7722E-02

J= 300 TIME (SEC.) = 0.900000E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.608204E 04
KINETIC ENERGY (IN.-LB.) = 0.410992E 04
ELASTIC ENERGY (IN.-LB.) = 0.420485E 03
PLASTIC WORK (IN.-LB.) = 0.155163E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.4577E 00	0.1347E 00	0.7134E 00	-0.2434E 00	0.4577E 00	0.7472E 01	-0.5338E 04	0.6857E 01	-0.1498E-01	0.1969E-02
2	0.6658E-01	0.1033E 01	0.5414E 00	-0.1324E 00	0.1519E 01	0.8232E 01	0.1408E 02	0.1894E 03	-0.4528E-01	0.5517E-01
3	-0.1830E 00	0.1052E 01	-0.4815E 00	-0.1115E 00	0.2697E 01	0.7946E 01	0.5222E 04	0.7610E 01	-0.5869E-02	0.1294E-01
4	-0.5529E 00	0.1747E 00	-0.5771E 00	-0.2354E 00	0.3277E 01	0.6782E 01	0.5427E 04	-0.4965E 01	0.1493E-01	0.2661E-02
5	-0.7466E 00	-0.7415E 00	-0.5509E 00	-0.1564E 00	0.3668E 01	0.5533E 01	0.3083E 04	-0.1274E 02	0.9449E-02	-0.2964E-02
6	-0.7060E 00	-0.1509E 01	-0.4235E 00	-0.9093E-01	0.4011E 01	0.4287E 01	0.8891E 03	-0.9075E 02	0.7367E-02	-0.5891E-02
7	-0.4692E 00	-0.2058E 01	-0.2871E 00	-0.4194E-01	0.4337E 01	0.3046E 01	0.3509E 03	-0.1412E 03	0.7983E-02	-0.7270E-02
8	-0.1086E 00	-0.2388E 01	-0.1306E 00	-0.8106E-02	0.4614E 01	0.1795E 01	0.9525E 02	-0.1634E 03	0.1073E-01	-0.1050E-01
9	0.3115E 00	-0.2398E 01	0.8754E-01	-0.3425E-02	0.4919E 01	0.5510E 00	0.2971E 03	-0.1441E 03	0.8485E-02	-0.7942E-02
10	0.6840E 00	-0.2078E 01	0.2562E 00	-0.3377E-01	0.5259E 01	-0.6840E 00	0.8320E 03	-0.9372E 02	0.8697E-02	-0.7271E-02
11	0.9329E 00	-0.1519E 01	0.4206E 00	-0.8879E-01	0.5568E 01	-0.1929E 01	0.3094E 04	-0.2931E 01	0.1086E-01	-0.2978E-02
12	0.9676E 00	-0.7031E 00	0.5624E 00	-0.1624E 00	0.5903E 01	-0.3178E 01	0.5392E 04	-0.8616E 01	0.1855E-01	-0.2751E-02
13	0.7129E 00	0.3158E 00	0.7818E 00	-0.3139E 00	0.6272E 01	-0.4444E 01	0.5125E 04	0.1168E 02	-0.1341E-01	0.1547E-01
14	0.2638E 00	0.1274E 01	0.4832E 00	-0.1091E 00	0.6428E 01	-0.5738E 01	-0.4177E 03	0.1691E 03	-0.4621E-01	0.5879E-01
15	-0.2751E-01	0.1235E 01	-0.5859E 00	-0.1537E 00	0.5532E 01	-0.6549E 01	-0.5414E 04	0.9449E 01	-0.2015E-01	0.3212E-02
16	-0.5223E 00	0.2305E 00	-0.8293E 00	-0.3251E 00	0.4236E 01	-0.6293E 01	-0.5103E 04	-0.8702E 01	0.1029E-01	-0.1123E-01
17	-0.7831E 00	-0.7896E 00	-0.6083E 00	-0.1723E 00	0.2975E 01	-0.5885E 01	-0.4088E 04	-0.6827E 01	0.4797E-02	-0.8466E-02
18	-0.7563E 00	-0.1520E 01	-0.4723E 00	-0.1055E 00	0.1738E 01	-0.5499E 01	-0.9635E 03	-0.8588E 02	0.5969E-02	-0.7527E-02
19	-0.5148E 00	-0.2235E 01	-0.3341E 00	-0.5458E-01	0.5148E 00	-0.5102E 01	0.1752E 03	-0.1489E 03	0.9097E-02	-0.8530E-02
20	-0.1285E 00	-0.2614E 01	-0.1533E 00	-0.1033E-01	-0.6937E 00	-0.4674E 01	0.4667E 03	-0.1673E 03	0.1425E-01	-0.1176E-01
21	0.3323E 00	-0.2622E 01	0.1141E 00	-0.4736E-02	-0.1925E 01	-0.4317E 01	0.6630E 03	-0.1502E 03	0.9912E-02	-0.8488E-02
22	0.7294E 00	-0.2246E 01	0.3029E 00	-0.4579E-01	-0.3178E 01	-0.4045E 01	0.1638E 04	-0.6739E 02	0.8625E-02	-0.5741E-02
23	0.9834E 00	-0.1623E 01	0.4506E 00	-0.1030E 00	-0.4427E 01	-0.3746E 01	0.4629E 04	-0.7883E 01	0.1406E-01	-0.1555E-02
24	0.1006E 01	-0.7483E 00	0.6110E 00	-0.1937E 00	-0.5695E 01	-0.3465E 01	0.5489E 04	-0.1212E 02	0.2537E-01	-0.4580E-02
25	0.6795E 00	0.3738E 00	0.9206E 00	-0.4323E 00	-0.7018E 01	-0.3267E 01	0.5202E 04	0.1362E 02	-0.1383E-01	0.1984E-01
26	0.1067E 00	0.1453E 01	0.5732E 00	-0.1555E 00	-0.8297E 01	-0.2906E 01	0.2185E 03	0.1848E 03	-0.4764E-01	0.6179E-01
27	-0.2242E 00	0.1469E 01	-0.5409E 00	-0.1259E 00	-0.8634E 01	-0.1750E 01	-0.5479E 04	0.1514E 02	-0.2886E-01	0.8575E-02
28	-0.7737E 00	0.4138E 00	-0.9271E 00	-0.4116E 00	-0.7751E 01	-0.7737E 00	-0.5221E 04	-0.1253E 02	0.1197E-01	-0.1900E-01
29	-0.1096E 01	-0.7051E 00	-0.5082E 00	-0.1710E 00	-0.6722E 01	0.7229E-01	-0.3718E 04	-0.2483E 02	0.7539E-02	-0.9312E-02
30	-0.1068E 01	-0.1569E 01	-0.4359E 00	-0.8857E-01	-0.5786E 01	0.9688E 00	-0.6900E 03	-0.7540E 02	0.7667E-02	-0.8629E-02
31	-0.8115E 00	-0.2165E 01	-0.2583E 00	-0.3534E-01	-0.4884E 01	0.1883E 01	0.2024E 03	-0.1514E 03	0.9311E-02	-0.8727E-02
32	-0.4218E 00	-0.2512E 01	-0.8319E-01	-0.2046E-02	-0.3968E 01	0.2779E 01	0.3739E 03	-0.1677E 03	0.1238E-01	-0.1110E-01
33	0.1805E-01	-0.2498E 01	0.1581E 00	-0.1134E-01	-0.3097E 01	0.3719E 01	0.2228E 03	-0.1449E 03	0.8345E-02	-0.7707E-02
34	0.3867E 00	-0.2143E 01	0.3227E 00	-0.5115E-01	-0.2263E 01	0.4692E 01	-0.7286E 03	-0.9288E 02	0.5618E-02	-0.6829E-02
35	0.6228E 00	-0.1570E 01	0.4506E 00	-0.9654E-01	-0.1387E 01	0.5632E 01	-0.3356E 04	-0.1743E 02	0.4341E-02	-0.8252E-02
36	0.6602E 00	-0.7916E 00	0.5792E 00	-0.1576E 00	-0.4865E 00	0.6561E 01	-0.5110E 04	-0.5504E 01	0.6165E-02	-0.7441E-02

6.3 A Variable Thickness Arbitrarily Curved Partial Ring Example+

The geometry of the structure, as shown in Fig. 7c,is a partial ring of 1.5 in. width and of thickness varying linearly from 0.1 in. at one end to 0.3 in. at the other. One end is hinged smoothly and a limited portion of the ring is subjected to a distributed elastic restraint (elastic foundation) with modulus 1000 psi. The ring is subjected to a normal-direction forcing function of magnitude 5000 lb at time zero and decreasing linearly to zero at time 400 μsec, the force is assumed to be distributed uniformly over a 9-degree segment.

The ring material is considered as being elastic perfectly-plastic (EL-PP) with a yield stress of 50,000 psi and an elastic modulus of 10^7 psi. Strain-rate effects are considered to be negligible, and the mass density is 0.25×10^{-3} $(\text{lb-sec}^2)/\text{in}^4$.

Ten equal-length finite elements are used to model the partial ring.

Let the JET 3C program be used to calculate the structural response. Printout is desired every 30 cycles, and the total run will be 900 cycles. The incremental time interval Δt to be used for this example will be calculated by the program by setting Δt=0.0 in Card 3.

6.3.1 Input Data

The values to be punched on the data cards are as follows:

			Format
Card 1			2E15.6
	B	= 0.150000 E+01	
	DENS	= 0.250000 E-03	
Card 2			7I5
	IK	= 10	
	NOGA	= 3	
	NFL	= 4	
	NSFL	= 1	
	MM	= 900	
	M1	= 30	
	M2	= 30	

+The ε_{cr} and the "maximum strain inspection and statement" features have been omitted.

			Format
Card 2a			4E15.6
Y(1)	= -0.873300 E+01	initial Y coordinate, Z coordinate, slope, and thickness at the first node	
Z(1)	= 0.0		
ANG(1)	= 0.900000 E+02		
H(1)	= 0.100000 E+00		

Cards 2a are repeated for each node until the total eleven (=IK+1) nodes are described.

Card 3			4E15.6
DELTAT	= 0.0	(to be calculated by the program)	
CRITS	= 0.100000 E+01		
DS	= 0.0	(strain-rate effects are neglected)	
Card 4			4E15.6
EPS(1)	= 0.500000 E-02		
SIG(1)	= 0.500000 E+05		
Card 5			4F15.10
AXG(1)	= 0.1127016654		
AXG(2)	= 0.5000000000		
AXG(3)	= 0.8872983346		
Card 6			4F15.10
AWG(1)	= 0.2777777778		
AWG(2)	= 0.4444444444		
AWG(3)	= 0.2777777778		
Card 7			4F15.10
TXG(1)	= -0.8611363115		
TXG(2)	= -0.3399810435		
TXG(3)	= 0.3399810435		
TXG(4)	= 0.8611363115		

			Format
Card 8			
TWG(1)	= 0.3478548451		
TWG(2)	= 0.6521451548		
TWG(3)	= 0.6521451548		
TWG(4)	= 0.3478548451		
Card 9			7I5
NBCOND	= 1	(one prescribed displacement condition)	
NBC(1)	= 3	smoothly-hinged at node 11	
NODEB(1)	= 11		
Card 10			3I5
NQR	= 1		
NORP	= 0		
NORU	= 1	(one distributed elastic restraint)	

Card 10a is not required since NORP=0

Card 10b			2E15.6,8I5
SCTU	= 0.100000 E+04	(elastic foundation modulus in translation)	
SCRU	= 0.0		
NRST(1)	= 1	starting element and numbers of elements over which the elastic foundation is to be distributed	
NREU(1)	= 4		
Card 11			4I5
NV	= 0	(no initial velocity distribution)	

Cards 12, 13, and 14 are not needed since NV=0

			Format
Card 15			4E15.6
TBEGIN	= 0.0		
TFINAL	= 0.400000 E-03		
AMP1FV	= 0.0	(no circumferential force component)	
AMP1FW	= 0.500000 E+04		
Card 16			3I5
NOFT1	= 0		
NOFT2	= 1	(one local uniform force distribution)	
NOFT3	= 0		

Card 17 is not required since NOFT1=0

Card 18			2I5, 2E15.6
NSTF2(1)	= 4	starting element and number of elements over which the uniform force distribution is to be specified	
NELF2(1)	= 1		
RTO2V(1)	= 0.0		
RTO2W(1)	= 0.100000 E+01		

Card 19 is not used since NOFT3=0

Card 20		3E15.6
T2	= 0.400000 E-03	
AMP2FV	= 0.0	
AMP2FW	= 0.0	

The input deck for this example problem should look as follows:

```
 0.150000E+01    0.250000E-03
 10      3    4    1   900    30    30
-0.873300E+01    0.0              0.900000E+02     0.100000E+00
-0.862548E+01    0.136615E+01     0.810000E+02     0.120000E+00
-0.830558E+01    0.269865E+01     0.720000E+02     0.140000E+00
-0.778116E+01    0.396470E+01     0.630000E+02     0.160000E+00
-0.706515E+01    0.513313E+01     0.540000E+02     0.180000E+00
-0.617516E+01    0.617516E+01     0.450000E+02     0.200000E+00
-0.513313E+01    0.706515E+01     0.360000E+02     0.220000E+00
-0.396470E+01    0.778116E+01     0.270000E+02     0.240000E+00
-0.269865E+01    0.830558E+01     0.180000E+02     0.260000E+00
-0.136615E+01    0.862548E+01     0.900000E+01     0.280000E+00
 0.0             0.873300E+01     0.0              0.300000E+00
 0.0             0.100000E+01     0.0
 0.500000E-02    0.500000E+05
 0.1127016654    0.5000000000     0.8872983346
 0.2777777778    0.4444444444     0.2777777778
-0.8611363116   -0.3399810436     0.3399810436     0.8611363116
 0.3478548451    0.6521451549     0.6521451549     0.3478548451
  1      3   11
  1      0    1
 0.100000E+04    0.0                1      4
  0
 0.0             0.400000E-03     0.0              0.500000E+04
  0      1    0
  4      1   0.0              0.100000E+01
 0.400010E-03    0.0              0.0
```

6.3.2 Solution Output for Example 3

For illustrative purposes and in the interest of conciseness, only the solution output for the following printout cycles 0, 1, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 570, 600, 870, and 900 is presented:

```
***JET3C***  A SPATIAL FINITE ELEMENT AND TEMPORAL CENTRAL DIFFERENCE PROGRAM
   USED TO CALCULATE THE NONLINEAR RESPONSES OF A VARIABLE THICKNESS ARBITRARILY
   CURVED PARTIAL  RING WITH THE FOLLOWING PARAMETERS

   WIDTH OF RING (IN)                 =    0.150000E 01
   DENSITY (LB-SEC**2/IN**4)          =    0.250000E-03
   NUMBER OF ELEMENTS                 =    10
   NUMBER OF SPANWISE GAUSSIAN PTS    =     3
   NUMBER OF DEPTHWISE GAUSSIAN PTS   =     4
   NUMBER OF MECHANICAL SUBLAYERS     =     1
   HINGED  DISPLACEMENT CONDITION AT NODE =   11

  CONSTRAINTS (ELASTIC FOUNDATION/SPRING) AS DESCRIBED BY INPUT
```

NODE	Y	Z	SLOPE	THICKNESS	NODE	Y	Z	SLOPE	THICKNESS
1	-0.873300E 01	0.0	0.157080E 01	0.100000E 00	2	-0.862548E 01	0.136615E 01	0.141372E 01	0.120000E 00
3	-0.830558E 01	0.269865E 01	0.125664E 01	0.140000E 00	4	-0.778116E 01	0.396470E 01	0.109956E 01	0.160000E 00
5	-0.706515E 01	0.513313E 01	0.942478E 00	0.180000E 00	6	-0.617516E 01	0.617516E 01	0.785398E 00	0.200000E 00
7	-0.513313E 01	0.706515E 01	0.628318E 00	0.220000E 00	8	-0.396470E 01	0.778116E 01	0.471239E 00	0.240000E 00
9	-0.269865E 01	0.830558E 01	0.314159E 00	0.260000E 00	10	-0.136615E 01	0.862548E 01	0.157080E 00	0.280000E 00
11	0.0	0.873300E 01	0.0	0.300000E 00					

```
  SIZE OF ASSEMBLED MASS OR STIFFNESS MATRIX =  270

   EIGEN VECTOR OF HIGHEST MODE
```

V	W	PSI	CHI
-0.150240E 00	0.211736E-02	0.836164E-02	0.100000E 01
-0.233103E-01	0.157452E-03	0.222318E-02	0.287419E 00
-0.922490E-02	0.135157E-04	0.139746E-02	0.120158E 00
-0.390908E-02	-0.113895E-04	0.766975E-03	0.514809E-01
-0.167551E-02	-0.105424E-04	0.385612E-03	0.222315E-01
-0.722912E-03	-0.638248E-05	0.184240E-03	0.966183E-02
-0.313590E-03	-0.334122E-05	0.852910E-04	0.422586E-02
-0.135938E-03	-0.162430E-05	0.385431E-04	0.186707E-02
-0.575604E-04	-0.738883E-06	0.170604E-04	0.851445E-03
-0.210456E-04	-0.272296E-06	0.752560E-05	0.438943E-03
0.0	0.0	0.381001E-05	0.328453E-03

```
   HIGHEST NATURAL FREQUENCY (RAD/SEC) =    0.16498910E 07

   TIME STEP SIZE USED IN PROGRAM (SEC) =    0.969761E-06

   THERE IS NO INITIAL IMPULSE

   STARTING TIME OF FORCING FUNCTION (SEC) =    0.0
   STOPPING TIME OF FORCING FUNCTION (SEC) =    0.400000E-03
```

```
J=    0       TIME (SEC.) =    0.0
TOTAL ENERGY INPUT (IN.-LB.)  =   0.0
    KINETIC ENERGY (IN.-LB.)  =   0.0
    ELASTIC ENERGY (IN.-LB.)  =   0.0
    PLASTIC WORK   (IN.-LB.)  =   0.0
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =   0.0
```

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.0	0.0	0.0	0.0	-0.8733E 01	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	-0.8625E 01	0.1366E 01	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	-0.8306E 01	0.2699E 01	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	-0.7781E 01	0.3965E 01	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	-0.7065E 01	0.5133E 01	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	-0.6175E 01	0.6175E 01	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	-0.5133E 01	0.7065E 01	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	-0.3965E 01	0.7781E 01	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	-0.2699E 01	0.8306E 01	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	-0.1366E 01	0.8625E 01	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.8733E 01				

```
J=    1       TIME (SEC.) =    0.969761E-06
TOTAL ENERGY INPUT (IN.-LB.)  =   0.926839E 00
    KINETIC ENERGY (IN.-LB.)  =   0.520651E 00
    ELASTIC ENERGY (IN.-LB.)  =   0.157948E-03
    PLASTIC WORK   (IN.-LB.)  =   0.406029E 00
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =   0.843067E-06
```

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3410E-08	-0.1071E-05	0.9312E-05	-0.1472E-06	-0.8733E 01	0.3408E-08	0.1201E-01	0.2920E-02	-0.8925E-07	0.1038E-06
2	-0.3821E-10	0.2800E-06	0.6906E-05	0.2024E-07	-0.8625E 01	0.1366E 01	-0.1097E 00	-0.1516E-01	0.3025E-06	-0.4150E-06
3	-0.1712E-09	0.1228E-05	0.1448E-04	0.1276E-06	-0.8306E 01	0.2699E 01	-0.4872E 00	-0.2039E 00	0.3408E-05	-0.3841E-05
4	0.1418E-07	0.1751E-04	0.8076E-04	0.2033E-05	-0.7781E 01	0.3965E 01	0.1230E 02	0.6764E 00	-0.4540E-05	0.1419E-04
5	-0.1629E-07	0.1576E-04	-0.7033E-04	0.1840E-05	-0.7065E 01	0.5133E 01	-0.5525E 00	-0.3732E 00	0.3941E-05	-0.4329E-05
6	0.3737E-09	0.1109E-05	-0.1062E-04	0.1130E-06	-0.6175E 01	0.6175E 01	-0.1642E 00	-0.6065E-01	0.4980E-06	-0.6023E-06
7	0.4903E-09	0.3382E-06	-0.3435E-05	0.2878E-07	-0.5133E 01	0.7065E 01	-0.5378E-01	-0.2546E-01	0.1769E-06	-0.2081E-06
8	0.3432E-09	0.1120E-06	-0.1138E-05	0.7224E-08	-0.3965E 01	0.7781E 01	-0.1667E-01	-0.1080E-01	0.6467E-07	-0.7356E-07
9	0.1852E-09	0.3666E-07	-0.3797E-06	0.1352E-08	-0.2699E 01	0.8306E 01	-0.4348E-02	-0.4342E-02	0.2275E-07	-0.2490E-07
10	0.7551E-10	0.1086E-07	-0.1374E-06	-0.2403E-09	-0.1366E 01	0.8625E 01	0.4504E-03	-0.1227E-02	0.5941E-08	-0.5734E-08
11	0.0	0.0	-0.8208E-07	-0.1119E-08	0.0	0.8733E 01				

J= 30 TIME (SEC.) = 0.290928E-C4
TOTAL ENERGY INPUT (IN.-LB.) = 0.180518E 03
KINETIC ENERGY (IN.-LB.) = 0.145763E 03
ELASTIC ENERGY (IN.-LB.) = 0.273579E 02
PLASTIC WORK (IN.-LB.) = 0.688578E 01
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.511973E 00

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.2461E-03	-0.6032E-03	0.3884E-02	-C.1958E-04	-0.8732E 01	0.2461E-03	0.4111E 03	0.5360E 01	0.7196E-04	0.4263E-03
2	0.5926E-03	-0.4819E-03	-0.5395E-03	0.5114E-03	-0.8625E 01	0.1367E 01	0.1123E 04	0.1872E 02	0.1326E-03	0.1019E-02
3	C.1370E-02	-0.1558E-02	-0.9899E-02	0.6159E-03	-0.8304E 01	0.2699E 01	0.1862E 04	-0.1538E 03	0.3562E-02	-0.1907E-02
4	0.1813E-02	0.1818E-01	0.4019E-01	C.1587E-03	-0.7797E 01	0.3975E 01	0.2196E 04	0.3429E 03	-0.3885E-02	0.5607E-02
5	-0.1410E-02	0.1635E-01	-0.3645E-01	0.2263E-03	-0.7079E 01	0.5142E 01	0.2130E 04	-0.2617E 03	0.3648E-02	-0.2153E-02
6	-0.1026E-02	-0.1551E-02	0.5483E-02	C.5161E-03	-0.6175E 01	0.6173E 01	0.1424E 04	0.5483E 02	-0.4519E-04	0.9494E-03
7	-0.4035E-03	-0.6242E-04	-0.1020E-02	0.3496E-03	-0.5133E 01	0.7065E 01	0.7895E 03	-0.7466E 01	0.2853E-03	0.1724E-03
8	-C.7542E-04	0.8928E-04	-0.3461E-03	C.1240E-03	-0.3965E 01	0.7781E 01	0.1972E 03	-0.7173E 01	0.9849E-04	0.6679E-05
9	0.2021E-05	0.7711E-05	0.1577E-03	-C.2551E-05	-0.2699E 01	0.8306E 01	-0.7769E 01	0.1451E 01	-0.9880E-05	0.6043E-05
10	-0.5536E-06	-0.1475E-04	0.7665E-04	0.2952E-05	-0.1366E 01	0.8625E 01	-0.4549E 00	0.2013E 01	-0.9678E-05	0.9469E-05
11	0.0	0.0	-0.1414E-04	C.1947E-05	0.0	0.8733E 01				

J= 60 TIME (SEC.) = 0.581856E-C4
TOTAL ENERGY INPUT (IN.-LB.) = 0.543343E 03
KINETIC ENERGY (IN.-LB.) = 0.412960E 03
ELASTIC ENERGY (IN.-LB.) = 0.792373E 02
PLASTIC WORK (IN.-LB.) = 0.451718E 02
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.597298E 01

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	C.9661E-02	0.3316E-02	-0.2292E-01	-0.4927E-04	-0.8736E 01	0.9661E-02	0.4825E 03	-0.3541E 02	0.1463E-02	-0.8782E-03
2	0.1013E-01	0.2086E-02	0.6316E-02	C.4750E-03	-0.8626E 01	0.1376E 01	0.1236E 04	0.8431E 01	0.4345E-03	0.8336E-03
3	0.1188E-01	-0.1338E-01	0.2059E-02	0.1949E-02	-0.8289E 01	0.2706E 01	0.2482E 04	-0.2623E 03	0.5933E-02	-0.3634E-02
4	0.7914E-02	0.7000E-01	0.8960E-01	-0.2488E-02	-0.7840E 01	0.4004E 01	0.3536E 04	0.4627E 03	-0.7560E-02	0.1308E-01
5	-0.4034E-02	0.6147E-01	-0.7689E-01	-C.2142E-02	-0.7117E 01	0.5166E 01	0.4264E 04	-0.4011E 03	0.6401E-02	-0.3152E-02
6	-C.6853E-02	-0.9042E-02	-0.7838E-02	0.1926E-02	-0.6174E 01	0.6164E 01	0.3661E 04	-0.1159E 03	0.2213E-02	0.1109E-03
7	-0.4211E-02	-0.1549E-03	0.5891E-02	C.9660E-03	-0.5136E 01	0.7063E 01	0.3108E 04	0.6460E 02	0.4123E-03	0.1389E-02
8	-0.2951E-02	-0.1519E-02	0.5867E-04	C.8269E-03	-0.3967E 01	0.7778E 01	0.2595E 04	0.1750E 01	0.6809E-03	0.7033E-03
9	-0.1848E-02	-0.6198E-04	-0.6793E-04	C.6944E-03	-0.2700E 01	0.8305E 01	0.2782E 04	-0.1436E 02	0.7656E-03	0.6080E-C3
10	-0.8668E-03	-0.2902E-03	0.7342E-03	C.6553E-03	-0.1367E 01	0.8625E 01	0.2685E 04	0.2171E 02	0.5139E-03	0.7204E-03
11	0.0	0.0	-0.2450E-03	0.6371E-03	0.0	0.8733E 01				

```
J=   90       TIME (SEC.) =    0.872784E-04
TOTAL ENERGY INPUT (IN.-LB.)   =    0.980835E 03
    KINETIC ENERGY (IN.-LB.)   =    0.715075E 03
    ELASTIC ENERGY (IN.-LB.)   =    0.124882E 03
    PLASTIC WORK   (IN.-LB.)   =    0.116541E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =   0.243368E 02
```

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3243E-01	-0.1033E-01	0.2905E-01	-0.4695E-03	-0.8723E 01	0.3243E-01	0.4863E 03	0.7480E 02	-0.2178E-02	0.2767E-02
2	0.3256E-01	-0.3511E-02	-0.3266E-01	-0.3443E-04	-0.8617E 01	0.1398E 01	0.1358E 04	-0.1421E 03	0.4059E-02	-0.2666E-02
3	0.3666E-01	-0.2001E-01	0.3833E-01	0.2782E-02	-0.8275E 01	0.2727E 01	0.1895E 04	-0.2914E 03	0.6455E-02	-0.4530E-02
4	0.2115E-01	0.1428E 00	0.1386E 00	-0.7142E-02	-0.7899E 01	0.4048E 01	0.3862E 04	0.4533E 03	-0.1087E-01	0.2100E-01
5	-0.3336E-02	0.1230E 00	-0.1183E 00	-0.6919E-02	-0.7167E 01	0.5203E 01	0.4710E 04	-0.4241E 03	0.7345E-02	-0.3486E-02
6	-0.1500E-01	-0.1066E-01	-0.4005E-01	0.2569E-02	-0.6178E 01	0.6157E 01	0.4266E 04	-0.4745E 03	0.5744E-02	-0.2987E-02
7	-0.1001E-01	-0.1276E-01	0.1701E-01	0.1253E-02	-0.5134E 01	0.7049E 01	0.4766E 04	0.2054E 03	-0.1720E-03	0.2935E-02
8	-0.7349E-02	-0.2013E-02	-0.1536E-02	0.1396E-02	-0.3970E 01	0.7776E 01	0.5464E 04	-0.6520E 02	0.1874E-02	0.1040E-02
9	-0.4736E-02	-0.4955E-02	0.3050E-02	0.1436E-02	-0.2702E 01	0.8299E 01	0.5576E 04	0.7938E 02	0.9412E-03	0.1812E-02
10	-0.2326E-02	-0.2532E-02	-0.1381E-02	0.1372E-02	-0.1368E 01	0.8623E 01	0.6382E 04	-0.1678E 03	0.2265E-02	0.6691E-03
11	0.0	0.0	0.6180E-02	0.1452E-02	0.0	0.8733E 01				

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J=  120       TIME (SEC.) =    0.116371E-03
TOTAL ENERGY INPUT (IN.-LB.)   =    0.143864E 04
    KINETIC ENERGY (IN.-LB.)   =    0.101955E 04
    ELASTIC ENERGY (IN.-LB.)   =    0.138904E 03
    PLASTIC WORK   (IN.-LB.)   =    0.215462E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)  =   0.647213E 02
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.6868E-01	-0.3379E-02	0.1368E-01	-0.3630E-03	-0.8730E 01	0.6868E-01	0.6811E 03	0.8449E 02	-0.2381E-02	0.3206E-02
2	0.6886E-01	-0.1885E-01	-0.5599E-01	-0.2006E-02	-0.8596E 01	0.1431E 01	0.1537E 04	-0.2612E 03	0.8681E-02	-0.6264E-02
3	0.7492E-01	-0.1696E-01	0.1020E 00	-0.1480E-03	-0.8266E 01	0.2765E 01	0.1686E 04	-0.2256E 03	0.5271E-02	-0.3487E-02
4	0.4239E-01	0.2252E 00	0.1817E 00	-0.1316E-01	-0.7963E 01	0.4105E 01	0.4813E 04	0.4258E 03	-0.1395E-01	0.3071E-01
5	0.3342E-02	0.1958E 00	-0.1780E 00	-0.1518E-01	-0.7222E 01	0.5251E 01	0.4920E 04	-0.4995E 03	0.9379E-02	-0.4745E-02
6	-0.2137E-01	-0.3710E-02	-0.7605E-01	0.2397E-02	-0.6188E 01	0.6157E 01	0.4908E 04	-0.6136E 03	0.9042E-02	-0.4855E-02
7	-0.1405E-01	-0.3445E-01	0.1482E-01	0.1400E-02	-0.5124E 01	0.7029E 01	0.5198E 04	0.2713E 02	0.1301E-02	0.1712E-02
8	-0.8750E-02	-0.1093E-01	0.1237E-01	0.1180E-02	-0.3968E 01	0.7767E 01	0.4590E 04	0.2765E 03	-0.5458E-03	0.2994E-02
9	-0.5643E-02	-0.1194E-01	-0.7067E-02	0.1159E-02	-0.2700E 01	0.8292E 01	0.4352E 04	-0.2929E 03	0.2682E-02	-0.5324E-03
10	-0.2034E-02	-0.1166E-01	0.9282E-02	0.9061E-03	-0.1366E 01	0.8614E 01	0.3823E 04	0.6066E 02	0.5903E-03	0.1167E-02
11	0.0	0.0	0.6548E-02	0.8258E-03	0.0	0.8733E 01				

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J=  150        TIME (SEC.) =    0.145464E-03
TOTAL ENERGY INPUT (IN.-LB.)  =     0.186126E 04
    KINETIC ENERGY (IN.-LB.)  =     0.130022E 04
    ELASTIC ENERGY (IN.-LB.)  =     0.137007E 03
    PLASTIC WORK    (IN.-LB.)  =     0.289390E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)   =    0.134641E 03
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	C.1203E 00	0.2810E-01	-0.7878E-01	-0.3575E-02	-0.8761E 01	0.1203E 00	0.8291E 03	-0.3963E 02	0.1813E-02	-0.8079E-03
2	0.1194E 00	-0.4677E-01	-0.4605E-01	-C.1197E-02	-0.8561E 01	0.1477E 01	0.1397E 04	-0.2736E 03	0.1011E-01	-0.7857E-02
3	0.1267E 00	-0.2096E-02	0.1439E 00	-C.2993E-02	-0.8264E 01	0.2819E 01	0.1698E 04	-0.1803E 03	0.4471E-02	-0.2676E-02
4	C.7350E-01	0.3138E 00	0.2084E 00	-0.1637E-01	-0.8027E 01	0.4173E 01	0.3830E 04	0.4542E 03	-0.1790E-01	0.3516E-01
5	C.1708E-01	0.2747E 00	-0.2187E 00	-C.2408E-01	-0.7277E C1	0.5308E 01	0.3711E 04	-0.4777E 03	0.8941E-02	-0.5028E-02
6	-0.2679E-01	0.7175E-02	-0.1181E 00	-0.1038E-02	-0.6199E 01	0.6161E 01	0.3069E 04	-0.7287E 03	0.1085E-01	-0.7865E-02
7	-0.1996E-01	-0.5732E-01	0.4306E-02	C.9216E-03	-0.5116E 01	0.7007E 01	0.2835E 04	-0.1859E 03	0.2228E-02	-0.5841E-03
8	-0.1177E-01	-0.3247E-01	0.2108E-01	0.4715E-03	-0.3960E 01	0.7747E 01	0.2579E 04	0.3101E 03	-0.1297E-02	0.2672E-02
9	-0.7137E-02	-0.2092E-01	-0.7112E-03	0.5293E-03	-0.2699E 01	0.8283E 01	0.2253E 04	-0.1034E 03	0.1123E-02	-0.1096E-04
10	-0.2762E-02	-0.2358E-01	0.5057E-02	C.6217E-03	-0.1365E 01	0.8602E 01	0.2448E 04	-0.4428E 03	0.2669E-02	-0.1543E-C2
11	0.0	0.0	0.2500E-01	C.1961E-03	0.0	0.8733E 01				

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J=  180        TIME (SEC.) =    0.174557E-C3
TOTAL ENERGY INPUT (IN.-LB.)  =     0.224440E 04
    KINETIC ENERGY (IN.-LB.)  =     0.150501E 04
    ELASTIC ENERGY (IN.-LB.)  =     0.139422E 03
    PLASTIC WORK    (IN.-LB.)  =     0.358447E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)   =    0.241517E 03
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.1874E 00	0.5036E-01	-0.1520E 00	-C.1234E-01	-0.8783E 01	0.1874E 00	0.2699E 03	-0.1235E 03	0.4247E-02	-0.3920E-02
2	0.1817E 00	-0.8044E-01	-0.5006E-01	-0.6246E-03	-0.8518E 01	0.1533E 01	0.5662E 03	-0.2982E 03	0.1179E-01	-0.1090E-01
3	0.1862E 00	0.2946E-01	0.1898E 00	-C.1251E-01	-0.8276E 01	0.2885E 01	0.3617E 03	-0.1697E 03	0.3688E-02	-0.3081E-02
4	0.1112E 00	0.4009E 00	0.2510E 00	-C.2790E-01	-0.8088E 01	0.4246E 01	0.8291E 03	0.5268E 03	-0.2443E-01	0.3837E-01
5	0.3315E-01	0.3557E 00	-0.2544E 00	-C.3374E-01	-0.7333E 01	0.5369E 01	0.1991E 04	-0.3611E 03	0.7045E-02	-0.4339E-02
6	-0.3349E-01	0.2441E-01	-0.1727E 00	-C.9151E-02	-0.6216E C1	0.6169E 01	0.2016E 04	-0.7901E 03	0.1374E-01	-0.1130E-01
7	-0.2895E-01	-0.7727E-01	-0.8704E-02	0.2660E-03	-0.5111E 01	0.6986E 01	0.1989E 04	-0.3908E 03	0.3532E-02	-0.2379E-02
8	-0.1686E-01	-0.6245E-01	0.2660E-01	-C.6178E-04	-0.3951E 01	0.7718E 01	0.1382E 04	0.2441E 03	-0.1194E-02	0.1931E-02
9	-0.9194E-02	-0.3668E-01	0.9443E-02	C.2501E-03	-0.2696E 01	0.8268E 01	0.1976E 04	-0.2517E 01	0.5015E-03	0.4739E-03
10	-0.3214E-02	-0.3118E-01	0.9587E-02	0.5910E-03	-0.1364E 01	0.8594E 01	0.2443E 04	-0.4719E 03	0.2806E-02	-0.1683E-02
11	0.0	0.0	0.3084E-01	-C.1973E-04	0.0	0.8733E 01				

J= 210 TIME (SEC.) = 0.203650E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.259502E 04
KINETIC ENERGY (IN.-LB.) = 0.162847E 04
ELASTIC ENERGY (IN.-LB.) = 0.148383E 03
PLASTIC WORK (IN.-LB.) = 0.428704E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.389458E 03

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.2567E 00	0.5313E-01	-0.1864E 00	-0.1869E-01	-0.8786E 01	0.2567E 00	0.2741E 03	-0.1632E 03	0.5561E-02	-0.5230E-02
2	0.2478E 00	-0.1079E 00	-0.5190E-01	0.3961E-03	-0.8480E 01	0.1594E 01	0.5661E 03	-0.3178E 03	0.1458E-01	-0.1331E-01
3	0.2474E 00	0.6366E-01	0.2432E 00	-0.2482E-01	-0.8290E 01	0.2954E 01	0.1078E 04	-0.6788E 02	0.2196E-02	-0.9533E-03
4	0.1488E 00	0.4920E 00	0.2711E 00	-0.3356E-01	-0.8152E 01	0.4321E 01	0.1353E 04	0.5258E 03	-0.2704E-01	0.4467E-01
5	0.5261E-01	0.4420E 00	-0.3056E 00	-0.4728E-01	-0.7392E 01	0.5435E 01	0.1938E 04	-0.4413E 03	0.7915E-02	-0.5246E-02
6	-0.3885E-01	0.4995E-01	-0.2111E 00	-0.1670E-01	-0.6238E 01	0.6183E 01	0.1310E 04	-0.8153E 03	0.1547E-01	-0.1318E-01
7	-0.3862E-01	-0.9814E-01	-0.2349E-01	0.2174E-03	-0.5107E 01	0.6963E 01	0.1375E 04	-0.5167E 03	0.4306E-02	-0.3508E-02
8	-0.2239E-01	-0.9323E-01	0.2318E-01	-0.1113E-03	-0.3942E 01	0.7688E 01	0.9389E 03	0.9198E 01	0.1916E-03	0.3094E-03
9	-0.1018E-01	-0.6316E-01	0.2253E-01	-0.9441E-04	-0.2689E 01	0.8242E 01	0.1038E 04	-0.4553E 02	0.5058E-03	0.6157E-05
10	-0.2634E-02	-0.3230E-01	0.2507E-01	0.4149E-04	-0.1364E 01	0.8593E 01	0.1684E 04	0.7111E 02	0.4893E-04	0.7253E-03
11	0.0	0.0	0.2187E-01	0.1871E-03	0.0	0.8733E 01				

J= 240 TIME (SEC.) = 0.232743E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.289018E 04
KINETIC ENERGY (IN.-LB.) = 0.164950E 04
ELASTIC ENERGY (IN.-LB.) = 0.160042E 03
PLASTIC WORK (IN.-LB.) = 0.506054E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.574586E 03

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3239E 00	0.3345E-01	-0.1784E 00	-0.1703E-01	-0.8766E 01	0.3239E 00	0.3194E 03	-0.1493E 03	0.5295E-02	-0.4816E-02
2	0.3170E 00	-0.1267E 00	-0.5259E-01	0.3041E-02	-0.8451E 01	0.1659E 01	0.7329E 03	-0.3133E 03	0.1756E-01	-0.1434E-01
3	0.3107E 00	0.9999E-01	0.2849E 00	-0.3646E-01	-0.8305E 01	0.3025E 01	0.1544E 04	0.2435E 01	0.1154E-02	0.5041E-03
4	0.1861E 00	0.5865E 00	0.2897E 00	-0.3788E-01	-0.8219E 01	0.4397E 01	0.1975E 04	0.5078E 03	-0.2827E-01	0.4944E-01
5	0.7250E-01	0.5261E 00	-0.3352E 00	-0.5694E-01	-0.7448E 01	0.5501E 01	0.2356E 04	-0.3328E 03	0.6860E-02	-0.3898E-02
6	-0.4458E-01	0.8114E-01	-0.2581E 00	-0.2751E-01	-0.6264E 01	0.6201E 01	0.2306E 04	-0.7715E 03	0.1961E-01	-0.1399E-01
7	-0.4948E-01	-0.1139E 00	-0.3800E-01	0.2438E-03	-0.5106E 01	0.6944E 01	0.1917E 04	-0.5795E 03	0.4938E-02	-0.3826E-02
8	-0.2878E-01	-0.1292E 00	0.1434E-01	0.2877E-03	-0.3932E 01	0.7653E 01	0.1504E 04	-0.4035E 03	0.2984E-02	-0.2181E-02
9	-0.1102E-01	-0.9149E-01	0.4271E-01	-0.5966E-03	-0.2681E 01	0.8215E 01	0.1012E 04	0.1347E 03	-0.4893E-03	0.9885E-03
10	-0.2145E-02	-0.3446E-01	0.3519E-01	-0.4914E-03	-0.1363E 01	0.8591E 01	0.5370E 03	0.3530E 03	-0.1556E-02	0.1803E-02
11	0.0	0.0	0.1929E-01	-0.5973E-04	0.0	0.8733E 01				

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J=  270        TIME (SEC.) =     0.261835E-C3
TOTAL ENERGY INPUT (IN.-LB.)  =     0.311976E 04
    KINETIC ENERGY (IN.-LB.)  =     0.159222E 04
    ELASTIC ENERGY (IN.-LB.)  =     0.183684E 03
    PLASTIC WORK   (IN.-LB.)  =     0.553567E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)   =    0.790289E 03
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.3914E 00	-0.1018E-03	-0.1764E 00	-C.1665E-01	-0.8733E 01	0.3914E 00	-0.5000E 02	-0.1589E 03	0.5386E-02	-0.5356E-02
2	0.3898E 00	-0.1332E 00	-0.4261E-01	0.2684E-02	-0.8433E 01	0.1730E 01	-0.3315E 02	-0.3278E 03	0.1860E-01	-0.1653E-01
3	C.3743E 00	0.1394E 00	0.3291E 00	-0.5072E-01	-0.8322E 01	0.3098E 01	0.5682E 03	0.9147E 02	-0.8627E-03	0.1654E-C2
4	0.2251E 00	0.6733E 00	0.3049E 00	-0.4336E-01	-0.8279E 01	0.4471E 01	0.5557E 03	0.5390E 03	-0.3142E-01	0.5127E-01
5	C.9302E-01	0.6059E 00	-0.3599E 00	-0.6588E-01	-0.7501E 01	0.5565E 01	0.1844E 04	-0.2310E 03	0.5554E-02	-0.2949E-02
6	-0.4880E-01	0.1181E 00	-0.2993E 00	-C.3944E-01	-0.6293E 01	0.6224E 01	0.1784E 04	-0.7471E 03	0.2126E-01	-0.1455E-C1
7	-0.6276E-01	-0.1267E 00	-0.6460E-01	-C.1249E-02	-0.5109E 01	0.6926E 01	0.2437E 04	-0.7655E 03	0.7476E-02	-0.5515E-02
8	-0.3752E-01	-0.1690E 00	0.1300E-01	C.1021E-02	-0.3921E 01	0.7614E 01	0.2798E 04	-0.6420E 03	0.4855E-02	-0.3362E-02
9	-0.1440E-01	-0.1169E 00	0.5813E-01	-C.1052E-02	-0.2676E 01	0.8190E 01	0.2420E 04	0.2719E 03	-0.8948E-03	0.2089E-C2
10	-0.3178E-02	-0.4435E-01	0.4294E-01	-0.4286E-03	-0.1362E 01	0.8581E 01	0.2374E 04	0.3595E 03	-0.1164E-02	0.2256E-02
11	0.0	0.0	0.2676E-01	C.1092E-03	0.0	0.8733E 01				

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J=  300        TIME (SEC.) =     0.290928E-C3
TOTAL ENERGY INPUT (IN.-LB.)  =     0.329408E 04
    KINETIC ENERGY (IN.-LB.)  =     0.147862E 04
    ELASTIC ENERGY (IN.-LB.)  =     0.177128E 03
    PLASTIC WORK   (IN.-LB.)  =     0.611C50E 03
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.)   =    0.102728E 04
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I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.4513E 00	-0.5052E-01	-0.1373E 00	-C.1039E-01	-0.8682E 01	0.4513E 00	0.7007E 02	-0.1387E 03	0.4792E-02	-0.4616E-02
2	0.4589E 00	-0.1324E 00	-0.2005E-01	C.3635E-02	-0.8423E 01	0.1799E 01	-0.1964E 03	-0.3185E 03	0.1838E-01	-0.1645E-C1
3	0.4349E 00	0.1816E 00	0.3484E 00	-0.5739E-01	-0.8344E 01	0.3168E 01	0.4843E 03	0.1047E 03	-0.1134E-02	0.1851E-02
4	0.2645E 00	0.7540E 00	0.3198E 00	-0.4807E-01	-0.8333E 01	0.4543E 01	0.7507E 03	0.5432E 03	-0.3307E-01	0.5473E-01
5	0.1162E 00	0.6807E 00	-0.3859E 00	-C.7576E-01	-0.7548E 01	0.5627E 01	0.1780E 04	-0.2120E 03	0.5320E-02	-0.2759E-02
6	-C.4803E-01	0.1594E 00	-0.3283E 00	-0.4883E-01	-0.6322E 01	0.6254E 01	0.1527E 04	-0.6142E 03	0.1997E-01	-0.1343E-01
7	-0.7442E-01	-0.1404E 00	-0.1094E 00	-C.4882E-02	-0.5111E 01	0.6908E 01	0.2022E 04	-0.9240E 03	0.1192E-01	-0.1013E-01
8	-0.4565E-01	-0.2054E 00	0.2237E-01	C.6824E-03	-0.3912E 01	0.7577E 01	0.2018E 04	-0.5717E 03	0.4198E-02	-0.3120E-02
9	-0.1833E-01	-0.1440E 00	0.6255E-01	-0.1470E-02	-0.2672E 01	0.8163E 01	0.2282E 04	0.1865E 03	-0.4603E-03	0.1587E-02
10	-0.3947E-02	-0.6330E-01	0.5213E-01	-C.8964E-03	-0.1360E 01	0.8562E 01	0.1833E 04	0.1857E 03	-0.4620E-03	0.1305E-02
11	C.0	0.0	0.4377E-01	-0.5169E-03	0.0	0.8733E 01				

J= 570 TIME (SEC.) = 0.552763E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.351680E 04
KINETIC ENERGY (IN.-LB.) = 0.242508E 03
ELASTIC ENERGY (IN.-LB.) = 0.196965E 03
PLASTIC WORK (IN.-LB.) = 0.100965E 04
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.206768E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.6884E 00	-0.4602E 00	0.2987E 00	-0.4442E-01	-0.8273E 01	0.6884E 00	-0.9423E 02	0.6414E 02	-0.2012E-02	0.1990E-02
2	0.6673E 00	0.3183E-01	0.2486E 00	-0.2986E-01	-0.8553E 01	0.2030E 01	0.3564E 03	0.2009E 03	0.3029E-02	-0.2694E-03
3	0.5887E 00	0.4700E 00	0.2837E 00	-0.3676E-01	-0.8571E 01	0.3404E 01	0.8587E 03	-0.2470E 02	0.1331E-02	-0.2827E-03
4	0.4111E 00	0.9732E 00	0.2980E 00	-0.4409E-01	-0.8462E 01	0.4773E 01	0.3931E 03	-0.1419E 03	-0.2651E-01	0.4692E-01
5	0.2350E 00	0.9788E 00	-0.2924E 00	-0.4304E-01	-0.7719E 01	0.5899E 01	0.4517E 02	0.5884E 03	-0.9744E-02	0.9777E-02
6	0.1301E-01	0.4610E 00	-0.4343E 00	-0.9120E-01	-0.6492E 01	0.6510E 01	0.4374E 03	0.4401E 03	0.9923E-02	-0.4146E-02
7	-0.1188E 00	-0.9116E-01	-0.3424E 00	-0.5815E-01	-0.5176E 01	0.6922E 01	-0.2011E 03	-0.7321E 03	0.1701E-01	-0.1756E-01
8	-0.1135E 00	-0.4306E 00	-0.1357E 00	-0.7183E-02	-0.3870E 01	0.7346E 01	0.7160E 03	-0.1191E 04	0.2425E-01	-0.1854E-01
9	-0.3956E-01	-0.4559E 00	0.9976E-01	-0.4594E-02	-0.2595E 01	0.7860E 01	0.4483E 03	-0.1093E 04	0.7585E-02	-0.7234E-02
10	0.3636E-02	-0.2597E 00	0.1751E 00	-0.1537E-01	-0.1322E 01	0.8370E 01	0.4058E 03	-0.4563E 03	0.2263E-02	-0.2077E-02
11	0.0	0.0	0.1956E 00	-0.1923E-01	0.0	0.8733E 01				

J= 600 TIME (SEC.) = 0.581856E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.351680E 04
KINETIC ENERGY (IN.-LB.) = 0.310412E 03
ELASTIC ENERGY (IN.-LB.) = 0.202702E 03
PLASTIC WORK (IN.-LB.) = 0.106403E 04
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.193966E 04

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.6615E 00	-0.4329E 00	0.2905E 00	-0.4203E-01	-0.8300E 01	0.6615E 00	-0.4352E 02	0.6837E 02	-0.2122E-02	0.2161E-02
2	0.6405E 00	0.4305E-01	0.2369E 00	-0.2687E-01	-0.8568E 01	0.2006E 01	0.5594E 03	0.2033E 03	0.3029E-02	-0.7538E-04
3	0.5657E 00	0.4614E 00	0.2700E 00	-0.3291E-01	-0.8570E 01	0.3379E 01	0.1304E 04	-0.5051E 02	0.1988E-02	-0.5437E-03
4	0.3963E 00	0.9450E 00	0.2927E 00	-0.4257E-01	-0.8443E 01	0.4747E 01	0.8297E 03	-0.2487E 03	-0.2486E-01	0.4561E-01
5	0.2266E 00	0.9614E 00	-0.2739E 00	-0.3733E-01	-0.7710E 01	0.5882E 01	0.1549E 03	0.5956E 03	-0.9787E-02	0.9896E-02
6	0.1543E-01	0.4690E 00	-0.4170E 00	-0.8351E-01	-0.6496E 01	0.6518E 01	0.6511E 03	0.5457E 03	0.7679E-02	-0.2279E-02
7	-0.1155E 00	-0.7423E-01	-0.3519E 00	-0.6158E-01	-0.5183E 01	0.6937E 01	-0.3792E 03	-0.5286E 03	0.1542E-01	-0.1607E-01
8	-0.1176E 00	-0.4431E 00	-0.1637E 00	-0.1128E-01	-0.3868E 01	0.7333E 01	0.9414E 03	-0.1182E 04	0.2882E-01	-0.2051E-01
9	-0.3974E-01	-0.4845E 00	0.1079E 00	-0.4816E-02	-0.2587E 01	0.7833E 01	0.5795E 03	-0.1136E 04	0.7919E-02	-0.7476E-02
10	0.5077E-02	-0.2745E 00	0.1861E 00	-0.1716E-01	-0.1318E 01	0.8355E 01	0.1129E 04	-0.4384E 03	0.2345E-02	-0.1826E-02
11	0.0	0.0	0.2058E 00	-0.2105E-01	0.0	0.8733E 01				

J= 870 TIME (SEC.) = 0.843692E-03
TOTAL ENERGY INPUT (IN.-LB.) = 0.351680E 04
KINETIC ENERGY (IN.-LB.) = 0.172693E 04
ELASTIC ENERGY (IN.-LB.) = 0.203944E 03
PLASTIC WORK (IN.-LB.) = 0.133835E 04
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.247585E 03

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.2145E 00	0.2909E 00	-0.2380E 00	-0.2880E-01	-0.9024E 01	0.2145E 00	0.2421E 03	-0.7088E 02	0.2656E-02	-0.2269E-02
2	0.1577E 00	0.1457E-01	-0.1767E 00	-C.1436E-01	-0.8615E 01	0.1524E 01	0.6040E 03	-0.2739E 03	0.1428E-01	-0.1120E-01
3	C.1605E 00	-0.3385E-01	0.9285E-01	-C.5426E-03	-0.8224E 01	0.2841E 01	0.9581E 03	-0.4154E 03	0.1675E-01	-0.1376E-01
4	C.9800E-01	0.3255E 00	0.3725E 00	-0.7279E-01	-0.8027E 01	0.4200E 01	0.9806E 03	-0.3885E 03	-0.1782E-01	0.3924E-01
5	0.9727E-02	0.5101E 00	-0.8628E-01	-C.2522E-02	-0.7472E 01	0.5441E 01	-0.1142E 04	0.5527E 03	-0.9871E-02	0.9022E-02
6	-0.7572E-01	0.2593E 00	-0.2232E 00	-0.2073E-01	-0.6412E 01	0.6305E 01	0.5703E 03	0.7730E 03	-0.1921E-02	0.7388E-02
7	-0.1316E 00	-0.1148E 00	-0.2841E 00	-0.4044E-01	-0.5172E 01	0.6895E 01	0.1651E 03	0.3227E 03	0.9145E-02	-0.9473E-02
8	-0.1214E 00	-0.4474E 00	-0.1729E 00	-C.1356E-01	-0.3870E C1	0.7327E 01	-0.2768E 03	-0.5534E 03	0.2880E-01	-0.1907E-01
9	-0.4023E-01	-0.5268E 00	0.9057E-01	-0.1598E-02	-0.2574E 01	0.7792E 01	-0.9490E 02	-0.9984E 03	0.1168E-01	-0.1159E-01
10	0.9837E-02	-0.3088E 00	0.2088E 00	-0.2176E-01	-0.1308E 01	0.8322E 01	-0.1258E 02	-0.5124E 03	0.2434E-02	-0.2440E-C2
11	0.0	0.0	0.2318E 00	-0.2703E-01	0.0	0.8733E 01				

J= 900 TIME (SEC.) = 0.872784E-C3
TOTAL ENERGY INPUT (IN.-LB.) = 0.351680E 04
KINETIC ENERGY (IN.-LB.) = 0.180109E 04
ELASTIC ENERGY (IN.-LB.) = 0.185895E 03
PLASTIC WORK (IN.-LB.) = 0.136080E 04
ENERGY STORED IN THE ELASTIC RESTRAINTS (IN.-LB.) = 0.169010E 03

I	V	W	PSI	CHI	COPY	COPZ	L	M	STRAIN(IN)	STRAIN(OUT)
1	0.1711E 00	0.3490E 00	-0.2841E 00	-0.4085E-01	-0.9082E 01	0.1711E 00	0.1308E 03	-0.7786E 02	0.2818E-02	-0.2567E-02
2	0.9598E-01	0.4623E-02	-0.2172E 00	-0.2237E-01	-0.8615E 01	0.1462E 01	0.2530E 03	-0.2798E 03	0.1431E-01	-0.1168E-01
3	0.1012E 00	-0.1063E 00	0.5776E-01	C.2421E-02	-0.8173E 01	0.2762E 01	0.6631E 03	-0.4229E 03	0.2012E-01	-0.1603E-C1
4	0.5387E-01	0.2337E 00	0.3893E 00	-C.8005E-01	-0.7965E 01	0.4119E 01	0.9828E 03	-0.3781E 03	-0.1796E-01	0.3938E-01
5	-0.2454E-01	0.4336E 00	-0.7170E-01	-0.1668E-02	-0.7430E 01	0.5368E 01	-0.1350E 04	0.5013E 03	-0.9374E-02	0.8381E-02
6	-0.9498E-01	0.2059E 00	-0.2003E 00	-C.1593E-01	-0.6388E 01	0.6254E 01	0.2267E 03	0.7732E 03	-0.2218E-02	0.7362E-02
7	-0.1375E 00	-0.1404E 00	-0.2631E 00	-0.3485E-01	-0.5162E 01	0.6871E 01	-0.3127E 03	0.3730E 03	0.8626E-02	-0.9231E-02
8	-0.1197E 00	-0.4465E 00	-0.1564E 00	-0.1096E-01	-0.3869E 01	0.7329E 01	-0.6336E 03	-0.4086E 03	0.2778E-01	-0.1823E-01
9	-0.3929E-01	-0.5095E 00	0.9691E-01	-C.2365E-02	-0.2579E 01	0.7809E 01	-0.6254E 03	-0.7642E 03	0.1026E-01	-0.1044E-01
10	0.7817E-02	-0.2917E 00	0.2021E 00	-0.2052E-01	-0.1313E 01	0.8339E 01	-0.6100E 03	-0.3218E 03	0.1390E-02	-0.1671E-02
11	0.0	0.0	0.2165E 00	-C.2368E-01	0.0	0.8733E 01				

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1. McCallum, R.B., Leech, J.W., and Witmer, E.A., "Progress in the Analysis of Jet Engine Burst-Rotor Containment Devices", ASRL TR 154-1, Aeroelastic and Structures Research Laboratory, MIT, August 1969. (Available as NASA CR-107900.)

2. McCallum, R.B., Leech, J.W., and Witmer, E.A., "On the Interaction Forces and Responses of Structural Rings Subjected to Fragment Impact". ASRL TR 154-2, Aeroelastic and Structures Research Laboratory, MIT, Sept. 1970. (Available as NASA CR-72801.)

3. Wu, R. W-H., and Witmer, E.A., "Finite-Element Analysis of Large Transient Elastic-Plastic Deformations of Simple Structures, with Application to the Engine Rotor Fragment Containment/Deflection Problem", ASRL TR 154-4, Aeroelastic and Structures Research Laboratory, MIT, January 1972 (Available as NASA CR-120886.).

4. Stricklin, J.A., Martinez, J.E., Tillerson, J.R., Hong, J.H., and Haisler, W.E., "Nonlinear Dynamic Analysis of Shells of Revolution by the Matrix Displacement Method". Dept. of Aerospace Eng., Texas A & M University, Report 60-77, Feb. 1970

UNIFORM THICKNESS
CIRCULAR PARTIAL RING

UNIFORM THICKNESS
CIRCULAR COMPLETE RING

VARIABLE THICKNESS
ARBITRARILY CURVED
PARTIAL RING

VARIABLE THICKNESS
ARBITRARILY CURVED
COMPLETE RING

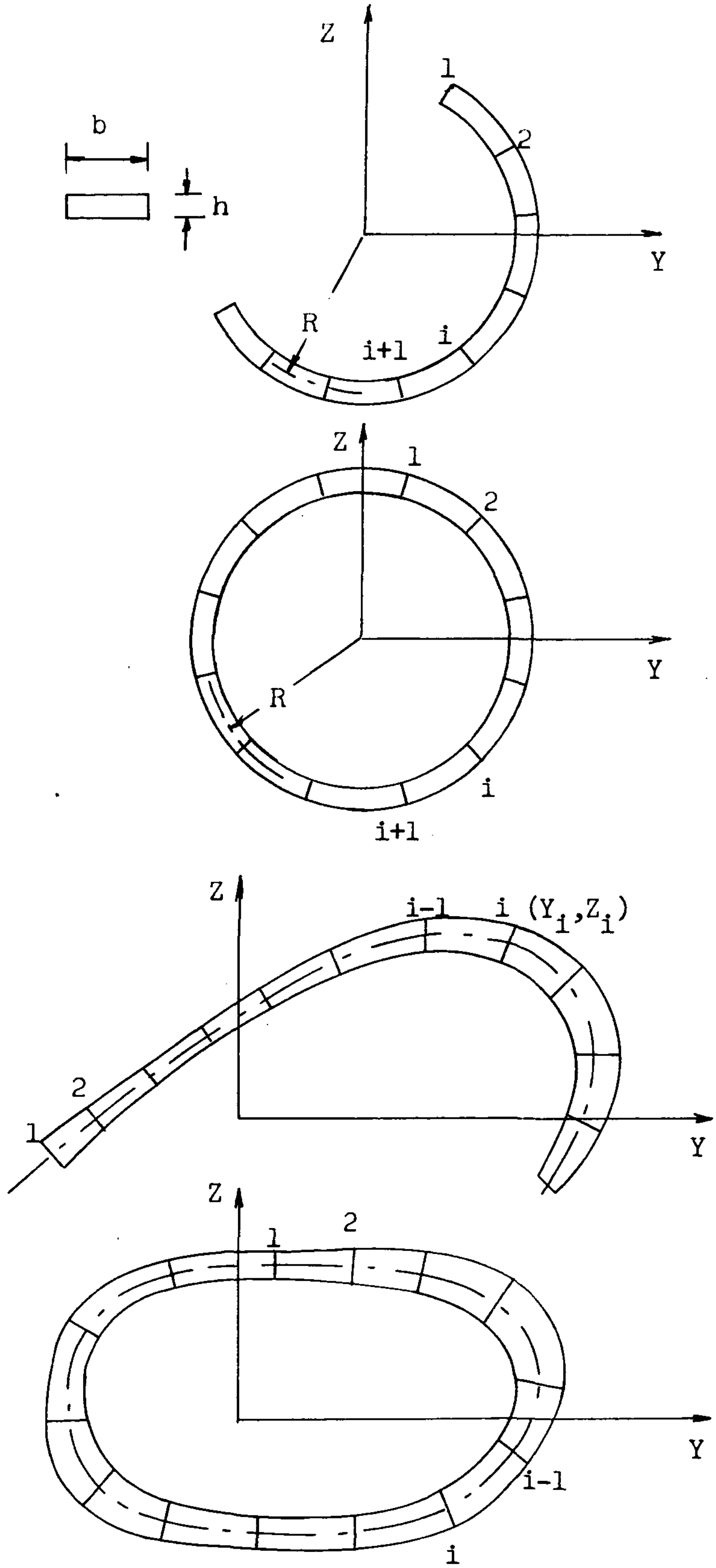
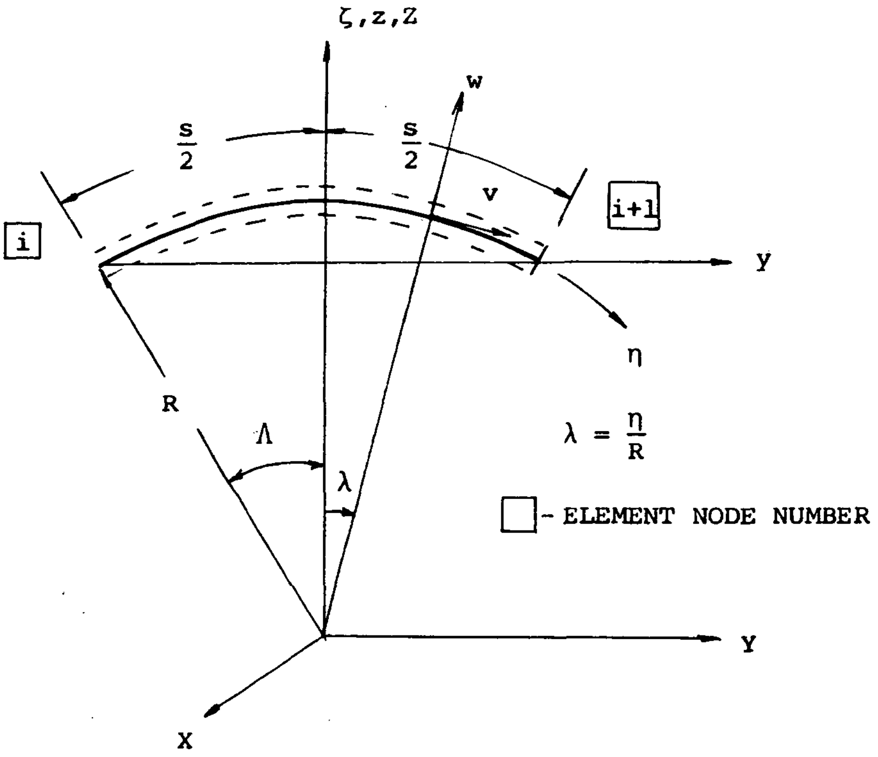
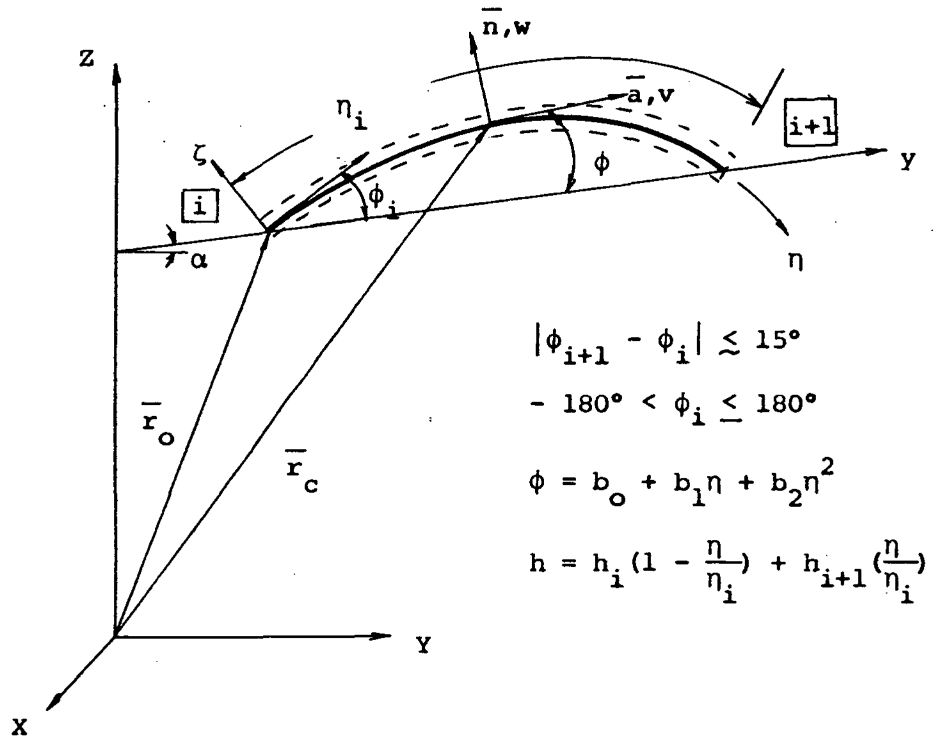


FIG. 1 GEOMETRICAL SHAPES OF THE STRUCTURAL RING

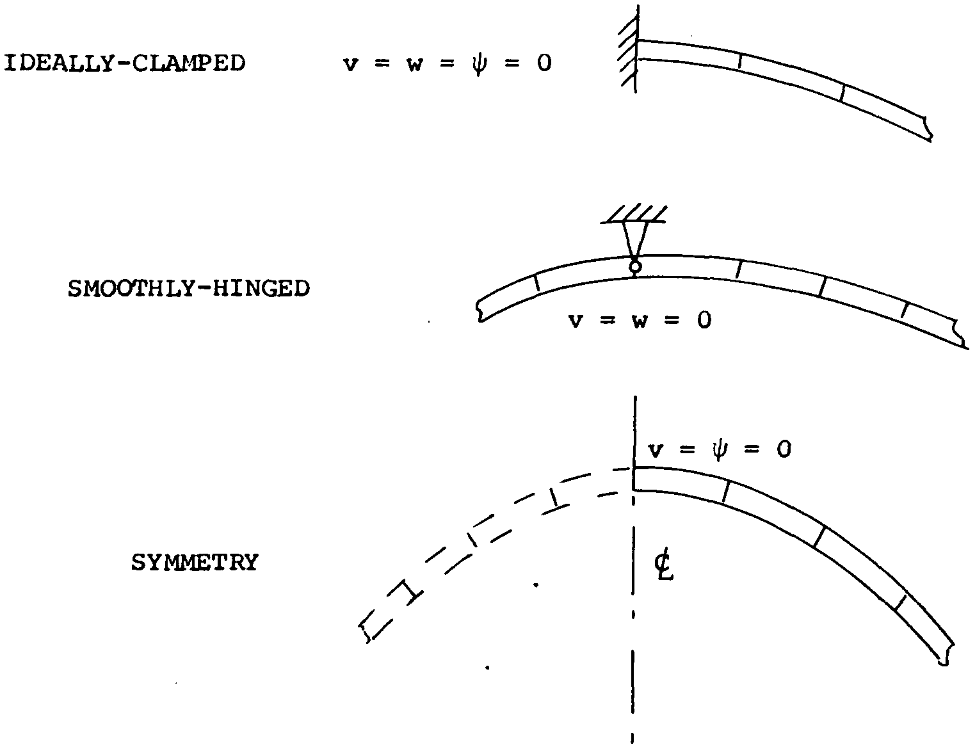


(a) Uniform Thickness Circular Ring Element

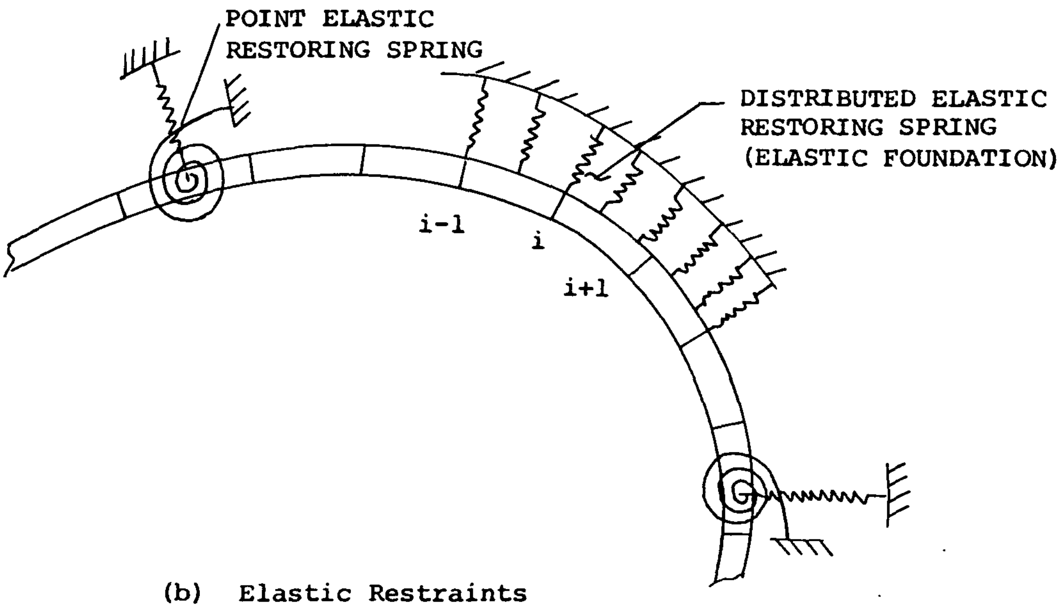


(b) Variable Thickness Arbitrarily-Curved Ring Element

FIG. 2 NOMENCLATURE FOR GEOMETRY, COORDINATES, AND DISPLACEMENTS OF CURVED-BEAM ELEMENTS



(a) Prescribed Displacement Conditions



(b) Elastic Restraints

FIG. 3 SCHEMATICS FOR THE SUPPORT CONDITIONS OF THE STRUCTURE

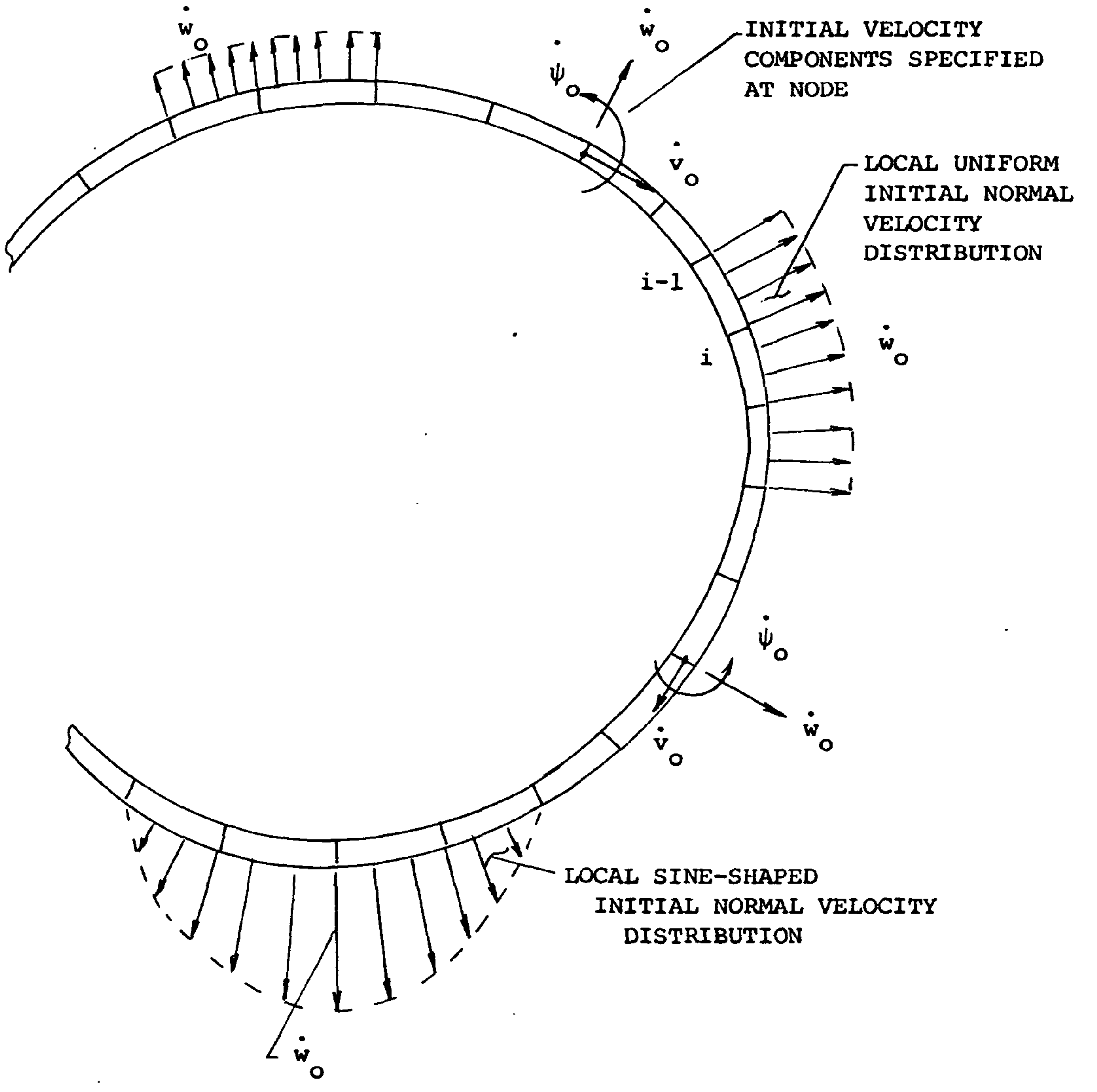
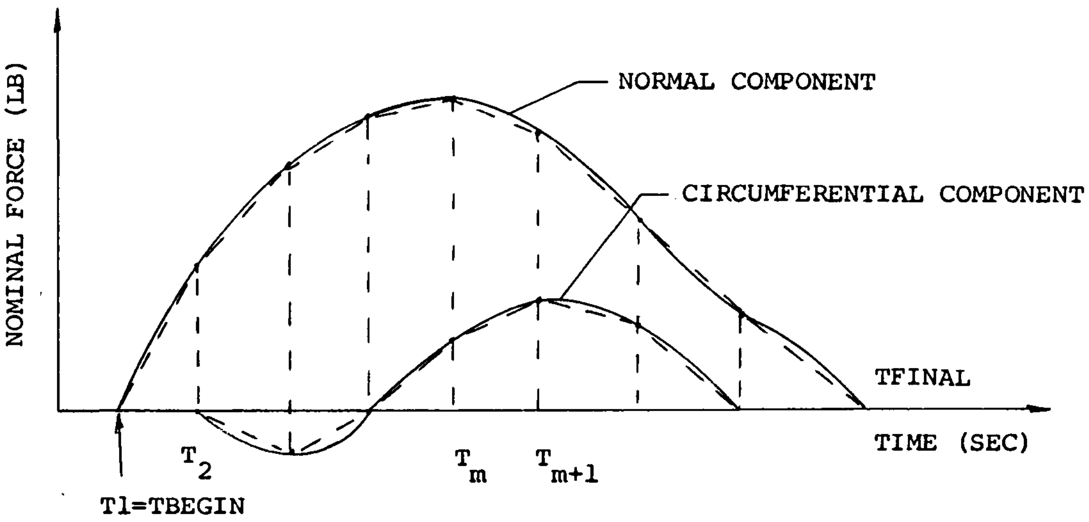
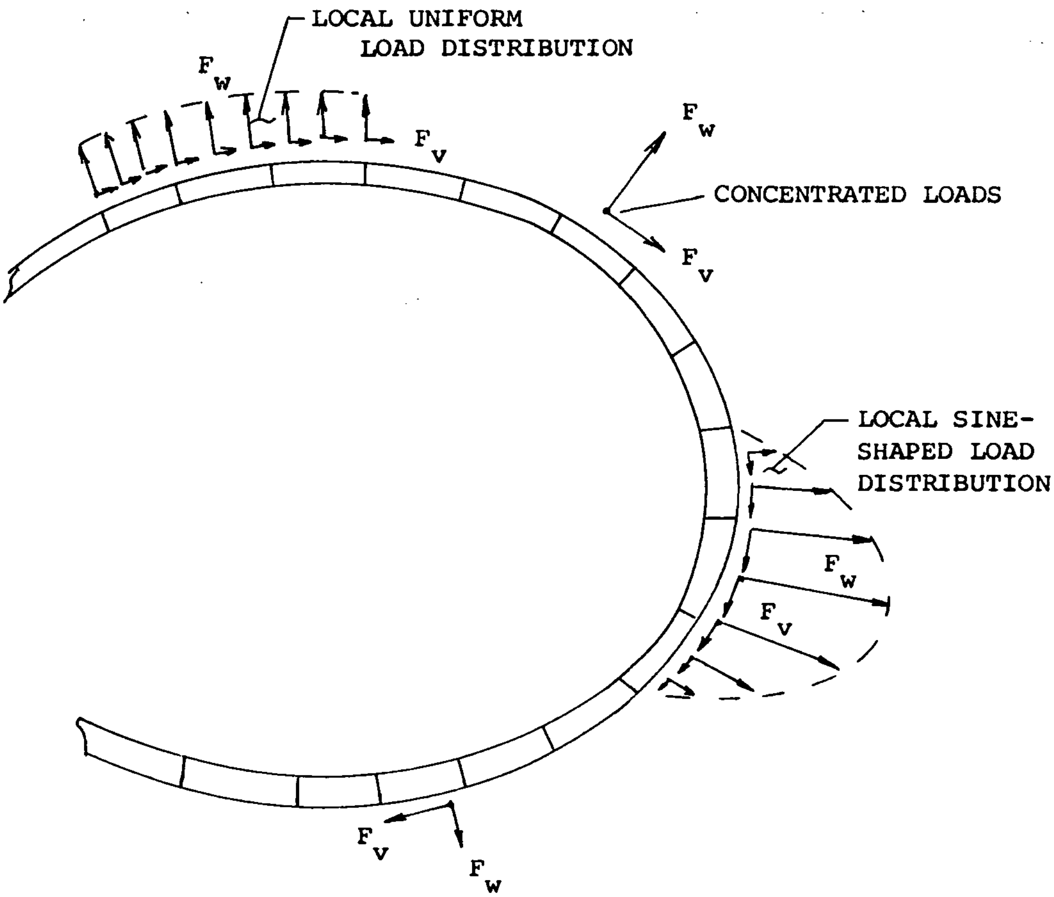


FIG. 4 SCHEMATIC OF INITIAL-VELOCITY PROVISIONS

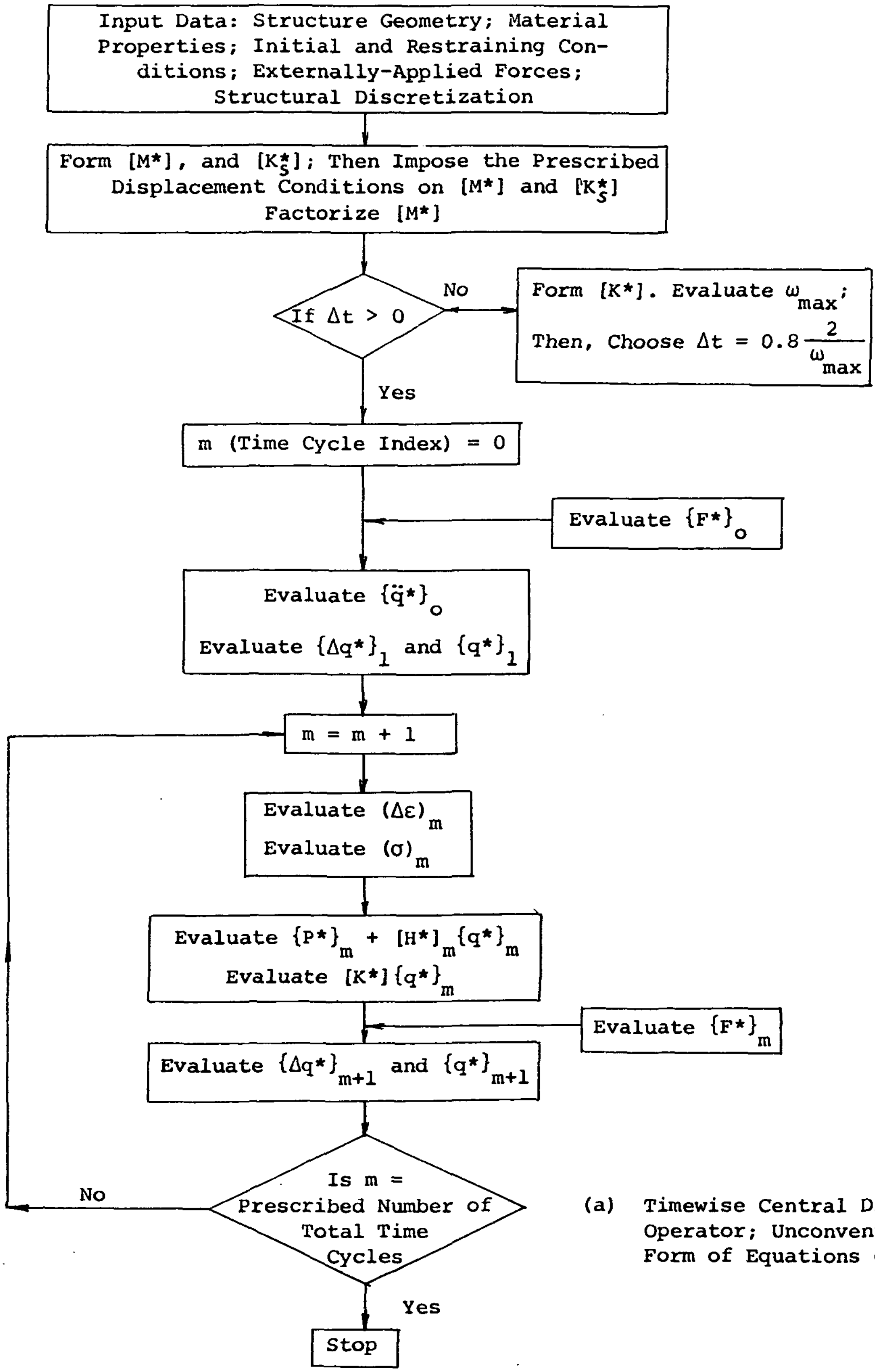


(a) "Nominal Force" Component Time History



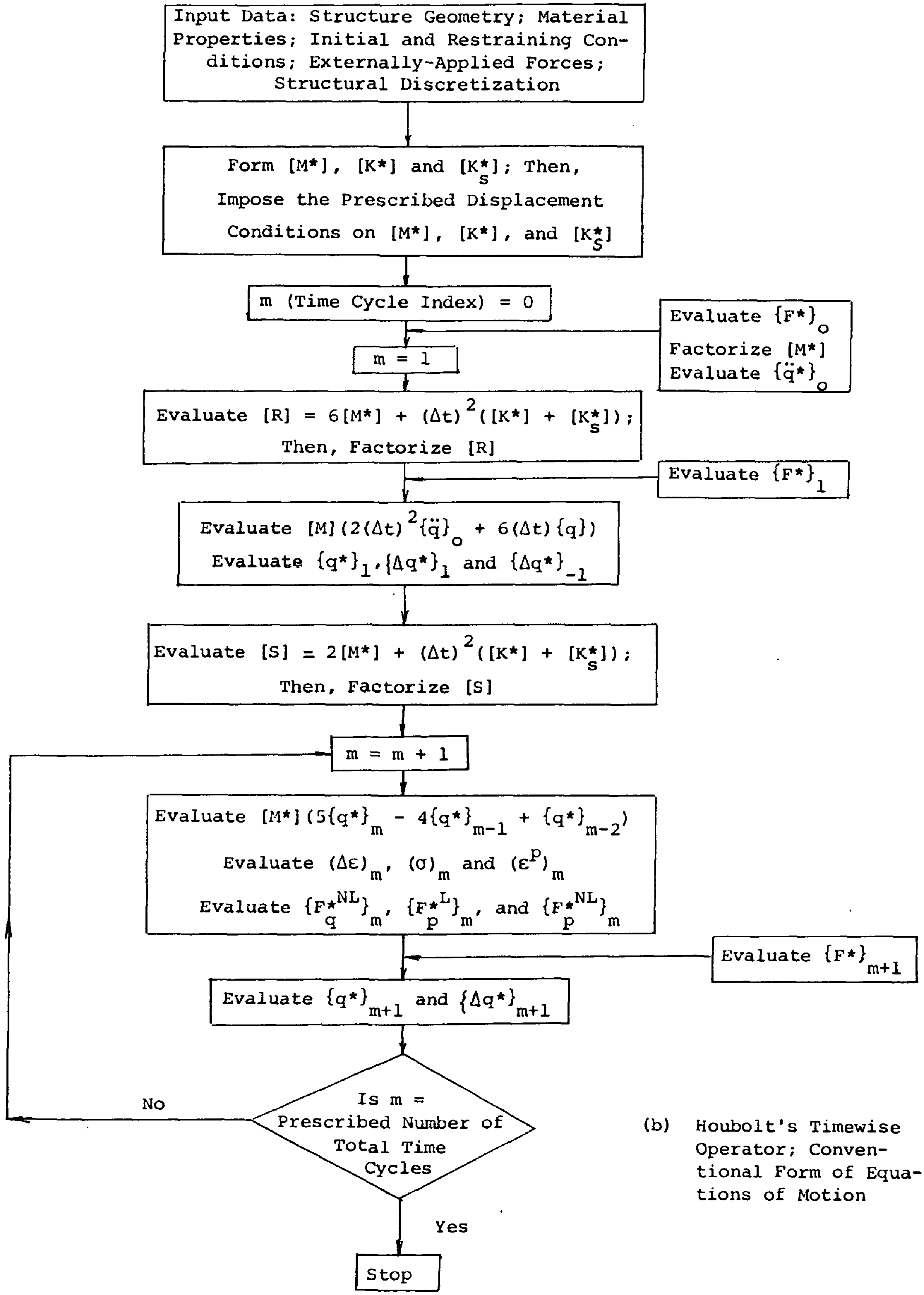
(b) Spatial Force Distribution

FIG. 5 TIME HISTORY AND SPATIAL DISTRIBUTIONS OF THE EXTERNALLY-APPLIED LOADINGS



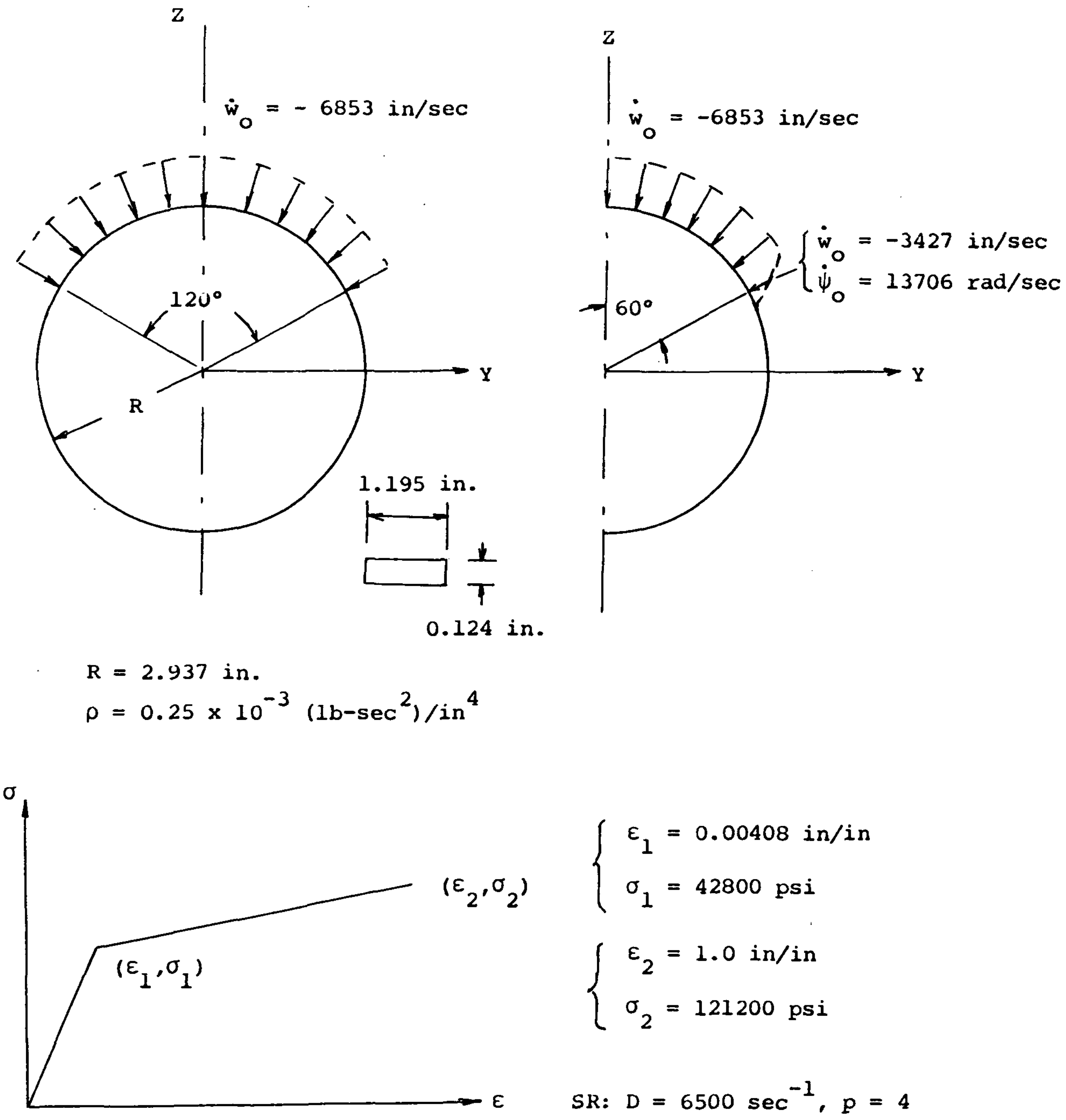
(a) Timewise Central Difference Operator; Unconventional Form of Equations of Motion

FIG. 6 FLOW CHART OF SOLUTION PROCESS FOR PREDICTING LARGE-DEFLECTION ELASTIC-PLASTIC TRANSIENT STRUCTURAL RESPONSES



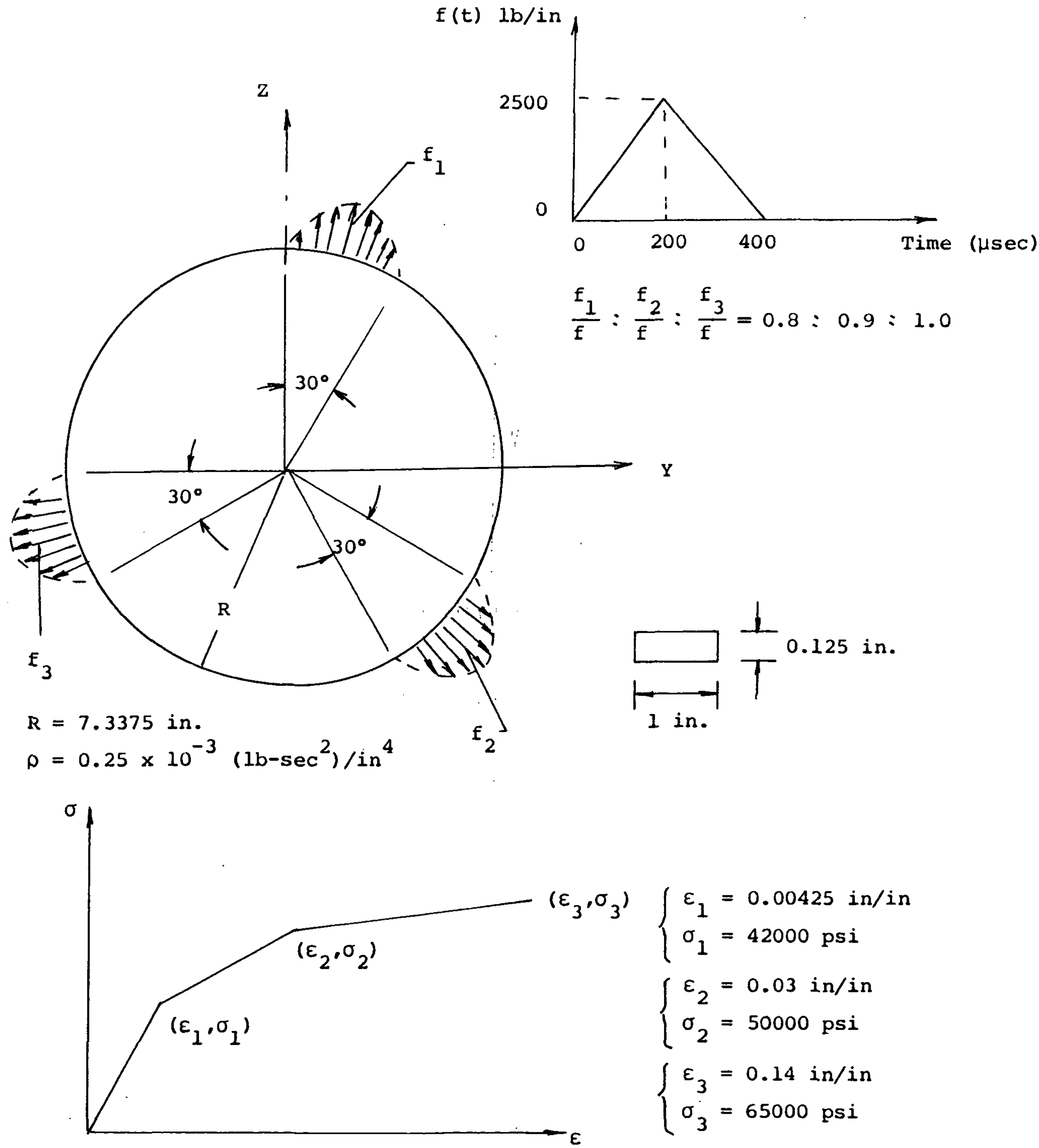
(b) Houbolt's Timewise Operator; Conventional Form of Equations of Motion

FIG. 6 CONCLUDED



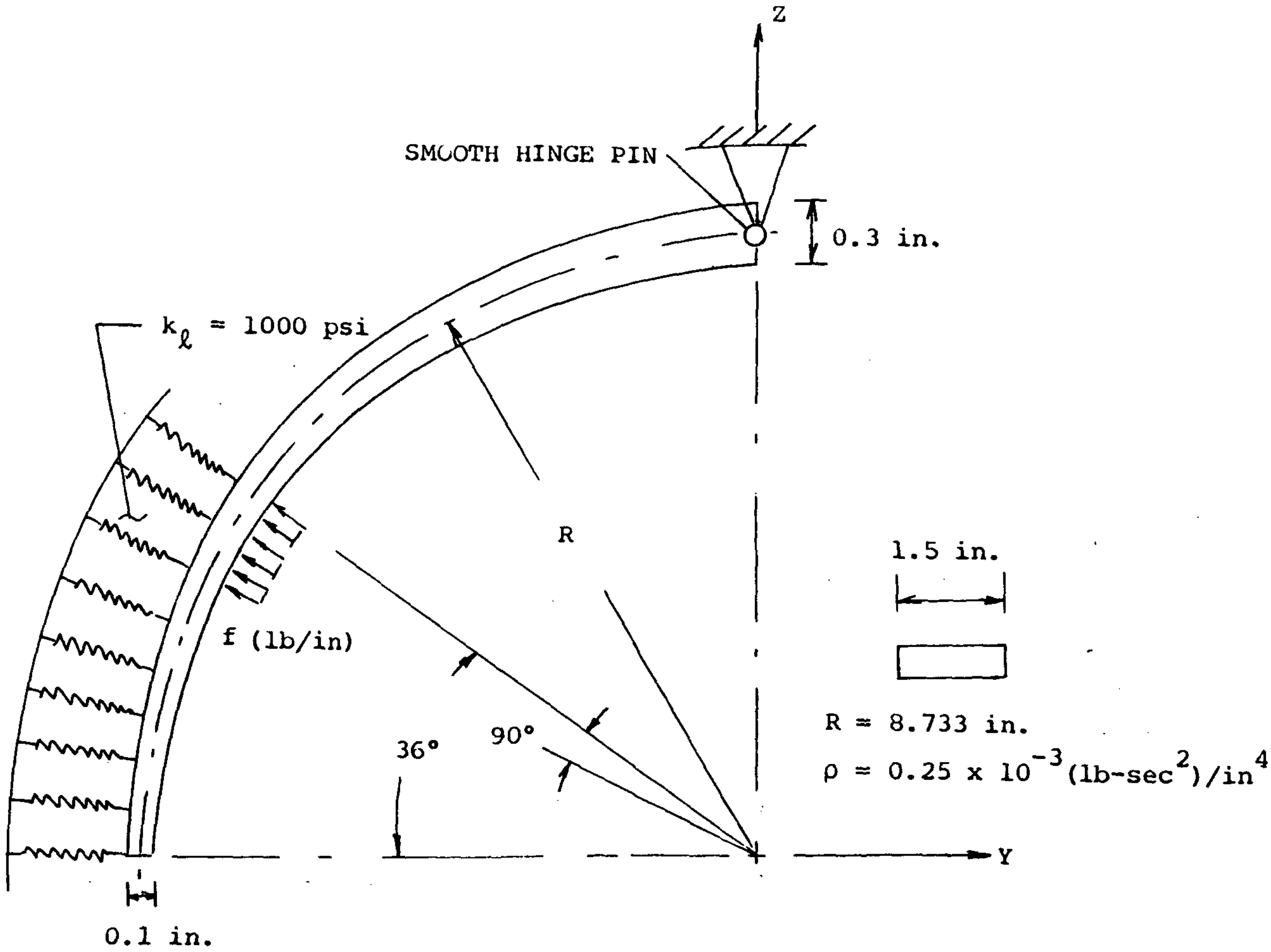
(a) Example 1

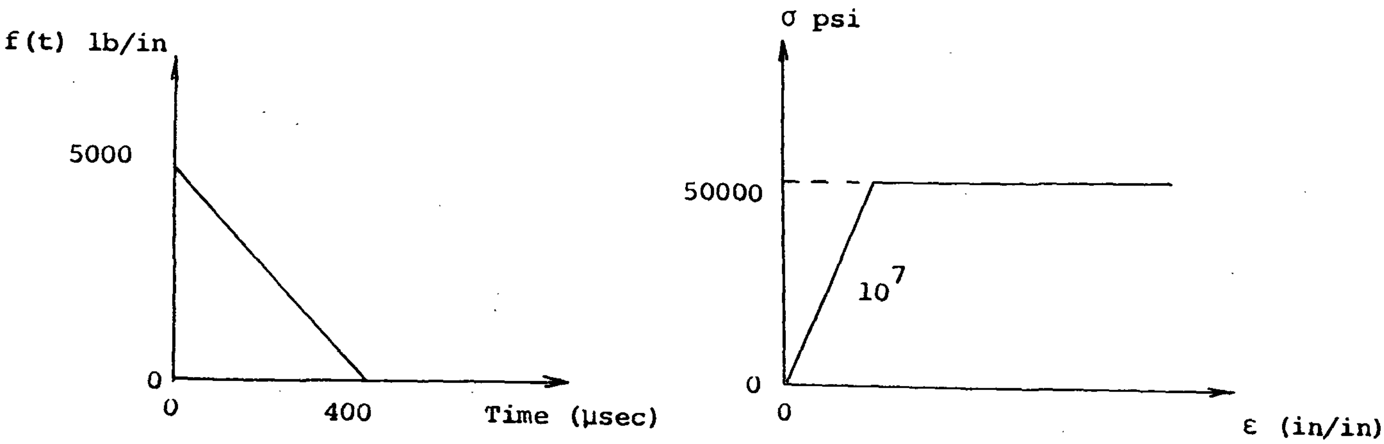
FIG. 7 CONFIGURATIONS AND PROBLEM DATA FOR ILLUSTRATIVE EXAMPLES IN SECTION 6.



(b) Example 2

FIG. 7 CONTINUED





(c) Example 3

FIG. 7 CONCLUDED

APPENDIX A

GOVERNING EQUATIONS ON WHICH THE PROGRAMS ARE BASED

A.1 Variable Thickness Arbitrarily-Curved Rings

The discrete element to be considered is a general curved beam element as shown in Fig. 2b. The slope, ϕ, of the centroidal axis, which is the angle between the tangent vector and the y-axis of the local reference Cartesian coordinate may be approximated by a second-order polynomial in η as follows:

$$\phi(\eta) = b_0 + b_1 \eta + b_2 \eta^2 \tag{A.1}$$

where η is the length coordinate measured from node i along the centroidal axis, and the constants b_o, b_1, and b_2 can be determined from the known initial geometry of the curved beam element. Assume that the change in element slope between nodes i and i+1 is small so that

$$\cos(\phi_{i+1} - \phi_i) \doteq 1 \tag{A.2a}$$

and

$$\sin(\phi_{i+1} - \phi_i) \doteq \phi_{i+1} - \phi_i \tag{A.2b}$$

This restricts the slope change within an element to $\lesssim$ 15 degrees. The arc length, η_i, of the element is approximated to be the same as the length of a circular arc passing through the nodal points at the slope ϕ_i and ϕ_{i+1}; η_i is given by

$$\eta_i = \frac{L_i\,(\phi_{i+1} - \phi_i)}{2\sin\left(\frac{\phi_{i+1} - \phi_i}{2}\right)} \tag{A.3a}$$

where L_i is the length of the chord joining nodes i and i+1 and is given by

$$L_i = \left[(Z_{i+1} - Z_i)^2 + (Y_{i+1} - Y_i)^2\right]^{\frac{1}{2}} \tag{A.3b}$$

The three constants in Eq. A.1 are then determined from the relations

$$\begin{aligned} \phi(\eta = 0) &= \phi_i \\ \phi(\eta = \eta_i) &= \phi_{i+1} \\ \int_0^{\eta_i} \sin\phi \, d\eta &\doteq \int_0^{\eta_i} \phi \, d\eta = 0 \end{aligned} \tag{A.4}$$

From Eq. A.4, the constants in Eq. A.1 are found to be

$$b_0 = \phi_i$$
$$b_1 = -2(\phi_{i+1} + 2\phi_i)/\eta_i \qquad \text{(A.5)}$$
$$b_2 = 3(\phi_{i+1} + \phi_i)/(\eta_i)^2$$

Accordingly, the radius of curvature, R, of the centroidal axis may be expressed as $R = -(d\phi/\partial\eta)^{-1} = -(b_1 + b_2\eta)^{-1}$, and the coordinates $Y(\eta)$ and $Z(\eta)$ of the centroidal axis are given by

$$Y(\eta) = Y_i + \int_0^\eta \cos[\phi(\eta) + \alpha]\, d\eta \qquad \text{(A.6a)}$$

and

$$Z(\eta) = Z_i + \int_0^\eta \sin[\phi(\eta) + \alpha]\, d\eta \qquad \text{(A.6b)}$$

where

$$\alpha = \tan^{-1}\left(\frac{Z_{i+1} - Z_i}{Y_{i+1} - Y_i}\right) \qquad \text{(A.6c)}$$

The thickness variation is approximated as being linear between nodes; thus

$$h(\eta) = h_i\left(1 - \frac{\eta}{\eta_i}\right) + h_{i+1}\frac{\eta}{\eta_i} \qquad \text{(A.7)}$$

Employing the Bernoulli-Euler hypothesis, the displacement field $\tilde{v}$, $\tilde{w}$ of the beam may be specified by the middle plane displacements v and w, and the rotation, ψ, as follows:

$$\tilde{v}(\zeta, \eta) = v(\eta) - \zeta\psi(\eta)$$
$$\tilde{w}(\zeta, \eta) = w(\eta) \qquad \text{(A.8)}$$

where

$$\psi(\eta) = \frac{\partial w}{\partial \eta} - \frac{v}{R} \qquad \text{(A.8a)}$$

To account for the strain-inducing modes and the rigid-body modes, the assumed displacement field takes the form:

$$\begin{Bmatrix} v \\ w \end{Bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi & -(Z-Z_i)\cos(\phi+\alpha)+(Y-Y_i)\sin(\phi+\alpha) & \eta & 0 & 0 & \eta^2 & \eta^3 \\ -\sin\phi & \cos\phi & (Z-Z_i)\sin(\phi+\alpha)+(Y-Y_i)\cos(\phi+\alpha) & 0 & \eta^2 & \eta^3 & 0 & 0 \end{bmatrix} \begin{Bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_8 \end{Bmatrix} \tag{A.9a}$$

or in more compact matrix form, Eq. A.9 becomes

$$\{\underset{\sim}{u}\} \equiv \begin{Bmatrix} v \\ w \end{Bmatrix} = \begin{bmatrix} G_v(\eta) \\ \hdashline G_w(\eta) \end{bmatrix} \{\beta\} \equiv [U(\eta)]\{\beta\} \tag{A.9b}$$

The generalized displacements {q} are selected so that there are four degrees of freedom v, w, ψ, $\chi = (\partial v/\partial\eta) + w/R$ at each node of the element:

$$\{q\} = \lfloor v_i \quad w_i \quad \psi_i \quad \chi_i \quad v_{i+1} \quad w_{i+1} \quad \psi_{i+1} \quad \chi_{i+1} \rfloor^T = [A]\{\beta\} \tag{A.10}$$

where

$$[A] = \begin{bmatrix} \cos\phi_i & \sin\phi_i & 0 & 0 & 0 & 0 & 0 & 0 \\ -\sin\phi_i & \cos\phi_i & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ \cos\phi_{i+1} & \sin\phi_{i+1} & A_{53} & \eta_i & 0 & 0 & \eta_i^2 & \eta_i^3 \\ -\sin\phi_{i+1} & \cos\phi_{i+1} & A_{63} & 0 & \eta_i^2 & \eta_i^3 & 0 & 0 \\ 0 & 0 & 1 & \eta_i(\phi')_{\eta_i} & 2\eta_i & 3\eta_i^2 & \eta_i^2(\phi')_{\eta_i} & \eta_i^3(\phi')_{\eta_i} \\ 0 & 0 & 0 & 1 & -\eta_i^2(\phi')_{\eta_i} & -\eta_i^3(\phi')_{\eta_i} & 2\eta_i & 3\eta_i^2 \end{bmatrix} \tag{A.10a}$$

and

$$A_{53} = (Y_{i+1} - Y_i) \sin (\phi_{i+1} + \alpha) - (Z_{i+1} - Z_i) \cos (\phi_{i+1} + \alpha)$$

$$A_{63} = (Y_{i+1} - Y_i) \cos (\phi_{i+1} + \alpha) + (Z_{i+1} - Z_i) \sin (\phi_{i+1} + \alpha) \qquad \text{(A.10b)}$$

Corresponding to the assumed displacement field Eq. A.9, one finds

$$\psi = \lfloor 0 \;\; 0 \;\; 1 \;\; -\frac{\eta}{R} \;\; 2\eta \;\; 3\eta^2 \;\; -\frac{\eta^2}{R} \;\; -\frac{\eta^3}{R} \rfloor \{\beta\} \equiv \lfloor G_\psi \rfloor \{\beta\} \qquad \text{(A.11a)}$$

and

$$\chi = \lfloor 0 \;\; 0 \;\; 0 \;\; 1 \;\; \frac{\eta^2}{R} \;\; \frac{\eta^3}{R} \;\; 2\eta \;\; 3\eta^2 \rfloor \{\beta\} \equiv \lfloor G_\chi \rfloor \{\beta\} \qquad \text{(A.11b)}$$

Under the Bernoulli-Euler hypothesis, the only nonvanishing strain component and corresponding stress component are the axial strain, ε, and axial stress, σ. For this case, the nonlinear strain-displacement relation may be expressed as:

$$\varepsilon = \varepsilon_0 + \zeta \, \kappa \qquad \text{(A.12)}$$

where

$$\varepsilon_0 = \frac{\partial v}{\partial \eta} + \frac{w}{R} + \frac{1}{2} \left(\frac{\partial w}{\partial \eta} - \frac{v}{R} \right)^2$$

$$\equiv \lfloor B_1 \rfloor \{\underset{\sim}{u}\} + \frac{1}{2} \lfloor \underset{\sim}{u} \rfloor \{B_2\} \lfloor B_2 \rfloor \{\underset{\sim}{u}\} \qquad \text{(A.12a)}$$

$$\kappa = -\frac{\partial}{\partial \eta} \left(\frac{\partial w}{\partial \eta} - \frac{v}{R} \right) \equiv \lfloor B_3 \rfloor \{\underset{\sim}{u}\}$$

Combining Eqs. A.9 through A.12, one obtains

$$\{\underset{\sim}{u}\} = [U(\eta)] [A^{-1}] \{q\} \qquad \text{(A.13)}$$

and

$$\varepsilon_0 = \lfloor D_1 \rfloor \{q\} + \frac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\}$$

$$\kappa = \lfloor D_3 \rfloor \{q\} \qquad \text{(A.14)}$$

where

$$\lfloor D_i \rfloor = \lfloor B_i \rfloor [U][A^{-1}] \qquad \text{for } i = 1, 2, 3 \qquad (A.14a)$$

and

$$\lfloor B_1 \rfloor [U] = \lfloor 0 \quad 0 \quad 0 \quad 1 \quad -\eta^2\phi' \quad -\eta^3\phi' \quad 2\eta \quad 3\eta^2 \rfloor$$

$$\lfloor B_2 \rfloor [U] = \lfloor 0 \quad 0 \quad 1 \quad \eta\phi' \quad 2\eta \quad 3\eta^2 \quad \eta^2\phi' \quad \eta^3\phi' \rfloor$$

$$\lfloor B_3 \rfloor [U] = \lfloor 0 \quad 0 \quad 0 \quad \begin{pmatrix} -\phi' \\ -\eta\phi'' \end{pmatrix} \quad -2 \quad -6\eta \quad \begin{pmatrix} -2\eta\phi' \\ -\eta^2\phi'' \end{pmatrix} \begin{pmatrix} -3\eta^2\phi' \\ -\eta^3\phi'' \end{pmatrix} \rfloor \qquad (A.14b)$$

In the process of solution, it is necessary to evaluate the strain increment $\Delta\varepsilon_m$ from time t_{m-1} to time t_m. Using Eqs. A.12 and A.14, one has

$$\Delta\varepsilon_m = \Delta\varepsilon_{om} + \zeta \Delta K_m \qquad (A.15)$$

where

$$\Delta\varepsilon_{om} = \lfloor D_1 \rfloor \{\Delta q\}_m + \lfloor q \rfloor_m \{D_2\} \lfloor D_2 \rfloor \{\Delta q\}_m - \frac{1}{2} \lfloor \Delta q \rfloor_m \{D_2\} \lfloor D_2 \rfloor \{\Delta q\}_m$$

$$\Delta K = \lfloor D_3 \rfloor \{\Delta q\}_m \qquad (A.15a)$$

The consistent mass matrix of the ith discrete element may be obtained from the expression for the kinetic energy, T_i, as follows:

$$T_i = \frac{1}{2} \iiint_{V_i} \rho_o (\dot{\tilde{v}}^2 + \dot{\tilde{w}}^2)\, dV = \frac{1}{2} \iiint_{V_i} \rho_o [(\dot{v} - \zeta\dot{\psi})^2 + \dot{w}^2]\, dV \qquad (A.16)$$

or

$$T_i = \frac{1}{2} \int_0^{\eta_i} \lfloor \dot{v} \quad \dot{w} \quad \dot{\psi} \rfloor [B] \begin{Bmatrix} \dot{v} \\ \dot{w} \\ \dot{\psi} \end{Bmatrix} d\eta \qquad (A.16a)$$

where

$$[B] = \begin{bmatrix} \rho_o b h & 0 & 0 \\ 0 & \rho_o b h & 0 \\ 0 & 0 & \rho_o \frac{b h^3}{12} \end{bmatrix} \qquad (A.16b)$$

and V_i is the initial undeformed volume of the ith discrete element, ρ_o is the mass density per unit volume, b is the width, and h is the thickness given by Eq. A.7.

With the assumption that the velocity field is of a form which is consistent with the displacement function, Eqs. A.9 and A.11, one has

$$\begin{Bmatrix} \dot{v} \\ \dot{w} \\ \dot{\psi} \end{Bmatrix} = \begin{bmatrix} U(\eta) \\ --- \\ G_\psi(\eta) \end{bmatrix} \{\dot{\beta}\} \equiv [N(\eta)]\{\dot{\beta}\} = [N(\eta)][A^{-1}]\{\dot{q}\} \qquad \text{(A.17)}$$

Substituting Eq. A.17 into Eq. A.16b, one has

$$T_i = \frac{1}{2} \lfloor \dot{q} \rfloor [A^{-1}]^T \int_0^{\eta_i} [N]^T [B][N]\, d\eta \, [A^{-1}] \{\dot{q}\} \qquad \text{(A.18a)}$$

or

$$T_i = \frac{1}{2} \lfloor \dot{q} \rfloor [m] \{\dot{q}\} \qquad \text{(A.18b)}$$

where the consistent mass matrix [m] of the element is

$$[m] = [A^{-1}]^T \int_0^{\eta_i} [N]^T [B][N]\, d\eta \, [A^{-1}] \qquad \text{(A.18c)}$$

The equivalent generalized nodal forces which correspond to the externally-applied loading can be obtained from the variational statement of the work of the externally-applied loading, δW_i:

$$\delta W_i = \int_0^{\eta_i} [F_v(\eta,t)\,\delta v + F_w(\eta,t)\,\delta w]\, d\eta \qquad \text{(A.19a)}$$

where

$$\begin{aligned} \bar{F}(\eta,t) &= F_v(\eta,t)\,\bar{a} + F_w(\eta,t)\,\bar{n} \\ &= g_v(\eta) f_v(t)\,\bar{a} + g_w(\eta) f_w(t)\,\bar{n} \end{aligned} \qquad \text{(A.19b)}$$

is the externally-applied time-varying forcing function.

Substituting the assumed displacement function, Eqs. A.9 and A.10 into Eq. A.19, one has

$$\begin{aligned} \delta W_i = \lfloor \delta q \rfloor [A^{-1}]^T \Big\langle & \int_0^{\eta_i} \{G_v(\eta)\}\, g_v(\eta)\, d\eta \, f_v(t) \\ & + \int_0^{\eta_i} \{G_w(\eta)\}\, g_w(\eta)\, d\eta \, f_w(t) \Big\rangle \end{aligned} \qquad \text{(A.20)}$$

$$\equiv \lfloor \delta q \rfloor \{f\}$$

where

$$\{f\} = [A^{-1}]^T \langle \int_0^{\eta_i} \{G_v\} g_v \, d\eta \, f_v + \int_0^{\eta_i} \{G_w\} g_w \, d\eta \, f_w \rangle$$

= element generalized nodal load vector (A.20a)

For a load concentrated at η_c of the element (i.e., $g_i(\eta) = g_i\delta(\eta - \eta_c)$, for $i = v, w$), one has

$$\{f\} = [A^{-1}]^T [f_c'] \begin{Bmatrix} g_v \, f_v(t) \\ g_w \, f_w(t) \end{Bmatrix} \tag{A.20b}$$

where

$$[f_c'] = \begin{bmatrix} \cos(\phi_{\eta_c}) & \sin(\phi_{\eta_c}) & (f_c')_{13} & \eta_c & 0 & 0 & \eta_c^2 & \eta_c^3 \\ -\sin(\phi_{\eta_c}) & \cos(\phi_{\eta_c}) & (f_c')_{23} & 0 & \eta_c^2 & \eta_c^3 & 0 & 0 \end{bmatrix}^T \tag{A.20c}$$

and

$$(f_c')_{13} = -(Z_{\eta_c} - Z_i)\cos(\phi_{\eta_c} + \alpha) + (Y_{\eta_c} - Y_i)\sin(\phi_{\eta_c} + \alpha)$$

$$(f_c')_{23} = (Z_{\eta_c} - Z_i)\sin(\phi_{\eta_c} + \alpha) + (Y_{\eta_c} - Y_i)\cos(\phi_{\eta_c} + \alpha) \tag{A.20d}$$

For loading distributed uniformly over the element (i.e., $g_i(\eta) = g_i$ for $i = v, w$), one has

$$\{f\} = [A^{-1}]^T [f_u'] \begin{Bmatrix} g_v \, f_v(t) \\ g_w \, f_w(t) \end{Bmatrix} \tag{A.20e}$$

where

$$[f_u'] = \left[\int_0^{\eta_i} \{G_v(\eta)\} d\eta \;\vdots\; \int_0^{\eta_i} \{G_w(\eta)\} d\eta \right] \tag{A.20f}$$

For loading distributed linearly over the element, (i.e., $g_i(\eta) = g_{io} + g_{i1}\eta$ for $i = v, w$), one has

$$\{f\} = [A^{-1}]^T [f_{\ell o}'] \begin{Bmatrix} g_{vo} \, f_v(t) \\ g_{wo} \, f_w(t) \end{Bmatrix} + [A^{-1}]^T [f_{\ell 1}'] \begin{Bmatrix} g_{v1} \, f_v(t) \\ g_{w1} \, f_w(t) \end{Bmatrix} \tag{A.20g}$$

where

$$[f_{\ell o}'] = \left[\int_0^{\eta_i} \{G_v(\eta)\} d\eta \;\vdots\; \int_0^{\eta_i} \{G_w(\eta)\} d\eta \right] \tag{A.20h}$$

and

$$[\, f'_{\ell 1} \,] = \left[\int_0^{\eta_i} \{ G_v(\eta) \} \, \eta \, d\eta \;\vdots\; \int_0^{\eta_i} \{ G_w(\eta) \} \, \eta \, d\eta \right] \tag{A.20i}$$

The equivalent nodal force which corresponds to the internal axial stress, σ, also can be obtained from the expression of the variation of the work of the axial stress:

$$\delta U_i = \iiint_{V_i} \sigma \, \delta \varepsilon \, dV = \iiint_{V_i} \sigma \, (\delta \varepsilon_o + \zeta \, \delta K) \, dV \tag{A.21}$$

Substituting Eq. A.14 into Eq. A.21 and introducing the stress resultants for the beam cross section

$$L = \iint_A \sigma \, dA \qquad , \qquad M = \iint_A \sigma \, \zeta \, dA \tag{A.22}$$

where the integrations being taken over the cross section, A, of the beam element, L, is the internal force, and M is the internal bending moment of the cross section, results in

$$\delta U_i = \lfloor \delta q \rfloor \left[\int_0^{\eta_i} (\{D_1\} L + \{D_3\} M) \, d\eta + \int_0^{\eta_i} \{D_2\} \lfloor D_2 \rfloor L \, d\eta \, \{q\} \right]$$

$$\equiv \lfloor \delta q \rfloor \, (\{p\} + [h] \{q\}) \tag{A.23}$$

where

$$\{p\} = \int_0^{\eta_i} (\{D_1\} L + \{D_3\} M) \, d\eta$$

$$[h] = \int_0^{\eta_i} (\{D_2\} \lfloor D_2 \rfloor L) \, d\eta \tag{A.23a}$$

Note that {p} and [h] are quantities pertinent to the unconventional formulation of equations of motion, Eq. 2.3.

In the <u>conventional formulation</u>, Eq. 2.2, the variation of the work of the axial stress, δU_i, is expressed in terms of displacements, and the plasticity effects are taken into account through the use of "effective plastic loading".

By substituting the relation

$$\sigma = E(\varepsilon - \varepsilon^{p}) = E(\varepsilon_0 + \zeta K - \varepsilon^{p}) \tag{A.24}$$

into Eq. A.21, one has

$$\delta U_i = \iiint_{V_i} E(\varepsilon_0 + \zeta K - \varepsilon^{p})(\delta\varepsilon_0 + \zeta\,\delta K)\,dV \tag{A.25}$$

Employing the strain-displacement relation, Eq. A.14, Eq. A.25 becomes

$$\begin{aligned}
\delta U_i =\; & \lfloor \delta q \rfloor \int_0^{\eta_i} \left(\{D_1\} Ebh \lfloor D_1 \rfloor + \{D_3\} \frac{Ebh^3}{12} \lfloor D_3 \rfloor \right) d\eta \, \{q\} \\
& + \lfloor \delta q \rfloor \left\langle \iint_A \int_0^{\eta_i} -E\varepsilon^{p} (\{D_1\} + \zeta \{D_3\})\, dV + \iint_A \int_0^{\eta_i} -E\varepsilon^{p} \{D_2\} \lfloor D_2 \rfloor \, dV \{q\} \right\rangle \\
& + \lfloor \delta q \rfloor \Big\langle \int_0^{\eta_i} Ebh \left(\tfrac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\} \right) \{D_1\}\, d\eta \\
& + \int_0^{\eta_i} Ebh \left(\lfloor D_1 \rfloor \{q\} + \tfrac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\} \right) \{D_2\} \lfloor D_2 \rfloor \, d\eta \, \{q\} \Big) \\
\equiv\; & \lfloor \delta q \rfloor \left([k]\{q\} - \{f_p^{L}\} - \{f_p^{NL}\} - \{f_q^{NL}\} \right)
\end{aligned} \tag{A.26}$$

where

$$[k] = \int_0^{\eta_i} \left(\{D_1\} Ebh \lfloor D_1 \rfloor + \{D_3\} \frac{Ebh^3}{12} \lfloor D_3 \rfloor \right) d\eta \tag{A.26a}$$

$$\{f_p^{L}\} = \iint_A \int_0^{\eta_i} \left(E\varepsilon^{p} \{D_1\} + \zeta E \varepsilon^{p} \{D_3\} \right) dV \tag{A.26b}$$

$$\{f_p^{NL}\} = \iint_A \int_0^{\eta_i} E\varepsilon^{p} \{D_2\} \lfloor D_2 \rfloor \, dV \, \{q\} \tag{A.26c}$$

$$\{f_q^{NL}\} = -\langle \int_0^{\eta_i} Ebh\left(\frac{1}{2}\lfloor q \rfloor \{D_2\}\lfloor D_2 \rfloor \{q\}\right) \{D_1\}\, d\eta$$
$$+ \int_0^{\eta_i} Ebh\left(\lfloor D_1 \rfloor \{q\} + \frac{1}{2}\lfloor q \rfloor \{D_2\}\lfloor D_2 \rfloor \{q\}\right) \{D_2\}\lfloor D_2 \rfloor\, d\eta\, \{q\} \rangle \tag{A.26d}$$

In Eqs. A.26b and A.26c, ε^p is the total plastic strain at the end of the mth time step. Thus

$$\varepsilon_m^p = \sum_{j=1}^{m-1} \Delta\varepsilon_j^p + \Delta\varepsilon_m^p \tag{A.27}$$

The effective stiffness matrix supplied by the elastic restraints may be obtained from the variation of the work done by the elastic restoring spring forces, δW_s:

$$-\delta W_s = \int_0^{\eta_i} (k_\ell v\, \delta v + k_\ell w\, \delta w + k_t \psi\, \delta \psi)\, d\eta \tag{A.28}$$

or

$$-\delta W_s = \int_0^{\eta_i} \lfloor \delta v \;\; \delta w \;\; \delta \psi \rfloor [C] \begin{Bmatrix} v \\ w \\ \psi \end{Bmatrix} d\eta \tag{A.28a}$$

where

$$[C] = \begin{bmatrix} k_\ell & & 0 \\ & k_\ell & \\ 0 & & k_t \end{bmatrix} \tag{A.28b}$$

and k_ℓ and k_t are the linear and torsional elastic spring constants, respectively.

Substituting the assumed displacement function into Eq. A.28, one has

$$-\delta W_s = \lfloor \delta q \rfloor [A^{-1}]^T \int_0^{\eta_i} [N]^T [C][N]\, d\eta\, [A^{-1}] \{q\}$$
$$\equiv \lfloor \delta q \rfloor [k_s] \{q\} \tag{A.29}$$

where

$$[k_s] = [A^{-1}]^T \int_0^{\eta_i} [N]^T [C][N]\, d\eta\, [A^{-1}] \tag{A.29a}$$

= effective element stiffness matrix supplied by the elastic restraint

Because of nonlinear material behavior, although the strain variation through the beam thickness, by the Bernoulli-Euler hypothesis, is linear, the variation of stress across the thickness may be nonlinear. For computational convenience, the stresses are evaluated at selected Gaussian points across the thickness, and the corresponding weighting factors are used in evaluating the pertinent integrals by Gaussian quadrature. The strain-hardening behavior of the material may be accounted for by using the mechanical sublayer model in which the material at each Gaussian station is treated as consisting of equally-strained sublayers of elastic, perfectly-plastic material, with each sublayer having the same elastic modulus but an appropriately different yield stress. For example, if the yield strain of the kth sublayer is ε_{ok}, the yield stress of that sublayer is

$$\sigma_{ok} = E\, \varepsilon_{ok} \quad , \qquad (k = 1, 2, \ldots, n) \tag{A.30}$$

where E is the elastic (Young's) modulus.

An illustration of the method of computing the axial stress and/or plastic strain increment is presented as follows. One begins by knowing the sublayer stress $\sigma_{jk,m-1}$ at time t_{m-1} for the kth sublayer of the jth depthwise Gaussian station, and the strain increment $\Delta\varepsilon_{j,m}$ at station j at time t_m (that is, the strain increment from time t_{m-1} to time t_m). One then takes a trial value (superscript T) of $\sigma_{jk,m}$ which is computed by assuming an elastic path:

$$\sigma^T_{jk,m} = \sigma_{jk,m-1} + E\, \Delta\varepsilon_{j,m} \tag{A.31}$$

A check is then performed to see what the correct value of $\sigma_{jk,m}$ must be.

If $-\sigma_{ok} \leq \sigma^{T}_{jk,m} \leq \sigma_{ok}$ then $\sigma_{jk,m} = \sigma^{T}_{jk,m}$ and $\Delta \varepsilon^{p}_{jk,m} = 0$

If $\sigma^{T}_{jk,m} > \sigma_{ok}$ then $\sigma_{jk,m} = \sigma_{ok}$ and $\Delta \varepsilon^{p}_{jk,m} = \dfrac{\sigma^{T}_{jk,m} - \sigma_{ok}}{E}$

If $\sigma^{T}_{jk,m} < -\sigma_{ok}$ then $\sigma_{jk,m} = -\sigma_{ok}$ and $\Delta \varepsilon^{p}_{jk,m} = \dfrac{\sigma^{T}_{jk,m} + \sigma_{ok}}{E}$ (A.32)

This procedure is applied to all sublayers of each Gaussian station j; having done this, the axial force and moment of the beam cross section can be determined by

$$L = \iint_A \sigma \, dA \doteq b \frac{h}{2} \sum_j \left(\sum_k \sigma_{jk} A_{jk} \right)$$

$$M = \iint_A \sigma \zeta \, dA \doteq b \frac{h}{2} \sum_j \zeta_j \left(\sum_k \sigma_{jk} A_{jk} \right) \quad \text{(A.33)}$$

In a similar manner the integration of the plastic strain over the cross section of the beam element can be determined by

$$\iint_A \varepsilon^{p} dA \doteq b \frac{h}{2} \sum_j \left(\sum_k \varepsilon^{p}_{jk} A_{jk} \right)$$

$$\iint_A \zeta \varepsilon^{p} dA \doteq b \frac{h}{2} \sum_j \zeta_j \left(\sum_k \varepsilon^{p}_{jk} A_{jk} \right) \quad \text{(A.34)}$$

where A_{jk} is a combination of the mechanical sublayer weighting factor and the Gaussian weighting factor W_j, which is defined by

$$A_{jk} = \frac{W_j}{E} \left(E_k - E_{k+1} \right) \quad \text{(A.35)}$$

In Eq. A.35, W_j is the Gaussian weighting factor and

$$E_k = \frac{\sigma_k - \sigma_{k-1}}{\varepsilon_k - \varepsilon_{k-1}} \quad \text{(A.36)}$$

is the kth slope of the polygonal approximate stress-strain diagram.

If desired, the sublayer yield stresses may be treated as strain-rate dependent. Since the strain increment at the jth Gaussian station and hence the strain rate is known at this stage of computation, then the rate-dependent yield stress σ_{yk} os this kth sublayer at station j is

$$\sigma_{yk} = \sigma_{ok} \left[1 + \left| \frac{\Delta \varepsilon / \Delta t}{D} \right|^{\frac{1}{p}} \right] \tag{A.37}$$

where D and p are empirically-determined constants for the material and may, in general, be different for each sublayer.

σ_{ok} is the static uniaxial yield stress of the kth sublayer at any jth Gaussian station

A.2 Uniform Thickness Circular Ring

For application to a simple circular ring, the geometry and nomenclature of a typical circular ring element is shown in Fig. 2a where the local and global coordinates are arranged to take advantage of the symmetry of the ring element's geometry. For a circular ring element, the various matrices which have the same definition as those defined in Subsection A.1 are listed in the following:

$$\{\underset{\sim}{u}\} \equiv \begin{Bmatrix} v \\ w \end{Bmatrix} = \begin{bmatrix} G_v(\eta) \\ G_w(\eta) \end{bmatrix} \{\beta\} \equiv [U(\eta)]\{\beta\} \tag{A.38}$$

where

$$[U(\eta)] = \begin{bmatrix} \cos\lambda & -\sin\lambda & -R(1-\cos\lambda\cos\Lambda) & \eta & 0 & 0 & \eta^2 & \eta^3 \\ \sin\lambda & \cos\lambda & R(\sin\lambda\cos\Lambda) & 0 & \eta^2 & \eta^3 & 0 & 0 \end{bmatrix} \tag{A.38a}$$

$$\psi = \frac{\partial w}{\partial \eta} - \frac{v}{R} = \lfloor G_\psi(\eta) \rfloor \{\beta\} \tag{A.39}$$

where

$$\lfloor G_\psi \rfloor = \lfloor 0 \quad 0 \quad 1 \quad -\frac{\eta}{R} \quad 2\eta \quad 3\eta^2 \quad -\frac{\eta^2}{R} \quad -\frac{\eta^3}{R} \rfloor \tag{A.39a}$$

$$\chi = \frac{\partial v}{\partial \eta} + \frac{w}{R} = \lfloor G_\chi(\eta) \rfloor \{\beta\} \tag{A.40}$$

where

$$\lfloor G_\gamma(\eta) \rfloor = \lfloor 0 \quad 0 \quad 0 \quad 1 \quad \frac{\eta^2}{R} \quad \frac{\eta^3}{R} \quad 2\eta \quad 3\eta^2 \rfloor \tag{A.40a}$$

$$\{q\} = \lfloor v_i \quad w_i \quad \psi_i \quad \chi_i \quad v_{i+1} \quad w_{i+1} \quad \psi_{i+1} \quad \chi_{i+1} \rfloor^T = [A]\{\beta\} \tag{A.41}$$

where

$$[A] = \begin{bmatrix} \cos\Lambda & \sin\Lambda & -R(1-\cos^2\Lambda) & -\frac{S}{2} & 0 & 0 & \frac{S^2}{4} & -\frac{S^3}{8} \\ -\sin\Lambda & \cos\Lambda & -R\sin\Lambda\cos\Lambda & 0 & \frac{S^2}{4} & -\frac{S^3}{8} & 0 & 0 \\ 0 & 0 & 1 & \frac{S}{2R} & -S & \frac{3S^2}{4} & -\frac{S^2}{4R} & \frac{S^3}{8R} \\ 0 & 0 & 0 & 1 & \frac{S^2}{4R} & -\frac{S^3}{8R} & -S & \frac{3S^2}{4} \\ \cos\Lambda & -\sin\Lambda & -R(1-\cos^2\Lambda) & \frac{S}{2} & 0 & 0 & \frac{S^2}{4} & \frac{S^3}{8} \\ \sin\Lambda & \cos\Lambda & R\sin\Lambda\cos\Lambda & 0 & \frac{S^2}{4} & \frac{S^3}{8} & 0 & 0 \\ 0 & 0 & 1 & -\frac{S}{2R} & S & \frac{3S^2}{4} & -\frac{S^2}{4R} & -\frac{S^3}{8R} \\ 0 & 0 & 0 & 1 & \frac{S^2}{4R} & \frac{S^3}{8R} & S & \frac{3S^2}{4} \end{bmatrix} \tag{A.41a}$$

$$\varepsilon = \varepsilon_o + \zeta K \tag{A.42}$$

where

$$\varepsilon_o = \frac{\partial v}{\partial \eta} + \frac{w}{R} + \frac{1}{2}\left(\frac{\partial w}{\partial \eta} - \frac{v}{R}\right)^2$$

$$= \lfloor D_1 \rfloor \{q\} + \frac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\}$$

$$K = -\frac{\partial}{\partial \eta}\left(\frac{\partial w}{\partial \eta} - \frac{v}{R}\right) = \lfloor D_3 \rfloor \{q\} \tag{A.42a}$$

and

$$\lfloor D_i \rfloor = \lfloor B_i \rfloor [U(\eta)][A^{-1}] \qquad \text{for } i = 1, 2, 3 \tag{A.42b}$$

where in Eq. A.42b,

$$\lfloor B_1 \rfloor [U] = \lfloor 0 \quad 0 \quad 0 \quad 1 \quad \frac{\eta^2}{R} \quad \frac{\eta^3}{R} \quad 2\eta \quad 3\eta^2 \rfloor$$

$$\lfloor B_2 \rfloor [U] = \lfloor 0 \quad 0 \quad 1 \quad -\frac{\eta}{R} \quad 2\eta \quad 3\eta^2 \quad -\frac{\eta^2}{R} \quad -\frac{\eta^3}{R} \rfloor$$

$$\lfloor B_3 \rfloor [U] = \lfloor 0 \quad 0 \quad 0 \quad \frac{1}{R} \quad -2 \quad -6\eta \quad \frac{2\eta}{R} \quad \frac{3\eta^2}{R} \rfloor \tag{A.42c}$$

$$\begin{Bmatrix} \dot{v} \\ \dot{w} \\ \dot{\psi} \end{Bmatrix} = [N][A^{-1}]\{q\} \tag{A.43}$$

where

$$[N] = \begin{bmatrix} \cos\lambda & -\sin\lambda & -R(1-\cos\lambda\cos\Lambda) & \eta & 0 & 0 & \eta^2 & \eta^3 \\ \sin\lambda & \cos\lambda & R\sin\lambda\cos\Lambda) & 0 & \eta^2 & \eta^3 & 0 & 0 \\ 0 & 0 & 1 & -\frac{\eta}{R} & 2\eta & 3\eta^2 & -\frac{\eta^2}{R} & -\frac{\eta^3}{R} \end{bmatrix} \tag{A.43a}$$

$$[m] = [A^{-1}]^T \int_{-\frac{S}{2}}^{\frac{S}{2}} [N]^T [B][N]\, d\eta\, [A^{-1}] = [A^{-1}]^T [m'] [A^{-1}] \tag{A.44}$$

= the consistent mass matrix of the element.

where

$$[m'] = \begin{bmatrix} m'_{11} & & & & & & & \\ 0 & m'_{22} & & & \text{SYMMETRIC} & & & \\ m'_{31} & 0 & m'_{33} & & & & & \\ 0 & m'_{42} & 0 & m'_{44} & & & & \\ 0 & m'_{52} & 0 & m'_{54} & m'_{55} & & & \\ m'_{61} & 0 & m'_{63} & 0 & 0 & m'_{66} & & \\ m'_{71} & 0 & m'_{73} & 0 & 0 & m'_{76} & m'_{77} & \\ 0 & m'_{82} & 0 & m'_{84} & m'_{85} & 0 & 0 & m'_{88} \end{bmatrix} \tag{A.44a}$$

and

$$m_{11}' = m_{22}' = \tilde{m}\, s$$

$$m_{31}' = \tilde{m} R(-2R\sin\Lambda + s\cos\Lambda)$$

$$m_{61}' = \tilde{m} R^4(-2\Lambda^3\cos\Lambda + 6\Lambda^2\sin\Lambda + 12\Lambda\cos\Lambda - 12\sin\Lambda)$$

$$m_{71}' = \tilde{m} R^3(2\Lambda^2\sin\Lambda + 4\Lambda\cos\Lambda - 4\sin\Lambda)$$

$$m_{42}' = -\tilde{m} R^2(-2\Lambda\cos\Lambda + 2\sin\Lambda)$$

$$m_{52}' = \tilde{m} R^3(2\Lambda^2\sin\Lambda + 4\Lambda\cos\Lambda - 4\sin\Lambda)$$

$$m_{82}' = -\tilde{m} R^4(-2\Lambda^3\cos\Lambda + 6\Lambda^2\sin\Lambda + 12\Lambda\cos\Lambda - 12\sin\Lambda)$$

$$m_{33}' = \tilde{m} R^2(s + s\cos^2\Lambda - 2R\sin 2\Lambda) + \tilde{I} s$$

$$m_{63}' = \tilde{m} R^5(-2\Lambda^3\cos\Lambda + 6\Lambda^2\sin\Lambda + 12\Lambda\cos\Lambda - 12\sin\Lambda)\cos\Lambda + \frac{\tilde{I} s^3}{4}$$

$$m_{73}' = -\tilde{m} R\left[\frac{s^3}{12} - R^3\cos\Lambda(2\Lambda^2\sin\Lambda + 4\Lambda\cos\Lambda - 4\sin\Lambda)\right] - \frac{\tilde{I} s^3}{12R}$$

$$m_{44}' = \left(\tilde{m} + \frac{\tilde{I}}{R^2}\right)\frac{s^3}{12}, \quad m_{54}' = -\frac{\tilde{I} s^3}{6R}$$

$$m_{84}' = \left(\tilde{m} + \frac{\tilde{I}}{R^2}\right)\frac{s^3}{80}, \quad m_{55}' = \frac{\tilde{m} s^5}{80} + \frac{\tilde{I} s^3}{3}$$

$$m_{85}' = -\frac{\tilde{I} s^5}{40R}, \quad m_{66}' = \frac{\tilde{m} s^7}{448} + \frac{9\tilde{I} s^5}{80}$$

$$m_{76}' = -\frac{3\tilde{I} s^5}{80R}, \quad m_{77}' = \left(\tilde{m} + \frac{\tilde{I}}{R^2}\right)\frac{s^5}{80}$$

$$m_{88}' = \left(\tilde{m} + \frac{\tilde{I}}{R^2}\right)\frac{s^7}{448} \qquad \text{(A.44b)}$$

where in Eq. A.44b, $\tilde{m} = \rho_o bh$, $I = \rho_o (bh^3/12)$

$$\{f\} = [A^{-1}]^T \left\langle \int_{-\frac{s}{2}}^{\frac{s}{2}} \{G_v(\eta)\} g_v(\eta) d\eta \, f_v(t) + \int_{-\frac{s}{2}}^{\frac{s}{2}} \{G_w(\eta)\} g_w(\eta) d\eta \, f_w(t) \right\rangle$$

= element generalized nodal load vector equivalent to externally-applied loading (A.45)

For a load concentrated at $\eta = \eta_c$ of the element (i.e., $g_i = g_i \delta(\eta - \eta_c)$ for i = v, w), one has

$$\{f\} = [A^{-1}]^T [f_c'] \begin{Bmatrix} g_v f_v(t) \\ g_w f_w(t) \end{Bmatrix} \quad \text{(A.45a)}$$

where

$$[f_c'] = \begin{bmatrix} \cos\lambda_{\eta_c} & -\sin\lambda_{\eta_c} & -R(1-\cos\lambda_{\eta_c}\cos\Lambda) & \eta_c & 0 & 0 & \eta_c^2 & \eta_c^3 \\ \sin\lambda_{\eta_c} & \cos\lambda_{\eta_c} & R\sin\lambda_{\eta_c}\cos\Lambda & 0 & \eta_c^2 & \eta_c^3 & 0 & 0 \end{bmatrix}^T \quad \text{(A.45b)}$$

For a loading distributed uniformly over the element (i.e., $(g_i(\eta) = g_i$ for i = v, w), one has

$$\{f\} = [A^{-1}]^T [f_u'] \begin{Bmatrix} g_v f_v(t) \\ g_w f_w(t) \end{Bmatrix} \quad \text{(A.45c)}$$

where

$$[f_u'] = \begin{bmatrix} 2R\sin\Lambda & 0 & -Rs + R^2\sin(2\Lambda) & 0 & 0 & 0 & \frac{s^3}{12} & 0 \\ 0 & 2R\sin\Lambda & 0 & 0 & \frac{s^3}{12} & 0 & 0 & 0 \end{bmatrix}^T \quad \text{(A.45d)}$$

For a loading distributed linearly over the element (i.e., $(g_i(\eta) = g_{io} + g_{i1}\eta$ for i = v,w), one has

$$\{f\} = [A^{-1}]^T [f_{l0}'] \begin{Bmatrix} g_{vo} f_v(t) \\ g_{wo} f_w(t) \end{Bmatrix} + [A^{-1}]^T [f_{l1}'] \begin{Bmatrix} g_{v1} f_v(t) \\ g_{w1} f_w(t) \end{Bmatrix} \quad \text{(A.45e)}$$

where

$$[f_{l0}'] = [f_u'] = \begin{bmatrix} 2R\sin\Lambda & 0 & -Rs + R^2\sin(2\Lambda) & 0 & 0 & 0 & \frac{s^3}{12} & 0 \\ 0 & 2R\sin\Lambda & 0 & 0 & \frac{s^3}{12} & 0 & 0 & 0 \end{bmatrix}^T \quad \text{(A.45f)}$$

and

$$[f'_{l1}] = \begin{bmatrix} 0 & -R^2(-2\Lambda\cos\Lambda + 2\sin\Lambda) & 0 & \frac{S^3}{12} & 0 & 0 & 0 & \frac{S^5}{80} \\ R^2(-2\Lambda\cos\Lambda + 2\sin\Lambda) & 0 & R^3\cos\Lambda(-2\Lambda\cos\Lambda + 2\sin\Lambda) & 0 & 0 & \frac{S^5}{80} & 0 & 0 \end{bmatrix}^T \tag{A.45g}$$

$$\delta U_i = \lfloor \delta q \rfloor \left(\{p\} + [h]\{q\} \right) \tag{A.46}$$

where

$$\{p\} = \int_{-\frac{S}{2}}^{\frac{S}{2}} \left(\{D_1\} L + \{D_3\} M \right) d\eta$$

$$[h] = \int_{-\frac{S}{2}}^{\frac{S}{2}} \left(\{D_2\} \lfloor D_2 \rfloor L \right) d\eta \tag{A.46a}$$

or

$$\delta U_i = \lfloor \delta q \rfloor \left([k]\{q\} - \{f_p^L\} - \{f_p^{NL}\} - \{f_q^{NL}\} \right) \tag{A.47}$$

where

$$\{f_p^L\} = \iint_A \int_{-\frac{S}{2}}^{\frac{S}{2}} \left(E\varepsilon^p \{D_1\} + \zeta E \varepsilon^p \{D_3\} \right) dV \tag{A.47a}$$

$$\{f_p^{NL}\} = \iint_A \int_{-\frac{S}{2}}^{\frac{S}{2}} E\varepsilon^p \{D_2\} \lfloor D_2 \rfloor \, dV \{q\} \tag{A.47b}$$

$$\{f_q^{NL}\} = -\Big\langle \int_{-\frac{S}{2}}^{\frac{S}{2}} Ebh \left(\tfrac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\} \right) \{D_1\} d\eta + \int_{-\frac{S}{2}}^{\frac{S}{2}} Ebh \left(\lfloor D_1 \rfloor \{q\} + \tfrac{1}{2} \lfloor q \rfloor \{D_2\} \lfloor D_2 \rfloor \{q\} \right) \{D_2\} \lfloor D_2 \rfloor d\eta \{q\} \Big\rangle \tag{A.47c}$$

$$[k] = [A^{-1}]^T [k'] [A^{-1}] \tag{A.47d}$$

and

$$[k'] = \begin{bmatrix} 0_{3\times 3} & & & & & \text{SYMMETRIC} \\ 0_{5\times 3} & (k_1+\frac{k_2}{R^2})s & & & & \\ & (\frac{k_1 s^3}{12R}-\frac{2k_2 s}{R}) & (\frac{k_1 s^5}{80R^2}+4k_2 s) & & & \\ & 0 & 0 & (\frac{k_1 s^7}{448R^2}+3k_2 s^3) & & \\ & 0 & 0 & (\frac{k_1 s^5}{40R}-\frac{k_2 s^3}{R}) & (k_1+\frac{k_2}{R^2})\frac{s^3}{3} & \\ & (k_1+\frac{k_2}{R^2})\frac{s^3}{4} & (\frac{3k_1 s^5}{80R}-\frac{k_2 s^3}{2R}) & 0 & 0 & (k_1+\frac{k_2}{R^2})\frac{9s^5}{80} \end{bmatrix}$$

where in Eq. A.47e, k_1 = Ebh, k_2 = $Ebh^3/12$ (A.47e)

$$[k_s] = [A^{-1}]^T \int_{-\frac{s}{2}}^{\frac{s}{2}} [N]^T [C][N] d\eta \, [A^{-1}] \quad \text{(A.48)}$$

= effective element stiffness matrix supplied by elastic restraint.

A.3 Solution Method

A.3.1 Timewise 3-Point Central-Difference Operator

The timewise 3-point central-difference operator is used to solve the dynamic equations of motion expressed in the unconventional form, Eq. 2.3. In this solution scheme, the relations between displacements and displacement increments at any instant of time t_m (subscript "m") are

$$\{\Delta q^*\}_m = \{q^*\}_m - \{q^*\}_{m-1} \quad \text{(A.49)}$$

and

$$\{q^*\}_m = \{q^*\}_o + \{\Delta q^*\}_1 + \cdots + \{\Delta q^*\}_m \quad \text{(A.50)}$$

At time t_m, the acceleration may be expressed in terms of displacement increments by the following central-difference finite-difference expression:

$$\{\ddot{q}^*\}_m = \frac{\{q^*\}_{m+1} - 2\{q^*\}_m + \{q^*\}_{m-1}}{(\Delta t)^2} + O(\Delta t)^2$$

$$= \frac{\{\Delta q^*\}_{m+1} - \{\Delta q^*\}_m}{(\Delta t)^2} + O(\Delta t)^2 \qquad \text{(A.51)}$$

Employing Eq. 2.3, the unconventional form of the dynamic equations of equilibrium at any time instant t_m becomes

$$[M^*]\{\ddot{q}^*\}_m = \{F^*\}_m - [K_s^*]\{q^*\}_m - \{P^*\}_m - [H^*]_m\{q^*\}_m \qquad \text{(A.52)}$$

Since the right-hand side of Eq. A.52 is known, one can solve for $\{\ddot{q}^*\}_m$. With $\{\ddot{q}\}_m$ now known, one can calculate $\{\Delta q^*\}_{m+1}$ from Eq. A.51 as

$$\{\Delta q^*\}_{m+1} = \{\Delta q^*\}_m + (\Delta t)^2 \{\ddot{q}^*\}_m \qquad \text{(A.53)}$$

Thus, from Eq. A.49 one has

$$\{q^*\}_{m+1} = \{q^*\}_m + \{\Delta q^*\}_{m+1} \qquad \text{(A.53a)}$$

With the specified initial velocity $\{\dot{q}^*\}_o$ and the load acting at time zero $\{F^*\}_o$, the calculation scheme commences by assuming the increment of displacement between time-step zero and time-step one is

$$\{\Delta q^*\}_1 = (\Delta t)\{\dot{q}^*\}_o + \frac{(\Delta t)^2}{2}\{\ddot{q}^*\}_o \qquad \text{(A.54)}$$

where $\{\ddot{q}^*\}_o$ can be calculated from

$$[M^*]\{\ddot{q}^*\}_o = \{F^*\}_o - [K_s^*]\{q^*\}_o - \{P^*\}_o - [H^*]_o\{q^*\}_o \qquad \text{(A.55)}$$

Also

$$\{q^*\}_1 = \{q^*\}_o + \{\Delta q^*\}_1 \qquad \text{(A.56)}$$

where it is assumed that the $\{q^*\}_o$ are prescribed.

After the calculation of $\{\Delta q^*\}_1$ and $\{q^*\}_1$, the strain increment at any point in the element can be obtained. With the strain increment available, the stress increment and stress is computed from the stress-strain relation. Then the stress resultants are obtained. Equations A.52 and A.53 furnish the displacement increment and displacement for the next time step. The process is cyclic thereafter.

A.3.2 Houbolt's Operator

The Houbolt operator is a 4-point backward difference implicit operator and is chosen to solve the equations of motion expressed in the conventional form, Eq. 2.2. In this solution scheme, the $\{\ddot{q}^*\}$ at any instant of time t_{m+1} are approximated by a 4-point backward-difference expression:

$$\{\ddot{q}^*\}_{m+1} = \frac{2\{q^*\}_{m+1} - 5\{q^*\}_m + 4\{q^*\}_{m-1} - \{q^*\}_{m-2}}{(\Delta t)^2} + 0(\Delta t)^2 \tag{A.57}$$

Employing Eq. A.57, the conventional form of the dynamic equations of equilibrium, Eq. 2.2, becomes

$$\langle 2[M^*] + (\Delta t)^2([K^*] + [K_s^*])\rangle \{q^*\}_{m+1} = (\Delta t)^2 \langle \{F^*\}_{m+1} + \{\overset{*}{F}{}_q^{NL}\}_{m+1} + \{\overset{*}{F}{}_p^{L}\}_{m+1} + \{\overset{*}{F}{}_p^{NL}\}_{m+1}\rangle + [M^*](5\{q^*\}_m - 4\{q^*\}_{m-1} + \{q^*\}_{m-2}) \tag{A.58}$$

It should be noted that the generalized nodal load vectors $\{\overset{*}{F}{}_q^{NL}\}_{m+1}$, $\{\overset{*}{F}{}_p^{L}\}_{m+1}$ and $\{\overset{*}{F}{}_p^{NL}\}_{m+1}$ (which may be due to large-deflections and elastic-plastic effects) depend on the displacements (or stresses, strains) at that time instant t_{m+1}, but these remain to be determined; thus, linear extrapolation by using the generalized nodal load vectors at two previous time steps is employed to estimate these forces values:

$$\{\overset{*}{F}{}_q^{NL}\}_{m+1} + \{\overset{*}{F}{}_p^{L}\}_{m+1} + \{\overset{*}{F}{}_p^{NL}\}_{m+1} \doteq 2(\{\overset{*}{F}{}_q^{NL}\}_m + \{\overset{*}{F}{}_p^{L}\}_m + \{\overset{*}{F}{}_p^{NL}\}_m) - (\{\overset{*}{F}{}_q^{NL}\}_{m-1} + \{\overset{*}{F}{}_p^{L}\}_{m-1} + \{\overset{*}{F}{}_p^{NL}\}_{m-1}) \tag{A.59}$$

In order to apply the calculation method represented by Eqs. A.58 and A.59, one must take into account the prescribed initial conditions, $\{q\}_o$, $\{\dot{q}\}_o$, and $\{F^*\}_o$. The following "starting procedure" for this method provides the generalized displacements $\{q^*\}_1$ at $t_1 = 1\Delta t$, and $\{q^*\}_{-1}$ at a negative (fictitious) time instant $t_{-1} = -1\Delta t$.

By employing the following approximations:

$$\{\dot{q}^*\}_o = \frac{2\{q^*\}_1 + 3\{q^*\}_o - 6\{q^*\}_{-1} + \{q^*\}_{-2}}{6(\Delta t)} \quad \text{(A.60)}$$

and

$$\{\ddot{q}^*\}_o = \frac{\{q^*\}_1 - 2\{q^*\}_o + \{q^*\}_{-1}}{(\Delta t)^2} + 0(\Delta t)^2 \quad \text{(A.61)}$$

one has

$$\{q^*\}_{-1} = (\Delta t)^2\{\ddot{q}^*\}_o + 2\{q^*\}_o - \{q^*\}_1 \quad \text{(A.62)}$$

$$\{q^*\}_{-2} = 6(\Delta t)^2\{\ddot{q}^*\}_o + 6(\Delta t)\{\dot{q}^*\}_o + 9\{q^*\}_o - 8\{q^*\}_1 \quad \text{(A.63)}$$

Substituting Eqs. A.62 and A.63 into Eq. A.58 for m = 0 and approximating the generalized nodal load vectors due to large-deflections and elastic-plastic effects at time step t_1 by their values at time zero, one obtains

$$\langle 6[M^*] + (\Delta t)^2([K^*] + [K_s^*])\rangle\{q^*\}_1 = (\Delta t)^2(\{F^*\}_1 + \{\overset{*}{F}{}_q^{NL}\}_o + \{\overset{*}{F}{}_p^{L}\}_o + \{\overset{*}{F}{}_p^{NL}\}_o) + [M^*]\langle 2(\Delta t)^2\{\ddot{q}^*\}_o + 6(\Delta t)\{\dot{q}^*\}_o + 6\{q^*\}_o\rangle$$

(A.64)

where $\{\ddot{q}\}_o$ can be calculated from

$$[M^*]\{\ddot{q}^*\}_o = \{F^*\}_o - ([K^*] + [K_s^*])\{q^*\}_o + (\{\overset{*}{F}{}_q^{NL}\}_o + \{\overset{*}{F}{}_p^{L}\}_o + \{\overset{*}{F}{}_p^{NL}\}_o) \quad \text{(A.65)}$$

Since the right-hand side of Eq. A.64 is known, one can solve for $\{q^*\}_1$. After the $\{q\}_1$ have been determined, $\{q\}_{-1}$ can be computed from Eq. A.62. One can then proceed to calculate $\{q^*\}_2$ from Eqs. A.58 and A.59, then $\{q^*\}_3$, $\{q^*\}_4$, etc.