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This report constitutes a reference manual for the Underwater Shock Analysis (USA) Code, a computer program for calculation of the transient response of a submerged structure to a spherical shock wave of arbitrary pressure profile and source location. The code considers the structure to be linear-elastic and treats the surrounding fluid as an infinite acoustic medium. A discrete-element (finite-element, finite-difference) computational model is used for the structure, while the computational model for the fluid is based upon the Doubly Asymptotic Approximation.

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SUMMARY

This report constitutes a reference manual for the Underwater Shock Analysis (USA) Code, a computer program for calculation of the transient response of a submerged structure to a spherical shock wave of arbitrary pressure profile and source location. The code considers the structure to be linear-elastic and treats the surrounding fluid as an infinite acoustic medium. A discrete-element (finite-element, finite-difference) computational model is used for the structure, while the computational model for the fluid is based upon the Doubly Asymptotic Approximation.

PREFACE

The authors express their appreciation to Dr. K. C. Park for his consultation and to Dr. C. L. Yen for providing the modal results for the infinite-cylinder problem and constructing the finite-element structural models used in the examples.

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SECTION I

INTRODUCTION

This report documents a computer program, the Underwater Shock Analysis (USA) Code, that calculates the transient response of a submerged structure to a spherical shock wave of arbitrary pressure-profile and source location. The structure is considered to be linear-elastic and the surrounding fluid is treated as an infinite acoustic medium. The computational model for the structure is constructed through the use of an auxiliary discrete-element (finite-element, finite-difference) code of choice [1, 2], while that for the fluid is constructed through the use of the Doubly Asymptotic Approximation (DAA) [3, 4].

1.1 DOUBLY ASYMPTOTIC APPROXIMATION

The principal advantage of the DAA is that it models the infinite acoustic medium surrounding the structure as a membrane covering the wet surface of the structure. Hence fluid motion is described merely in terms of wet-surface response variables, which are then linked by compatibility relations to the structural response variables. Furthermore, this description is a simple matrix ordinary differential equation with desirable computational properties.

The principal disadvantage of the DAA is that it constitutes an approximation to the "exact" boundary-element representation of the surrounding medium [5, 6]. The DAA does approach exactness for both high-frequency (early-time) and low-frequency (late-time) structural motions, however, and effects a smooth transition between the two asymptotes. In addition, it has exhibited satisfactory accuracy in a variety of check calculations [4, 5, 7]. Hence, in view of its desirable computational properties, the DAA is considered suitable for engineering analysis.

1.2 STAGGERED SOLUTION PROCEDURE

The governing matrix equation for structural response is a second-order ordinary differential equation in time, while that for fluid response is a first-order ordinary differential equation. Simultaneous solution of these equations by direct step-by-step numerical integration, however, is unacceptably expensive. Hence the USA Code utilizes a staggered solution procedure [8] for step-by-step solution of the equations in time.

Now a staggered solution procedure involves a response extrapolation at each time step, which usually leads to numerical instability for time increments exceeding a critical value. Because this critical value may be unacceptably small for many computations, the governing equations for fluid response have been modified in such a way that unconditional stability is achieved. Thus, through avoidance of both direct simultaneous solution and conditional stabity constraints, highly efficient computation is possible for the greatest variety of cases.

As an illustration of the capabilities of USA, a transient response calculation has been performed for a 2490 degree-of-freedom (DOF) structural model with a stiffness-matrix average half-bandwidth of 85 DOF. The central-processing-unit (CPU) time on a Univac 1108 required for the 280 time-step calculation (with a single change in time increment during the calculation) was 28 minutes. The corresponding time on a CDC 6600, on which the code also operates, would be about 10 minutes.

1.3 INPUT/OUTPUT

The USA Code requires three types of input data in order to perform its function. First, structural mesh-geometry, mass-matrix and stiffness-matrix data must be provided by the structural analysis code used by the analyst. Second, fluid mesh-geometry and boundary-element data must be furnished. Finally, charge standoff and incident pressure-profile, as well as time integration specifications must be provided.

The code, in its turn, outputs structural displacement and velocity histories and fluid pressure histories for the wet surface. Response data post-processors furnish pseudo-velocity shock spectra, and response-history and shock-spectrum plots. In addition, post-processors embedded in the structural analysis code may be used to obtain, for example, stress and strain response histories, as well as response-history and stress-contour plots. As currently configured, the USA Code can routinely handle problems with up to 2500 structural and 145 fluid DOF within a core allocation of 65000 decimal words. If primary core size is increased to 100000 decimal words, approximately 200 fluid DOF may be processed with a corresponding increase in the structural DOF.

1.4 SPECIAL FEATURES

A number of special features are incorporated in the code. First, a capability has been provided to handle a fluid mesh on the wet surface that is not coincident with the surface mesh for the structural model. This permits, for example, the use of a refined structural mesh in a region of high stress gradients, even though a relatively coarse mesh is retained for the fluid.

Second, options for variable-step time integration and computation restart are furnished. The former allows the use of small time increments during periods where the response is expected to be varying rapidly in time, and the use of large time increments for periods characterized by a slowly varying response. The latter permits the division of a response computation into segments, so that the analyst may examine the results at selected points along the way. Such examination is facilitated by the use of the "printer-plot" routine that augments the usual printout data with response plots "drawn" by the printer.

Finally, the code incorporates fluid wet-surface elements for both general and beam-like motions of the structure (see Appendix A). This feature is especially useful for compartment-by-compartment analysis of a submarine. Such an analysis utilizes a general-structure discrete-element model of a particular compartment of interest, with the remainder of the submarine modeled as a beam. Hence a detailed analysis of an entire submarine may be performed with several discrete-element models of moderate size, avoiding the use of a single gigantic model.

1.5 SPECIAL NON-FEATURES

Several features of modest complexity have yet to be incorporated into the USA Code. First, an option for automatic time-step integration would free the analyst from having to select integration time increments in accordance with his expectations regarding response behavior. Second, fluid wet-surface elements for bar-like motions of a structure would allow proper treatment of the longitudinal vibrations of a submarine analyzed on a compartment-by-compartment basis. Finally, a capability to handle very large problems would be useful in those cases where structural segmentation is not possible.

Two important features of greater complexity have yet to be incorporated into the code. The first is a treatment of hull cavitation, which may substantially affect structural response for incident shock waves of short duration. The second is the inclusion of free-surface (bulk cavitation) effects, especially as they influence the form of the incident-wave excitation. The introduction of these two features requires the treatment of highly non-linear phenomena, which presents a stiff challenge for future work.

SECTION II

THEORY

This section describes the theoretical foundation of the USA Code. It is constructed as an overview, with coverage of details left to referenced papers and reports, and to appendices.

2.1 STRUCTURAL RESPONSE EQUATION

The matrix ordinary differential equation for the dynamic response of a linear-elastic structure is [1]

$$\underset{\sim}{M}_s \ddot{\underline{x}} + \underset{\sim}{C}_s \dot{\underline{x}} + \underset{\sim}{K}_s \underline{x} = \underline{f} \qquad (2.1)$$

where $\underline{x}$ is the structural displacement vector, $\underset{\sim}{M}_s$, $\underset{\sim}{C}_s$ and $\underset{\sim}{K}_s$ are the structural mass, damping and stiffness matrices, respectively, $\underline{f}$ is the external force vector, and a dot denotes a temporal derivative. Generally, $\underset{\sim}{M}_s$, $\underset{\sim}{C}_s$ and $\underset{\sim}{K}_s$ are highly banded, symmetric matrices of large order; at present, the USA Code considers $\underset{\sim}{M}_s$ to be diagonal and $\underset{\sim}{C}_s$ to be zero.

For excitation of a submerged structure by an acoustic wave, $\underline{f}$ is given by

$$\underline{f} = -\underset{\sim}{G} \underset{\sim}{A}_f (\underline{p}_I + \underline{p}_S) \qquad (2.2)$$

where $\underline{p}_I$ and $\underline{p}_S$ are nodal pressure vectors for the wet-surface fluid mesh pertaining to the (known) incident wave and the (unknown) scattered wave, respectively, $\underset{\sim}{A}_f$ is the diagonal area matrix associated with elements in the fluid mesh, and $\underset{\sim}{G}$ is the transformation matrix that relates the structural and fluid nodal surface forces. More will be said about $\underset{\sim}{G}$ in the next subsection.

2.2 DAA EQUATION

The Doubly Asymptotic Approximation may be written [3,4]

$$\underset{\sim}{M}_f \dot{\underline{p}}_S + \rho c \underset{\sim}{A}_f \underline{p}_S = \rho c \underset{\sim}{M}_f \dot{\underline{u}}_S \qquad (2.3)$$

where $\underline{u}_S$ is the vector of scattered-wave fluid-particle velocities normal to the structure's wet surface, ρ and c are the density and sound velocity of the fluid, respectively, and $\underset{\sim}{M}_f$ is the symmetric fluid mass matrix for the wet-surface fluid mesh (see Appendix A). This matrix is produced by a boundary-element treatment of Laplace's equation for the irrotational flow generated in an infinite, inviscid, incompressible fluid by motions of the structure's wet surface; it is fully populated with non-zero matrix elements. When transformed into structural coordinates, the fluid mass matrix yields the added mass matrix, which, when combined with the structural mass matrix, yields the virtual mass matrix for motions of a structure submerged in an incompressible fluid [9].

As mentioned in Section I, the approximate relation (2.3) is called "doubly asymptotic" because it approaches exactness in both the high-frequency (early-time) and low-frequency (late-time) limits. For high-frequency motions, $|\dot{\underline{p}}_S| \gg |\underline{p}_S|$, so that (3) approaches the relation $\underline{p}_S = \rho c \underline{u}_S$, which is the correct limit for short acoustic wavelengths. For low-frequency motions, $|\dot{\underline{p}}_S| \ll |\underline{p}_S|$, so that (2.3) approaches the incompressible-flow relation $\underset{\sim}{A}_f \underline{p}_S = \underset{\sim}{M}_f \dot{\underline{u}}_S$, which is the correct limit for long acoustic wavelengths.

For excitation by an incident acoustic wave, $\underline{u}_S$ is related to structural response by the kinematic compatibility relation

$$\underset{\sim}{G}^T \dot{\underline{x}} = \underline{u}_I + \underline{u}_S \tag{2.4}$$

where the superscript "T" denotes matrix transposition. Equation 2.4 expresses the constraint that normal fluid-particle velocity match normal structural velocity on the wet surface of the structure. The fact that the transformation matrix relating those velocities is $\underset{\sim}{G}^T$ follows from the invariance of virtual work with respect to either of the wet surface coordinate systems. Generally, $\underset{\sim}{G}$ is a rectangular matrix whose height greatly exceeds its width, inasmuch as the number of structural DOF usually exceeds considerably the number of fluid DOF.

2.3 INTERACTION EQUATIONS

The introduction of (2.2) into (2.1) and (2.4) into (2.3) yields the interaction equations

$$\begin{aligned} \underset{\sim}{M}_s \ddot{\underline{x}} + \underset{\sim}{C}_s \dot{\underline{x}} + \underset{\sim}{K}_s \underline{x} &= - \underset{\sim}{G} \underset{\sim}{A}_f (\underline{p}_I + \underline{p}_S) \\ \underset{\sim}{M}_f \dot{\underline{p}}_S + \rho c \underset{\sim}{A}_f \underline{p}_S &= \rho c \underset{\sim}{M}_f (\underset{\sim}{G}^T \ddot{\underline{x}} - \dot{\underline{u}}_I) \end{aligned} \tag{2.5}$$

These equations may be solved simultaneously at each time step by the transfer of $- \underset{\sim}{G} \underset{\sim}{A}_f \underline{p}_S$ and $\rho c \underset{\sim}{M}_f \underset{\sim}{G}^T \ddot{\underline{x}}$ to the left sides of their respective equations. Such a procedure is exceedingly expensive, however, because of the large connectivity of the coefficient matrix involved. As mentioned in Section I, efficient computation is possible through the application of a staggered solution procedure that is unconditionally stable with respect to the choice of time increment.

The simplest implementation of the staggered solution procedure recommended in [8] may be effected as follows. $\underset{\sim}{M}_s$ is taken to be diagonal and, to allow for the possibility that $\underset{\sim}{M}_s$ may have zero entries for rotational DOF, $\underset{\sim}{G}$ is constructed such that only the translational DOF for the structure couple with the fluid DOF [see (2.4)]; then the first of (2.5) may be partitioned to obtain $\underset{\sim}{G}^T\ddot{x}$, which may then be introduced into the second of (2.5). Premultiplication of the resulting equation by $\frac{1}{\rho c}\, \underset{\sim}{A}_f\, \underset{\sim}{M}_f^{-1}$ then yields

$$\frac{1}{\rho c}\, \underset{\sim}{A}_f\, \dot{\underset{-}{p}}_S + (\underset{\sim}{D}_f + \underset{\sim}{D}_s)\, \underset{-}{p}_S = -\underset{\sim}{A}_f\, \underset{\sim}{G}^T\, \underset{\sim}{M}_s^{-1}(\underset{\sim}{C}_s\, \dot{\underset{-}{x}} + \underset{\sim}{K}_s\, \underset{-}{x}) - (\underset{\sim}{D}_s\, \underset{-}{p}_I + \underset{\sim}{A}_f\, \dot{\underset{-}{u}}_I) \tag{2.6}$$

where $\underset{\sim}{D}_f = \underset{\sim}{A}_f\, \underset{\sim}{M}_f^{-1}\, \underset{\sim}{A}_f$ and $\underset{\sim}{D}_s = \underset{\sim}{A}_f\, \underset{\sim}{G}^T\, \underset{\sim}{M}_s^{-1}\, \underset{\sim}{G}\, \underset{\sim}{A}_f$ are symmetric, and where $\underset{\sim}{M}_s^{-1}$ is a diagonal matrix with each nonzero element given as the reciprocal of the corresponding nonzero element of $\underset{\sim}{M}_s$ and each zero element mirroring the corresponding zero element of $\underset{\sim}{M}_s$. The first of (2.5) and (2.6) are herein termed "the augmented interaction equations".

2.4 SPHERICAL INCIDENT WAVE

Each element of the vectors $\underset{-}{p}_I$ and $\dot{\underset{-}{u}}_I$ for a spherical incident wave are given by

$$p_{Ii}(t) = \frac{S}{R_i}\, p_I\left(t - \frac{R_i - S}{c}\right)$$
$$\dot{u}_{Ii}(t) = \left[\frac{1}{\rho c}\, \dot{p}_{Ii}(t) + \frac{1}{\rho R_i}\, p_{Ii}(t)\right] \gamma_i \tag{2.7}$$

where S is the "charge standoff", i.e., the distance between the origin of the incident spherical wave and the nearest point on the structure's wet surface, R_i is the distance from the origin of the incident spherical wave to the ith fluid node on the wet surface. γ_i is the cosine of the angle between the vector corresponding to R_i and the wet-surface normal at the ith fluid node, and $p_I(t)$ is the incident-wave pressure-profile defined at $R_i = S$. For a shock wave, $p_I(t)$ is discontinuous at $t = 0$ and the $\dot{u}_{Ii}(t)$ contain singularities.

In order to remove shock-wave singularities from $\dot{\underset{-}{u}}_I$ in (2.6), a modified pressure vector is defined as

$$\underset{-}{p}_M = \underset{\sim}{\Gamma}\, \underset{-}{p}_I + \underset{-}{p}_S \tag{2.8}$$

where $\underset{\sim}{\Gamma}$ is a diagonal matrix with direction-cosine elements γ_i. The introduction of (2.8) into (2.6) and the first of (2.5), followed by utilization of the second of (2.7) then yields the modified, augmented, interaction equations

$$\underset{\sim}{M}_s\, \ddot{\underset{-}{x}} + \underset{\sim}{C}_s\, \dot{\underset{-}{x}} + \underset{\sim}{K}_s\, \underset{-}{x} = -\underset{\sim}{G}\, \underset{\sim}{A}_f\, [\underset{-}{p}_M + (\underset{\sim}{I} - \underset{\sim}{\Gamma})\, \underset{-}{p}_I] \tag{2.9}$$

$$\frac{1}{\rho c}\, \underset{\sim}{A}_f\, \dot{\underset{-}{p}}_M + (\underset{\sim}{D}_f + \underset{\sim}{D}_s)\, \underset{-}{p}_M = -\underset{\sim}{A}_f\, \underset{\sim}{G}^T\, \underset{\sim}{M}_s^{-1}\, (\underset{\sim}{C}_s\, \dot{\underset{-}{x}} + \underset{\sim}{K}_s\, \underset{-}{x}) - \underset{\sim}{H}\underset{-}{p}_I$$

in which $\underset{\sim}{I}$ is the identity matrix, and

$$\underset{\sim}{H} = \underset{\sim}{D}_s - (\underset{\sim}{D}_s + \underset{\sim}{D}_f - \frac{1}{\rho} \underset{\sim}{A}_f \underset{\sim}{R}^{-1}) \underset{\sim}{\Gamma} \tag{2.10}$$

where $\underset{\sim}{R}$ is the diagonal matrix formed by the distances R_i. Equations (2.9) (with $\underset{\sim}{C}_s = 0$) are the equations solved by the USA Code to determine the structural responses $\underline{x}$ and $\dot{\underline{x}}$, and the wet-surface pressures $\underline{p} = (\underset{\sim}{I} - \underset{\sim}{\Gamma})\, \underline{p}_I + \underline{p}_M$.

SECTION III

ORGANIZATION

The USA Code has been written in standard FORTRAN IV for use on both Univac and CDC computers. Machine dependency has been isolated in one utility program described below. Program modularity has been strictly enforced, with communication between computational modules controlled by means of a data management system.

The basic structure of the code is shown in Fig. 3-1. The structural preprocessor is a separate code selected by the user to provide the computational model for the structure. The skyline utility merely reformats $\underset{\sim}{M}_s$ and $\underset{\sim}{K}_s$ as provided by the structural preprocessor for processing by the USA Code (recall that $\underset{\sim}{C}_s$ is taken as zero). The fluid mass preprocessor forms $\underset{\sim}{A}_f$, $\underset{\sim}{M}_f$, and $\underset{\sim}{G}$, while the matrix augmentation preprocessor forms $\underset{\sim}{D}_f$, $\underset{\sim}{D}_s$, and $\underset{\sim}{A}_f \underset{\sim}{G}^T \underset{\sim}{M}_s^{-1}$ [see (2.9)]. The main processor is the time integrator, which forms $\underset{\sim}{\Gamma}$ and $\underset{\sim}{H}$ and then solves (2.9) in step-by-step fashion using the staggered solution procedure. The response postprocessor provides tabular and graphic output for the computed kinematic responses as well as pseudo-velocity shock spectra. Finally, the data manager controls the flow of data between processors. More detailed descriptions of the various program components follow, while information required for utilization of the code is contained in Appendices B through E.

3.1 THE DATA MANAGER DMGASP

DMGASP is a self-contained utility module that functions as a manager of auxiliary storage and as the focal point for all block input/output activities [10]. Constituting the lowest level of the NOSTRA Data Management System [11], it carries out the direct transfer of data blocks between core and peripheral storage. (The terminology "direct transfer" is used here to denote unformatted and unbuffered data transmission.) The basic auxiliary storage management operations embodied in DMGASP are

- Activate storage device
- Position device
- Read data block from device
- Write data block on device
- Deactivate device

In the USA Code, DMGASP is operated as a stand-alone I/O package that receives directives directly from the master processors. Assembly language versions of DMGASP currently exist for UNIVAC 1100 EXEC-8, CDC SCOPE 3.4, and CDC NOS operating systems; hence the USA Code may be used only on these systems at this time.

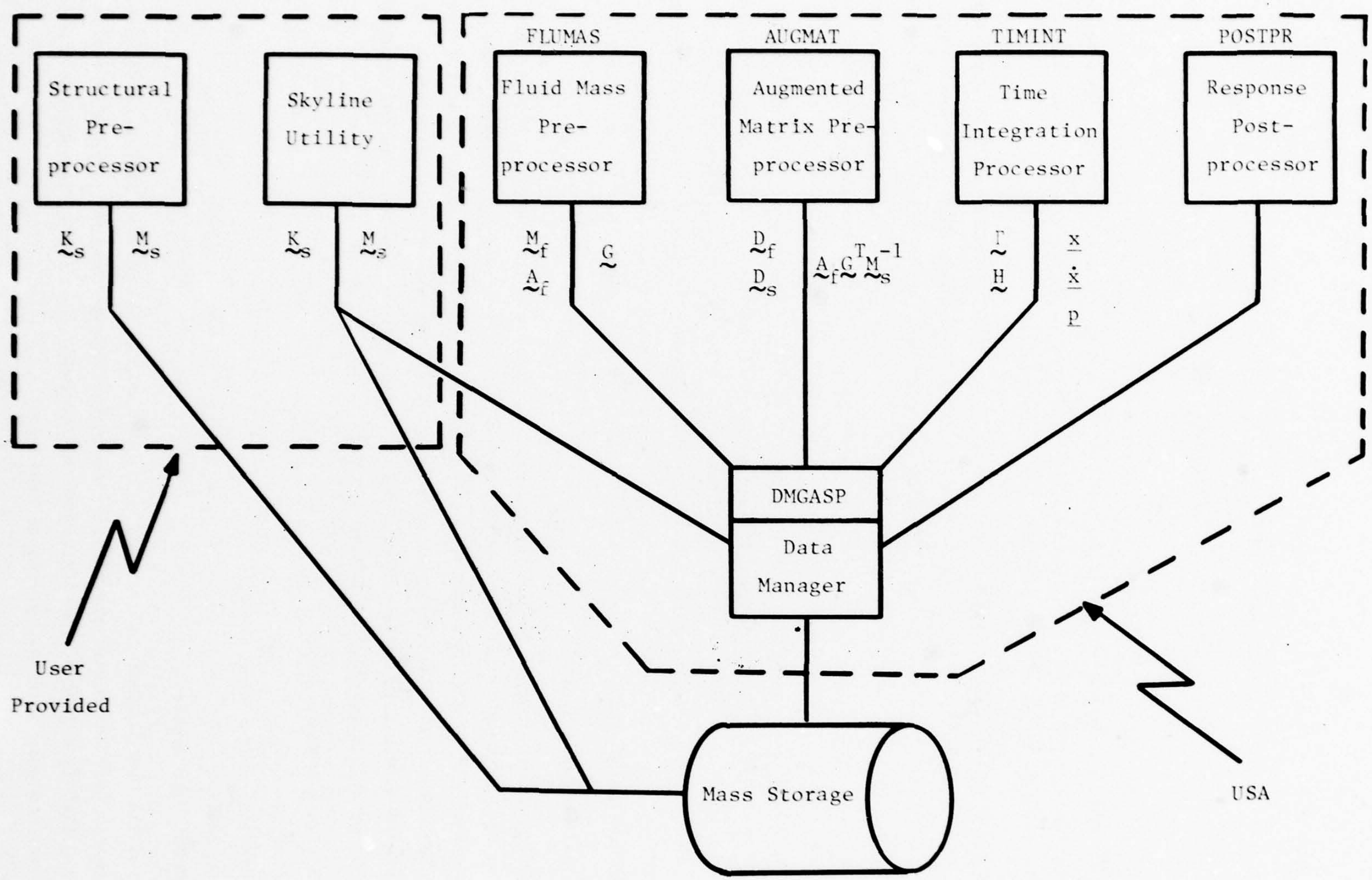

Figure 3-1. Organization of USA Code

3.2 THE STRUCTURAL PREPROCESSOR

This is a user-provided code that assembles the structural mass and stiffness matrices and generates information that relates the internal and external descriptions of the structural DOF. Input typically includes

- Mesh geometry
  - Coordinate systems
  - Node locations
- Element definitions
  - Type
  - Connectivity
- Material properties
  - Mass density
  - Moduli
- Constraints
  - Symmetry conditions
  - Element external constraints
  - Element internal constraints

Fluid internal to the submerged structure must be included in the structural model. At this time, USA treats only diagonal mass matrices associated with a lumped mass representation of the structure, and only single precision matrices can be processed.

3.3 THE SKYLINE UTILITY

This preprocessor converts the structural mass and stiffness matrices generated by the structural preprocessor into the internal "skyline" format required by the USA time integration processor [12,13]. As there are a variety of ways to store large, sparse, symmetric matrices, virtually any structural preprocessor that is to be used with the USA Code will require a utility package to change the storage format. At this time, conversion utilities have been written for SPAR [14] and NASTRAN [15]. User instructions for constructing the skyline utility for other structural codes are given in Appendix F.

Figure 3.1 shows 2 paths to mass storage from the skyline utility. The SPAR converter uses DMGASP for both input and output, whereas the NASTRAN converter uses unformatted buffered FORTRAN commands for input and DMGASP for output.

Constraints are also handled differently in these two utilities. NASTRAN provides a reduced stiffness matrix which already incorporates any prescribed constraints. SPAR does not; however, USA has the ability to apply constraints due to symmetry or attachment to ground during the time integration. Structural DOF that must be set to zero are flagged by the skyline utility [13].

3.4 THE FLUID MASS PREPROCESSOR FLUMAS

This code constructs the fluid mass matrix for a structure submerged in an infinite, inviscid, incompressible fluid by the boundary element technique [9]. In addition, it generates fluid mesh data and a set of transformation coefficients relating the structural and fluid DOF. The computation of these coefficients is based upon the use of centroidal node for the fluid elements and the assumption of a bilinear variation of displacement over the surface of each structural element. This assures that the description of the fluid pressure forces in the two mesh systems is statically equivalent without inducing moments at the structural nodes.

FLUMAS contains a refined formulation for the fluid mass matrix, which includes the primary effects of element curvature. In addition, it has the capability to treat structures containing both surface-of-revolution and general-geometry components, as described in Appendix A. The code can also efficiently construct the fluid mass matrix for a body with two planes of symmetry by using a mesh which covers 1/4 of the surface. Symmetric or anti-symmetric fluid motions can then be imposed in the quadrants not covered by the mesh. Two-dimensional "plane-strain" behavior of long cylinders can also be simulated by another branch in the code. Finally, a useful diagnostic tool contained within the code is the capability to solve the fluid-boundary-mode problem $\underset{\sim}{M}_f \underline{u} = \lambda \underset{\sim}{A}_f \underline{u}$ [9].

Typical input data for this processor includes

- Mesh geometry
  - Fluid Wet-Surface Mesh
  - Structure Wet-Surface Mesh
- Element definitions
  - General curved surface
  - Surface of revolution
- Material property
  - Mass density
- Constraints
  - Quarter model
  - Long cylinder

A detailed description of the required input data is given in Appendix B.

3.5 THE AUGMENTED MATRIX PREPROCESSOR AUGMAT

This preprocessor accepts data from the structural and fluid analyzers to construct the specific matrices required for solution of the augmented Eqs. (2.9). The output of this code includes not only the required matrices in skyline form, but also a distillation of the output from both the structural and fluid processors. This has been done so that only one permanent file need be referenced as input to the time integrator; this results in improved data handling and core usage. Input to this code involves the following information

- Mass matrices
  - Fluid
  - Structure
- Structural DOF correspondence table
  - External and internal node descriptions
  - Factorization order
  - DOF reduction due to constraints
- Fluid mesh geometry
  - Global coordinates of fluid nodes
  - Direction cosines for nodal surface normals
  - Areas of fluid elements
- Fluid/structure DOF transformation coefficients
- Fluid material properties
  - Mass density
  - Speed of sound

Although this constitutes a substantial amount of information, almost all of it is retrieved from permanent data files. A detailed discussion of the required input data is contained in Appendix C.

3.6 THE TIME INTEGRATION PROCESSOR TIMINT

This main processor constitutes an implementation of the unconditionally stable staggered solution technique developed in [8]. The primary output is a permanent data file that contains nodal values for structural displacement, structural velocity and wet-surface pressure at every time step. In addition, a parallel file is created that retains restart information at time intervals dictated by the user. The code has a variable time step capability and can treat a spherical incident wave of arbitrary pressure profile and charge location. Finally, selected response histories can be listed and then displayed for immediate examination using a "printer-plot" graphics package embedded both in TIMINT and in POSTPR (see Sect. 3.7).

The computational strategy for the staggered solution procedure is embodied in the following eight steps, assuming the solution is known at time t:

(1) Estimate the unknown structural restoring force $\underset{\sim}{K}_s \underline{x}$ at $t + \Delta t$ from the extrapolation of current and past values

(2) Transform this extrapolation into fluid node values and form the right-hand side of the fluid equation, which also involves the known incident pressure at $t + \Delta t$

(3) Solve the fluid equation and obtain a preliminary estimate of the total pressure vector at $t + \Delta t$

(4) Transform fluid pressures into structural nodal forces

(5) Solve the structural equation for the displacement and velocity vectors at $t + \Delta t$

(6) Transform the computed structural restoring forces at $t + \Delta t$ into fluid node values and reform the right hand side of the fluid equation

(7) Re-solve the fluid equation and obtain refined values for the total pressures at $t + \Delta t$

(8) Save system responses

Steps 1, 3, and 5 constitute the basic staggered solution technique, while Steps 2 and 4 are required because of the difference between the fluid and structural surface meshes. The iteration on the fluid solution reflected in Steps 6 and 7 has been added to enhance accuracy. Inasmuch as the computation time is overwhelmed by the structural solution requirements, this requires only a small increase in total run time. The use of a three-point extrapolation method in Step 1 also improves accuracy, as discussed in [8].

Implicit integration algorithms have been used for both the fluid and structural equations. The former is treated with the 3-step Park method [16] while the latter is treated with the "JO" implementation of the trapezoidal rule [17].

Typical input to this processor includes

- Charge characteristics
  - Location
  - Pressure profile
- Time step information
  - Start and finish times
  - Time increment values
- Restart data
- Display directives
  - Displacements
  - Velocities
  - Pressures
  - Pseudo-velocity shock spectra

Detailed user information concerning TIMINT is given in Appendix C.

3.7 THE RESPONSE POSTPROCESSOR POSTPR

This utility is responsible for the listing and "printer-plot" graphic display of selected system responses and pseudo-velocity shock spectra. Some of the same capabilities are also embedded in the TIMINT processor for immediate selective scanning of the output. POSTPR, however, is used for more detailed examination of the results at a later time. As a complete display of all structural and fluid DOF histories for even a moderate size problem could run into thousands of pages of output care must be exercised in the selection of data to be displayed. Usage of this code is discussed in Appendix E.

SECTION IV

EXAMPLE PROBLEMS

This section presents results generated by the USA Code for two idealized underwater shock problems. The structure studied in the first problem is a hollow circular beam of finite length, while that involved in the second problem is an infinite, circular cylindrical shell. In both problems, the structure is excited by a transverse, plane step-wave of unit incident pressure and material properties are used that correspond to a steel shell immersed in water. The input data are normalized so that the density and speed of sound for the fluid both equal unity; hence, the density, Young's modulus, and Poisson's ratio for the structural material are taken as 7.85, 98.125 and 0.3, respectively. The radius and wall thickness of the beam and the cylinder are 1 and 0.01, respectively, while the length of the beam is 9. In order to assess the accuracy of the computational results, selected response histories are compared with those obtained by other methods.

4.1 CIRCULAR BEAM

The response variable of primary interest in this problem is the late-time asymptotic translational velocity V_∞ of the structure. An analytical expression for this quantity may be obtained from (2.5) by taking $\underline{\dot{x}} = \underline{\gamma}_{Ps}\, v(t)$, where $\underline{\gamma}_{Ps}$ is the vector of direction cosines relating the translational motions of the structural nodes and the direction of propagation of the plane incident wave. (The elements of $\underline{\gamma}_{Ps}$ that pertain to the rotational DOF are, of course, zero.) The introduction of this relation into the first of 2.5, followed by premultiplication of the resulting equation by $\underline{\gamma}_{Ps}^T$, then yields

$$m_s \dot{v} \;=\; -\, \underline{\gamma}_S^T \, \underset{\sim}{G} \, \underset{\sim}{A}_f (\underline{p}_I + \underline{p}_S) \tag{4.1}$$

where $m_s = \underline{\gamma}_{Ps}^T \underset{\sim}{M}_f \underline{\gamma}_{Ps}$; this follows from the fact that $\underset{\sim}{C}_s \underline{\gamma}_{Ps} = \underset{\sim}{K}_s \underline{\gamma}_{Ps} = \underline{0}$.

After the wave front of the plane step-wave has enveloped the structure, i.e., for $t > t_e$,

$$\underline{p}_I = \rho\, c\, U_I\, \underline{1}$$

$$\overset{*}{\underline{p}}_I = \rho\, c\, U_I (t\underline{1} - \underline{t}_A)$$

$$\underline{u}_I = U_I \underline{\gamma}_P$$

where U_I is the fluid particle velocity characterizing the step-wave, $\underline{1}$ is the unity vector, the asterisk denotes the temporal integral of the quantity beneath it, $\underline{t}_A$ is the vector of incident-wave arrival times for the fluid surface elements, and $\underline{\gamma}_P$ is the vector of direction cosines relating the normals of the fluid elements to propagation vector of the plane incident wave. In addition, $|\dot{p}_S| << |p_S|$ for late-time motions (see Section 2.2), so that the second of (2.5) becomes

$$p_S = A_f^{-1} M_f (G^T \gamma_{Ps} \dot{v} - \dot{u}_I), \quad t >> t_e \tag{4.3}$$

The introduction of this relation into (4.1) then yields

$$(m_s + m_a)\dot{v} = -\gamma_{Ps}^T G A_f p_I + \gamma_{Ps}^T G M_f \dot{u}_I, \quad t >> t_e \tag{4.4}$$

where the added mass $m_a = \gamma_{Ps}^T G M_f G^T \gamma_{Ps}$. But, from (4.4), $G^T \gamma_{Ps} = \gamma_P$, so that m_a is also given as $m_a = \gamma_P^T M_f \gamma_P$.

With $G^T \gamma_{Ps} = \gamma_P$, the first of (4.2) yields $\gamma_{Ps}^T G A_f p_I = \rho c U_I \gamma_P^T A_f 1 = 0$, inasmuch as the wet surface of the structure is closed. Hence, the right side of (4.4) vanishes for $t > t_e$, which gives the expected result $\dot{v} = 0$. This prompts the use of integrated forms of (4.1) and (4.3) (with quiescent initial conditions), which yields, instead of (4.4),

$$(m_s + m_a) v = -\gamma_P^T A_f \overset{*}{p}_I + \gamma_P^T M_f u_I, \quad t >> t_e \tag{4.5}$$

The introduction of the second and third of (4.2) into this equation then provides the desired expression for late-time asymptotic translational velocity

$$V_\infty = \frac{m_d + m_a}{m_s + m_a} U_I \tag{4.6}$$

where the structure's displaced mass m_d may be shown to be expressible as $m_d = \rho c \gamma_P^T A_f (t1 - t_A)$. Note that (4.6) is a general result, applicable to any wet-surface geometry.

Two different uniform mesh geometries were used to study the circular beam. Ten- and twenty-node models were constructed with beam elements provided by the structural analyzer SPAR [18]. The corresponding fluid models contained 9 and 19 elements of equal size, with 12 and 24 circumferential integration points (see Appendix A). For the beam considered, $m_s = 4.439$ and $m_d = 28.274$; with m_a determined as $m_a = \gamma^T M_f \gamma$, mesh geometry has a small effect on the value calculated for V_∞. It was found that $m_a = 23.824$ for the coarse mesh and $m_a = 24.332$ for the fine mesh, which yield $V_\infty = 1.843$ and $V_\infty = 1.828$, respectively.

In the response calculations, a constant time step of 0.1 (20 steps per envelopment period) was used for both models; the results are shown in Figures 4-1 and 4-2. Velocities at the ends of the beam are higher than those at the center because the three-dimensional flow field at the ends offers less resistance to the plane wave excitation than the two-dimensional flow field at the center. It is noted that the responses of both models are similar although those for the finer mesh appear to tend to the rigid body asymptotic velocity more precisely.

4.2 INFINITE CYLINDRICAL SHELL

For this problem, a 72-node, 36-element SPAR model with a uniform circumferential mesh was constructed. The length of the cylindrical shell equalled the circumferential dimension of the square plate elements used for the model; hence the shell was one element long. Kinematic constraints of zero axial displacement and no end rotation were enforced through the skyline utility, as described in Section 3.3. The fluid model consists of 36 equally-spaced elements around the circumference; the two-dimensional nature of the infinite shell geometry was simulated by exercising an option in the fluid preprocessor FLUMAS that adds fictitious elements in the axial direction.

Two dimensional n=0, 1, and 2 modal response results were generated by USA using appropriate Fourier components of the incident-wave force vectors in (2.9). For comparison, DAA analytical solutions were generated by the method described in [7] and [19]. The primary response variables of interest were radial displacement for n=0, radial and tangential velocity for n=1, and radial and tangential displacement for n=2. A time step of 0.025 was used up to t=1; for t between 1 and 2 this was increased 0.05, and for t greater than 2 a time step of 0.1 was used.

The USA and corresponding analytical results are shown harmonic by harmonic in Figures 4-3 through 4-7. In all cases the maximum errors made by USA fall into the range of 1 to 2%.

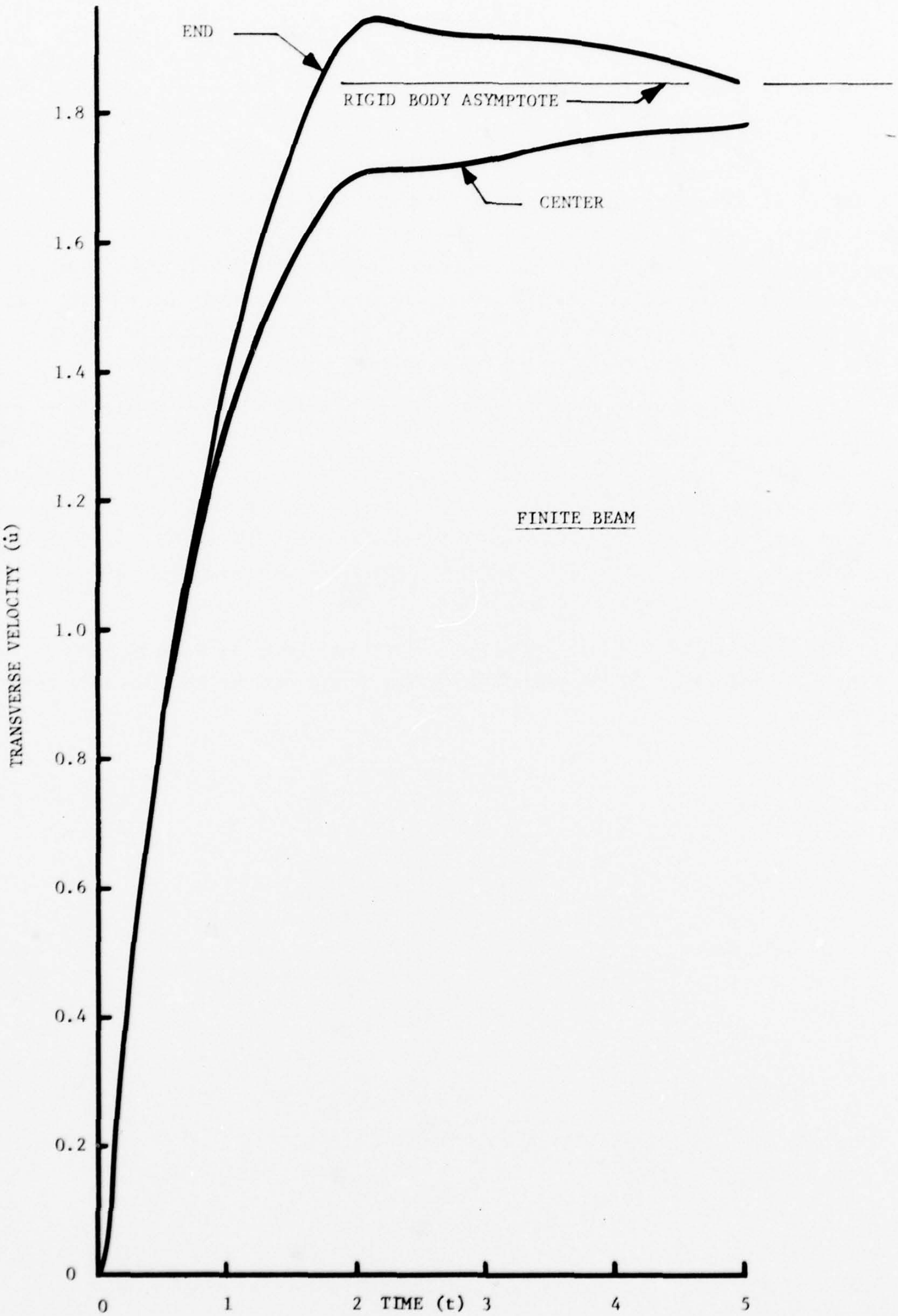

Figure 4-1. Transverse Velocity of Finite Beam, Coarse Mesh

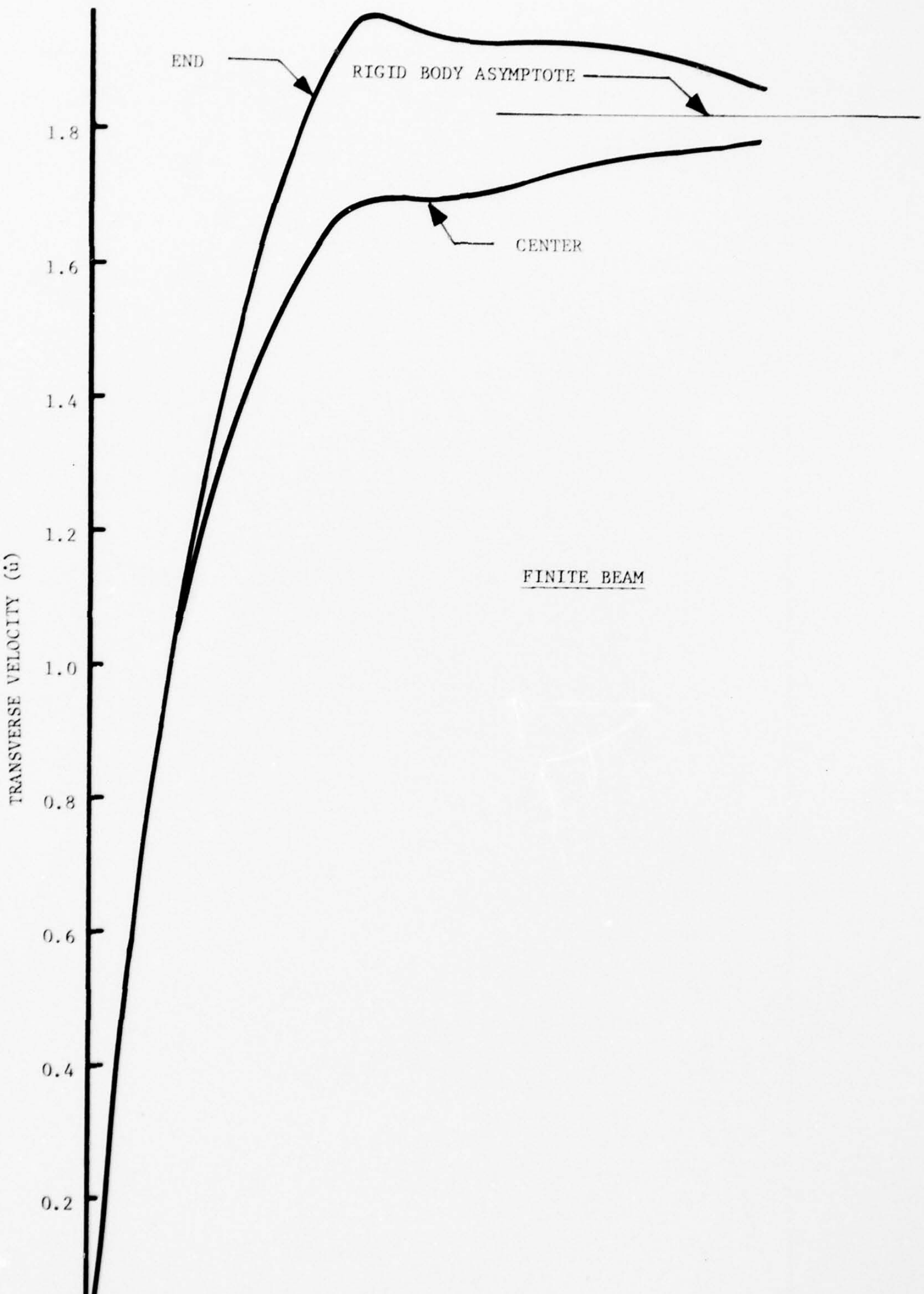

Figure 4-2. Transverse Velocity of Finite Beam, Halved Mesh

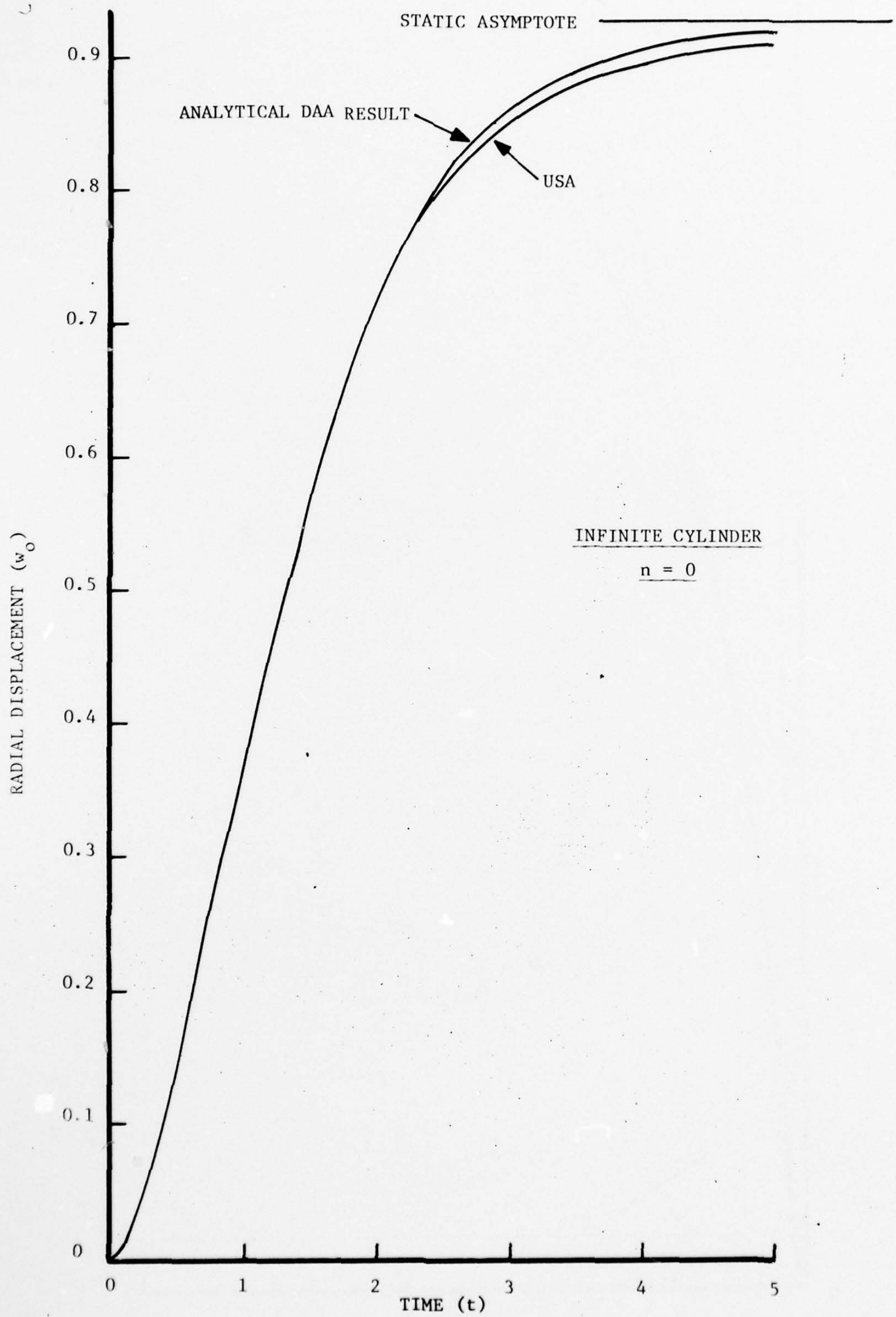

Figure 4-3. n=0 Radial Displacement of Infinite Cylinder

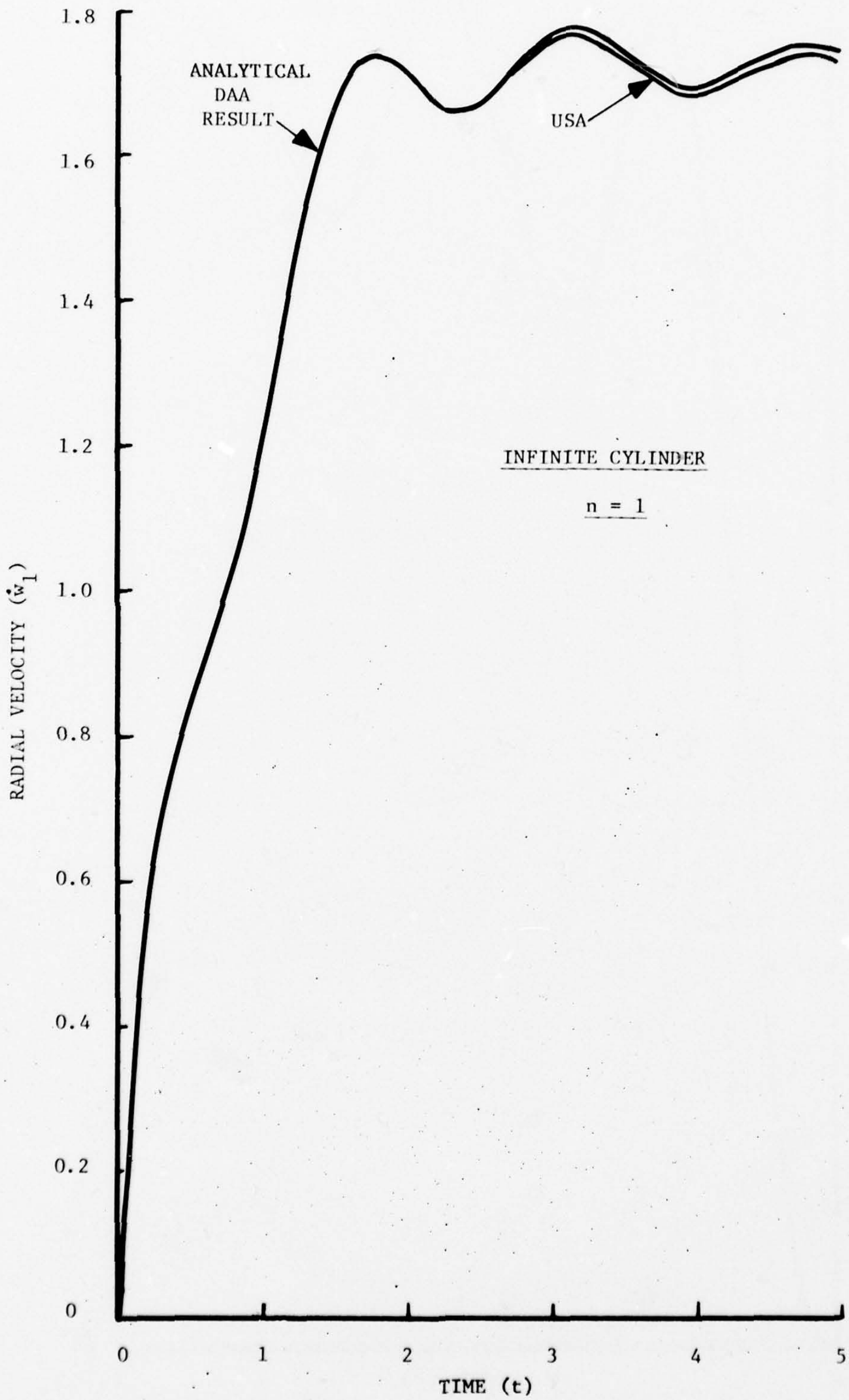

Figure 4-4. n=1 Radial Velocity of Infinite Cylinder

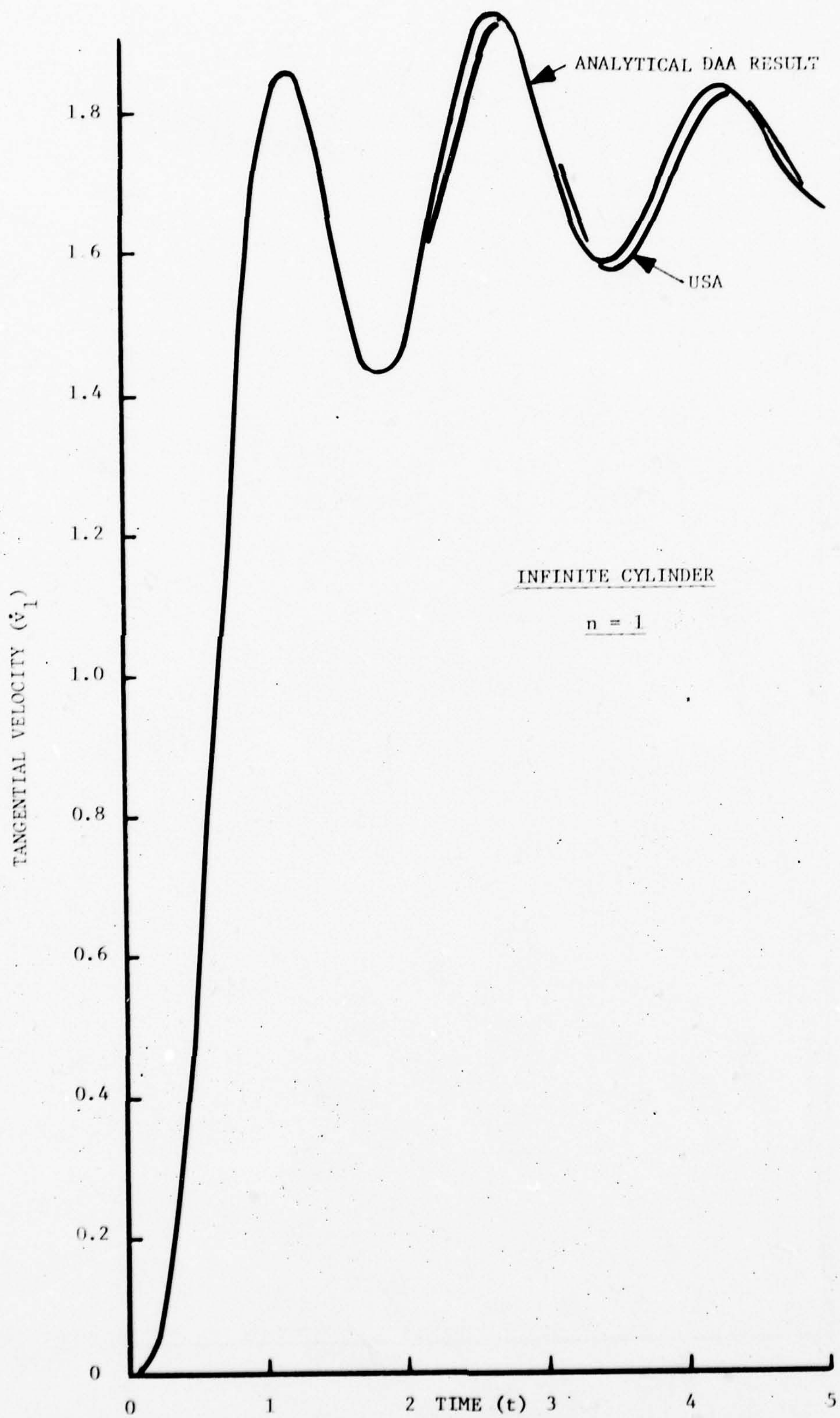

Figure 4-5. n=1 Tangential Velocity of Infinite Cylinder

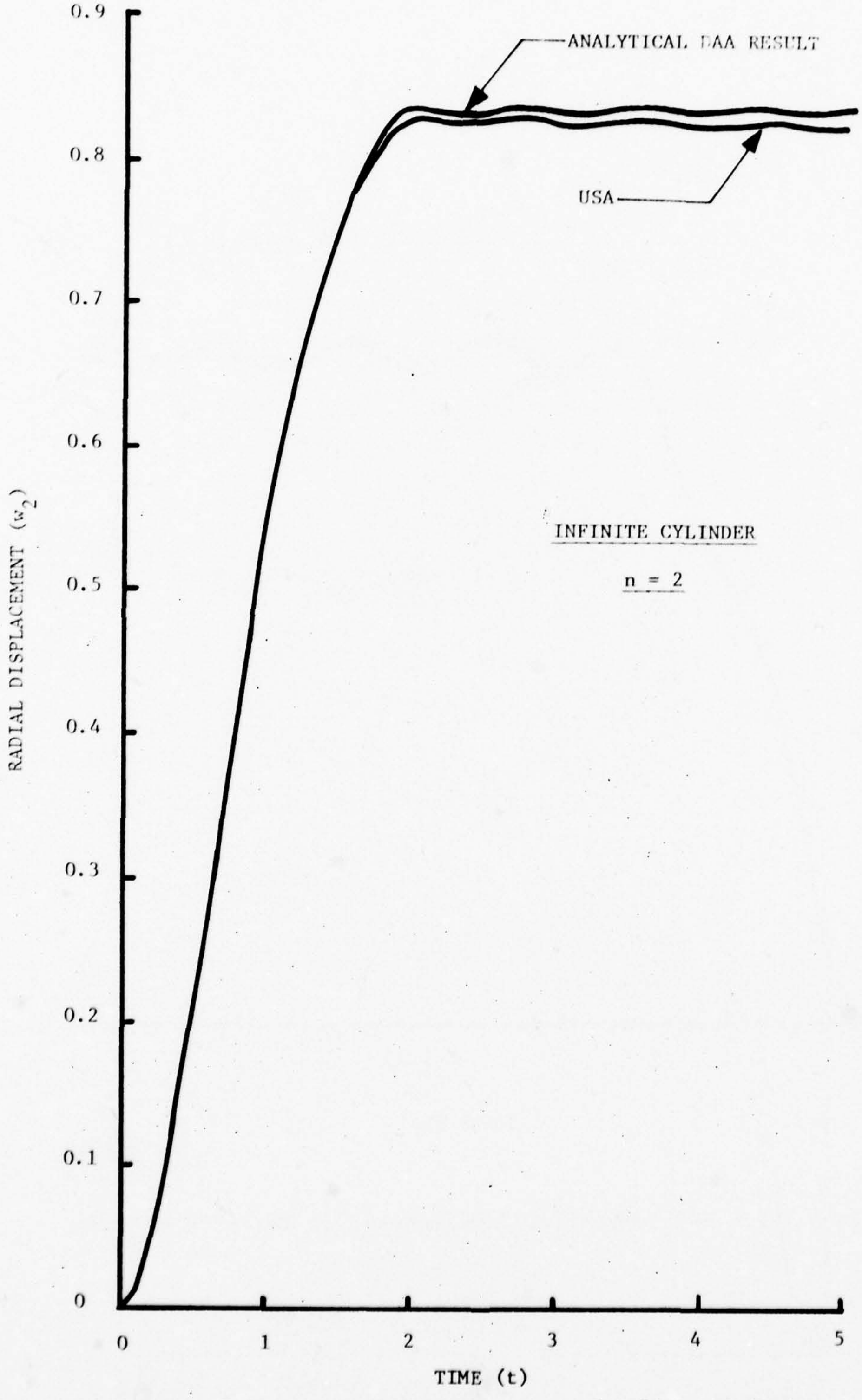

Figure 4-6. n=2 Radial Displacement of Infinite Cylinder

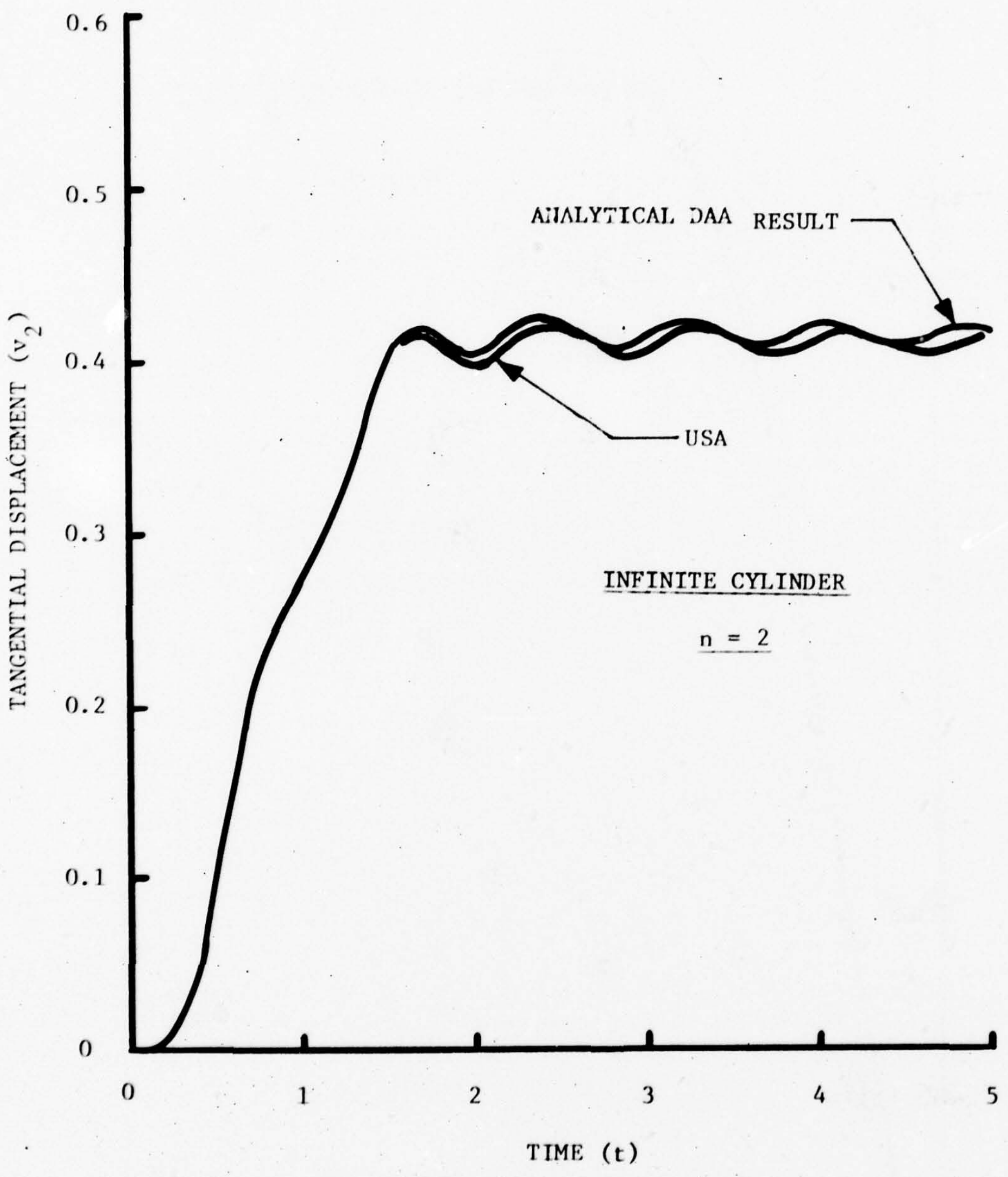

Figure 4-7. n=2 Tangential Displacement of Infinite Cylinder

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APPENDIX A

FLUID MASS COMPUTATION FOR A SUBMERGED STRUCTURE WITH BOTH ROTATIONALLY SYMMETRIC AND GENERAL-GEOMETRY COMPONENTS

Computer calculation of the fluid mass matrix for a submerged structure which is composed of both rotationally symmetric surfaces and general nonsymmetric surfaces may be accomplished using the fully three-dimensional boundary integral approach of Ref. [9]. In such a case, however, the use of general-surface elements for each rotationally symmetric surface is not efficient when it is known a priori that only certain circumferential harmonics of the fluid motion are of importance. This may occur, for example, when part of the structure consists of a beam of circular cross section for which only the $n = 1$ harmonic is required. Then, the order of the fluid mass matrix may be reduced from that for the fully three-dimensional structure by a redefinition of the fluid degrees-of-freedom.

For a general-surface element with a single centroidal control point, the associated degree-of-freedom has a direct physical interpretation, namely, the fluid velocity normal to the plane of the element. For rotationally symmetric surfaces, the elemental degrees-of-freedom become Fourier coefficients for the circumferential harmonics of the surface velocity at prescribed axial locations. This gives rise to the concept of the "surface of revolution" (SOR) element as opposed to the "general-surface" (GEN) element. In this appendix, we describe a technique for the inclusion of both SOR and GEN elements in the same fluid mass matrix.

A direct way to couple both SOR and GEN elements in a single matrix is first to construct the fluid mass matrix for the fully three-dimensional structure. Then, a transformation can be applied which is associated with a hybrid surface velocity vector representing both physical and generalized coordinates. To implement this two-stage procedure, we cover the entire surface of the structure with GEN elements and, in particular, require equal spacing of such elements around the circumference of the surfaces-of-revolution. The number of such elements in this latter category is taken to be the same at all axial stations and is denoted by N. A set of N circumferential GEN elements at any axial station is then regarded as a single SOR element having as many degrees-of-freedom as the number of Fourier coefficients which are chosen to describe the global fluid motion. The set of control points associated with the circumferential GEN elements will be referred to as integration points for their associated SOR elements.

We now assume that the fluid velocity vector for the full three-dimensional surface discretization $\underline{v}$ can be approximated in the mean by the hybrid fluid velocity vector $\underline{v}^*$ by the transformation

$$\underline{v} \approx \underset{\sim}{D}\, \underline{v}^* \tag{A.1}$$

in which

$$\underline{v} = \begin{bmatrix} \underline{v}^G \\ \underline{v}^S \end{bmatrix} , \quad \underline{v}^* = \begin{bmatrix} \underline{v}^G \\ \underline{v}^F \end{bmatrix} \tag{A.2}$$

$$D = \begin{bmatrix} \underset{\sim}{I} & \underset{\sim}{O} \\ \underset{\sim}{O} & \underset{\sim}{F} \end{bmatrix} \tag{A.3}$$

where the superscript G refers to the GEN elements located on the general geometry portions of the structure and the subscript S refers to the sets of GEN elements which make up the individual SOR elements; the vector $\underline{v}^F$ contains the Fourier velocity coefficients for these SOR elements. For convenience, we have partitioned the above arrays so that the entries pertaining to GEN elements appear first and will continue this convention in the following. The matrix $\underset{\sim}{F}$ is rectangular and has the form

$$\underset{\sim}{F} = \begin{bmatrix} \underline{C}_0^1 & \underline{C}_1^1 & \underline{S}_1^1 & \cdots & \underline{C}_M^1 & \underline{S}_M^1 & \underline{O} & & & & & \\ & \underline{C}_0^2 & \underline{C}_1^2 & \underline{S}_1^2 & \cdots & \underline{C}_M^2 & \underline{S}_M^2 & & & & & \\ & \ddots & \underline{O} & \ddots & \underline{O} & \ddots & \underline{O} & \ddots & \underline{O} & \ddots & & \\ \underline{O} & & \underline{C}_0^L & \underline{C}_1^L & \underline{S}_1^L & \cdots & \underline{C}_M^L & \underline{S}_M^L \end{bmatrix} \tag{A.4}$$

Here, M is the maximum number of circumferential harmonics and L is the total number of SOR elements while the vectors $\underline{C}_m^\ell$ and $\underline{S}_m^\ell$ for the ℓ^{th} SOR element and the m^{th} circumferential harmonic are given by

$$\underline{C}_m^\ell = \begin{bmatrix} 1 \\ \cos\frac{2\pi m}{N} \\ \vdots \\ \cos\frac{2\pi m i}{N} \\ \vdots \\ \cos\frac{2\pi m(N-1)}{N} \end{bmatrix} , \quad \underline{S}_m^\ell = \begin{bmatrix} 0 \\ \sin\frac{2\pi m}{N} \\ \\ \sin\frac{2\pi m i}{N} \\ \\ \sin\frac{2\pi m(N-1)}{N} \end{bmatrix} \tag{A.5}$$

where i is the circumferential integration point index. If the transformation (A.1) is now applied to the fluid velocity vector, then invariance of the total kinetic energy of the fluid provides the direct means for reduction of the mass matrix as

$$\underset{\sim}{M}^* = \underset{\sim}{D}^T \underset{\sim}{M} \underset{\sim}{D} \tag{A.6}$$

where the transcipt T denotes matrix transposition and $\underset{\sim}{M}$ is the previously computed fluid mass matrix for the fully three-dimensional structure.

Application of the preceding procedure can involve a large expenditure of computational effort, particularly if the number of SOR elements and circumferential integration points is large. In such a case, matrix partitioning and out-of-core operations may be required. Even when large matrices can be handled by such core management techniques, the computations include the factorization of a large, full, unsymmetric matrix and subsequent solution operations just to form the mass matrix before reduction. These considerations have prompted the development of an alternate but approximate approach that uses intermediately formed matrices of the same order as the final reduced mass matrix with a corresponding saving of computation time.

Calculation of the fluid mass matrix based upon the simple source formulation involves three state variables, the source strength $\underline{\sigma}$, the velocity potential $\underline{\phi}$ and the normal derivative of the velocity potential $\underline{\phi}_n$, which are related by the matrix equations [9]

$$\begin{aligned} \underline{\phi} &= \underset{\sim}{B}\,\underline{\sigma} \\ \underline{\phi}_n &= -\underset{\sim}{C}\,\underline{\sigma} \end{aligned} \tag{A.7}$$

Here, $\underset{\sim}{B}$ and $\underset{\sim}{C}$ are full, unsymmetric, square matrices while $\underline{\phi}$, $\underline{\phi}_n$, and $\underline{\sigma}$ are column vectors. We take the order of this system to be the number of discrete fluid degrees-of-freedom for the full three-dimensional surface discretization. The actual coefficients of $\underset{\sim}{B}$ and $\underset{\sim}{C}$ and the precise manner in which they are combined to form the fluid mass matrix are unimportant to the development here and the interested reader is referred to [9] for this exposition. However, we will use certain aspects of the connectivity of $\underset{\sim}{B}$ and $\underset{\sim}{C}$ later.

A fundamental assumption made in [9] is that the source strength $\underline{\sigma}$ is constant over each element. Here, we make the same assumption for all elements, and further stipulate that the variation of $\underline{\sigma}$ and $\underline{\phi}$ as well as $\underline{\phi}_n$ (the negative of the fluid velocity vector) around the circumference of each SOR element can be expressed by the same finite Fourier series embedded in the transformation in (A.1). If there are only SOR elements in the structure, it can be shown that this relationship is exact, harmonic by harmonic, however, the presence of general-geometry structure components in the flow field perturbs this exactness. We then have

$$\underset{\sim}{\sigma} \approx \underset{\sim}{D}\,\underset{\sim}{\sigma}^{*}$$
$$\underset{\sim}{\phi} \approx \underset{\sim}{D}\,\underset{\sim}{\phi}^{*} \qquad \text{(A.8)}$$
$$\underset{\sim}{\phi}_{n} \approx \underset{\sim}{D}\,\underset{\sim}{\phi}_{n}^{*}$$

so that Eq. (A.8) can be substituted into Eq. (A.7) to obtain

$$\underset{\sim}{D}\,\underset{\sim}{\phi}^{*} \approx \underset{\sim}{B}\,\underset{\sim}{D}\,\underset{\sim}{\sigma}^{*}$$
$$\underset{\sim}{D}\,\underset{\sim}{\phi}_{n}^{*} \approx -\underset{\sim}{C}\,\underset{\sim}{D}\,\underset{\sim}{\sigma}^{*} \qquad \text{(A.9)}$$

We are now able to construct a set of equations in the reduced system similar to Eq. (A.7) by multiplying Eq. (A.9) by the left inverse of D, which is defined as [19].

$$\underset{\sim}{D}_{L}^{-1} = (\underset{\sim}{D}^{T}\,\underset{\sim}{D})^{-1}\,\underset{\sim}{D}^{T} \qquad \text{(A.10)}$$

It then follows that the counterparts of $\underset{\sim}{B}$ and $\underset{\sim}{C}$ in the reduced system are

$$\underset{\sim}{B}^{*} \approx \underset{\sim}{D}_{L}^{-1}\,\underset{\sim}{B}\,\underset{\sim}{D}$$
$$\underset{\sim}{C}^{*} \approx \underset{\sim}{D}_{L}^{-1}\,\underset{\sim}{C}\,\underset{\sim}{D} \qquad \text{(A.11)}$$

$\underset{\sim}{D}_{L}^{-1}$ is easily obtained from the orthogonality and normalization conditions for the finite Fourier series, i.e., [20]

$$\sum_{i=1}^{N} \sin\frac{2\pi m\,(i-1)}{N}\,\cos\frac{2\pi n\,(i-1)}{N} = O$$
$$\sum_{i=1}^{N} \sin\frac{2\pi m\,(i-1)}{N}\,\sin\frac{2\pi n\,(i-1)}{N} = \begin{cases} O & m \neq n \\ N/2 & m = n \end{cases} \qquad \text{(A.12)}$$
$$\sum_{i=1}^{N} \cos\frac{2\pi m\,(i-1)}{N}\,\cos\frac{2\pi n\,(i-1)}{N} = \begin{cases} O & m \neq n \\ N/2 & m = n \neq o \\ N & m = n = o \end{cases}$$

Using Eqs. (A.3), (A.4), (A.5), and (A.12), we find that

$$\left(\underset{\sim}{D}^{T}\,\underset{\sim}{D}\right)^{-1} = \begin{bmatrix} \underset{\sim}{I} & \underset{\sim}{O} \\ \underset{\sim}{O} & \underset{\sim}{G} \end{bmatrix} \qquad \text{(A.13)}$$

where $\underset{\sim}{G}$ is a diagonal matrix given by

$$\tilde{G} = \frac{1}{N} \begin{bmatrix} 1 & & & & & \\ & 2 & & & O & \\ & & 2 & & & \\ & & & 2 & & \\ & & & & \ddots & \\ & O & & & & 2 \end{bmatrix} \tag{A.14}$$

We now show that the formation of $\tilde{B}$ and $\tilde{C}$ and the transformation indicated in Eq. (A.1) can be carried out simultaneously to give the matrices $\tilde{B}^*$ and $\tilde{C}^*$ directly. Consistent with the partitioning of Eqs. (A.2) and (A.3), $\tilde{B}$ may be expressed as

$$\tilde{B} = \begin{bmatrix} \tilde{B}^{GG} & \tilde{B}^{GS} \\ \tilde{B}^{SG} & \tilde{B}^{SS} \end{bmatrix} \tag{A.15}$$

where the first superscript refers to the element type (GEN or SOR) for which the potential is being evaluated and the second superscript indicates the element type whose source strength contributes to that potential [see the first of Eq. (A.7)]. Now, using Eqs. (A.3), (A.10), (A.11), (A.13), and (A.15), we obtain

$$\tilde{B}^* = \begin{bmatrix} \tilde{B}^{GG} & \tilde{B}^{GS} \tilde{F} \\ \tilde{G} \tilde{F}^T \tilde{B}^{SG} & \tilde{G} \tilde{F}^T \tilde{B}^{SS} \tilde{F} \end{bmatrix} \tag{A.16}$$

A similar result can be written for $\tilde{C}^*$; however, as the development to follow is the same for both $\tilde{B}^*$ and $\tilde{C}^*$, only that for $\tilde{B}^*$ is presented.

Equation (A.16) shows that the relationship between GEN elements is unaltered by the transformation, but that the matrices coupling GEN and SOR elements require matrix multiplication. For the matrix $\tilde{B}^{GS} \tilde{F}$, we have

$$b^*_{ij} = \sum_{j'=1}^{N} b^{j'}_{ij} \begin{matrix} \cos \\ \sin \end{matrix} \left[\frac{2\pi m (j' - 1)}{N} \right] \tag{A.17}$$

where the subscript i identifies a particular GEN element, the subscript j identifies a particular SOR element, and the index j' identifies one of the N integration points around the circumference of the j^{th} SOR element. Hence, the $b^{j'}_{ij}$ can be computed sequentially over the index j' and the summation performed conjunctively. The same technique, of course, can be applied to the matrix $\tilde{G} \tilde{F}^T \tilde{B}^{SG}$ as

$$b^{*}_{ji} = \frac{\epsilon_m}{N} \sum_{j'=1}^{N} b^{j'}_{ji} \begin{matrix}\cos\\ \sin\end{matrix} \left[\frac{2\pi m (j' - 1)}{N}\right] \qquad (A.18)$$

where

$$\epsilon_m = \begin{cases} 1 & m = 0 \\ 2 & m > 0 \end{cases} \qquad (A.19)$$

Construction of the matrix relating SOR elements is complicated by the fact that double summations are involved. From Eq. (A.16), we have

$$b^{*}_{ij} = \frac{\epsilon_m}{N} \sum_{j'=1}^{N} \sum_{j'=1}^{N} b^{i'j'}_{ij} \begin{matrix}\cos\\ \sin\end{matrix} \left[\frac{2\pi m (i' - 1)}{N}\right] \begin{matrix}\cos\\ \sin\end{matrix} \left[\frac{2\pi n (j' - 1)}{N}\right] \qquad (A.20)$$

where the subscripts i and j identify SOR elements and the indices i' and j' identify integration points on the i^{th} and j^{th} SOR elements, respectively. It will now be shown that Eq. (A.20) can be simplified to an equation involving a single summation by examination of the connectivity of B^{SS} .

As discussed in [9] , the matrix elements of $\underset{\sim}{B}$ and $\underset{\sim}{C}$ are, except for a multiplicative constant, functions only of the geometry of the finite element mesh. Now, it is clear from Figure A-1 that the relative geometry of points A/D is identical to that of points B/E, that the relative geometry of points A/E is identical to that of B/F, etc. Hence, the $N \times N$ submatrix that relates the source strengths at the integration points on segment j to the values of the potential at the integration points on segment i must have identical terms along every diagonal. Moreoever, the variation in any row (or column) is that of an even function because of the rotationally symmetric geometry, i.e., the relationship of C/D is identical to that of C/F, etc. On the basis of these facts, Eq. (A.20) may be considerably simplified.

Consider, for example, the expansion

$$S = \frac{\epsilon_m}{N} \sum_{k=1}^{N} \sum_{\ell=1}^{N} U_{k\ell} \cos \frac{2\pi m (k - 1)}{N} \cos \frac{2\pi n (\ell - 1)}{N} \qquad (A.21)$$

with the condition that

$$U_{k+1,\ell+1} = U_{k\ell} \qquad (A.22)$$

and the understanding that if a subscript on the left becomes greater than N it is replaced by $k + 1 - N$, etc. Now, the double summation in Eq. (A.21) is ordered by rows and columns; however, we can rearrange it into N terms, each of which represents summation along either the main diagonal or an extended diagonal†. Then, taking advantage of Eq. (A.22), we obtain

$$
\begin{aligned}
N S/\epsilon_m = & \; U_{11} \sum_{k=1}^{N} \cos \frac{2\pi m (k-1)}{N} \cos \frac{2\pi n (k-1)}{N} + \\
& U_{12} \sum_{k=1}^{N} \cos \frac{2\pi m k}{N} \cos \frac{2\pi n (k-1)}{N} + \\
& U_{13} \sum_{k=1}^{N} \cos \frac{2\pi m (k+1)}{N} \cos \frac{2\pi n (k-1)}{N} + \ldots \\
& \ldots + U_{1N} \sum_{k=1}^{N} \cos \frac{2\pi m (k+N-2)}{N} \cos \frac{2\pi n (k-1)}{N}
\end{aligned}
\tag{A.23}
$$

Next, we reorganize the general term that appears in Eq. (A.23) as

$$
\begin{aligned}
& U_{1,\ell+1} \sum_{k=1}^{N} \cos \frac{2\pi m (k-1+\ell)}{N} \cos \frac{2\pi n (k-1)}{N} = \\
& \qquad U_{1,\ell+1} \cos \frac{2\pi m \ell}{N} \sum_{k=1}^{N} \cos \frac{2\pi m (k-1)}{N} \cos \frac{2\pi n (k-1)}{N} - \\
& \qquad U_{1,\ell+1} \sin \frac{2\pi m \ell}{N} \sum_{k=1}^{N} \sin \frac{2\pi m (k-1)}{N} \cos \frac{2\pi n (k-1)}{N}
\end{aligned}
\tag{A.24}
$$

If $m \neq n$, it follows from Eq. (A.12) that the general term is zero and, hence, the sum S is equal to zero. If $m = n$, then Eqs. (A.12) and (A.24) reduce Eq. (A.23) to

$$
S = \sum_{k=1}^{N} U_{1k} \cos \frac{2\pi m (k-1)}{N} \tag{A.25}
$$

In a similar manner, the other possible combinations of trigonometric functions in Eq. (A.20) may be simplified; such simplification yields, for $m \neq n$,

$$
b^*_{ij} = 0 \tag{A.26}
$$

---

† The latter consists of a diagonal in the upper triangle plus its complement in the lower triangle.

while for $m = n$ in the cos/cos and sin/sin combinations in Eq. (A.20),

$$b^*_{ij} = \sum_{j'=1}^{N} b^{1j'}_{ij} \cos \frac{2\pi m(j'-1)}{N} \tag{A.27}$$

and, for $m = n$ in the sin/cos and cos/sin combinations in Eq. (A.20),

$$b^*_{ij} = \sum_{j'=1}^{N} b^{1j'}_{ij} \sin \frac{2\pi m(j'-1)}{N} \tag{A.28}$$

Finally, as it has been demonstrated that the $b^{i'j'}_{ij}$ must be even functions around the circumference of any SOR segment, the contribution of Eq. (A.28) to the final results must vanish, leaving only Eq. (A.27). This, of course, also means that the computation required to form Eq. (A.27) can essentially be halved.

The results of the preceding development may be summarized as follows:

- The coupling that occurs between SOR segments occurs, harmonic by harmonic, without coupling of different harmonics
- The coupling is the same for both the sine and cosine functions, and is given by Eq. (A.27)
- The sine and cosine functions of a particular harmonic do not couple

Thus far, we have substantially reduce the computations required to form the $\underset{\sim}{B}^*$ and $\underset{\sim}{C}^*$ matrices. A few steps remain, however, in order to reach the final objective, viz., efficient formation of the fluid mass matrix for the coupled structure.

As discussed in [9] , $\underset{\sim}{B}^*$ and $\underset{\sim}{C}^*$ are used to form the fluid kinetic energy expression, which is derivable from an appropriate surface integral. In the discretized, fully three-dimensional system, this requires a diagonal matrix $\underset{\sim}{dA}$ whose elements are simply the incremental areas of each surface element. The kinetic energy T is then

$$T = -\frac{1}{2} \rho \int_S \underline{\phi}^T_n \, \underset{\sim}{dA} \, \underline{\phi} \tag{A.29}$$

where ρ is the fluid density and the integration extends over the fully three-dimensional surface S. We may write this expression in the reduced system by simply substituting from Eq. (A.8), with the result that

$$\underset{\sim}{dA}^* = \underset{\sim}{D}^T \underset{\sim}{dA} \underset{\sim}{D} \tag{A.30}$$

Carrying out the matrix multiplications, we obtain

$$\underset{\sim}{dA}^* = \begin{bmatrix} \underset{\sim}{dA}^G & \underset{\sim}{O} \\ \underset{\sim}{O} & \underset{\sim}{F}^T \underset{\sim}{dA}^S \underset{\sim}{F} \end{bmatrix} \tag{A.31}$$

For each submatrix appropriate to a particular SOR element and harmonic that appears in $\underset{\sim}{F}^T \, d\underset{\sim}{A}^S \, \underset{\sim}{F}$, the expansion gives

$$d a^*_{ii} = \frac{N}{\epsilon_m} d a^{11}_{ii} \qquad \text{(A.32)}$$

where $d a^{11}_{ii}$ is the incremental area for a single integration element around the circumference of the segment in the full three dimensional discretization.

The preceding results can now be applied to any of the computational schemes described in [9] . As is noted there, however, one particular scheme, labeled "I2," has been found to be surprisingly accurate in relation to its computational demands and hence has been chosen here as the "baseline" method. In this case, the incremental areas appearing in Eqs. (A.29) through (A.32) may be replaced by the total area of the element, as the "I2" scheme essentially assumes that $\underline{\phi}$ and $\underline{\phi}_n$, as well as $\underline{\sigma}$, are constant over each surface element.

A modest study has been performed on a simple model in which the reduced mass matrix has been obtained directly from Eq. (A.6) and by the approximate method outlined above. This model consists of two cylindrical shell segments with a radial "fin" joined to one segment on the lateral surface as shown in Figure A-2; only the n=1 beam modes were kept in the reduced matrix. Comparisons have been made of the eigenvalues of the "fluid boundary mode" problem defined by

$$\underset{\sim}{M}^* \underline{x} = \lambda \underset{\sim}{A}^* x \qquad \text{(A.33)}$$

(In [9] the λ are identified with modal kinetic energy components.)

Typical results from the study are shown in the following table:

λ-Direct	λ-Approximate	Mode
0.59671	0.56960	S
0.47838	0.47826	A
0.29624	0.25955	S
0.27412	0.27108	A
0.21624	0.21622	A
0.19634	0.17554	S

where S denotes a symmetric or breathing mode relative to the two sides of the "fin" and A denotes an antisymmetric or rigid-body "fin" mode. We see that the eigenvalues for the rigid modes are in good agreement; however, the eigenvalues for the symmetric modes exhibit discrepancies of 5 to 14 percent. These discrepancies may be due to the retention of only the n = 1 modes in the reduced matrix; only further evaluation under more general conditions can clarify this point. At this time, however, it appears that the technique introduced here is a viable one, particularly for very large problems whose size precludes application of the direct method.

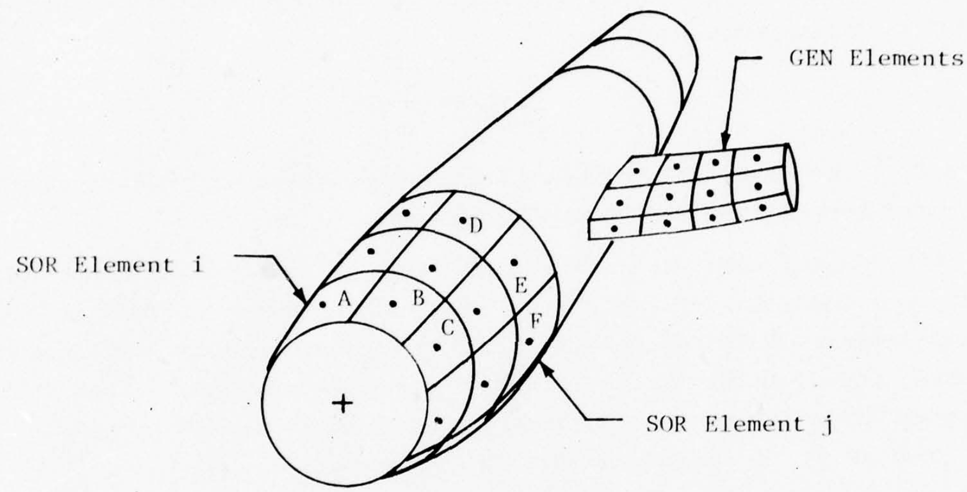

Figure A-1. Schematic of SOR and GEN Element Model

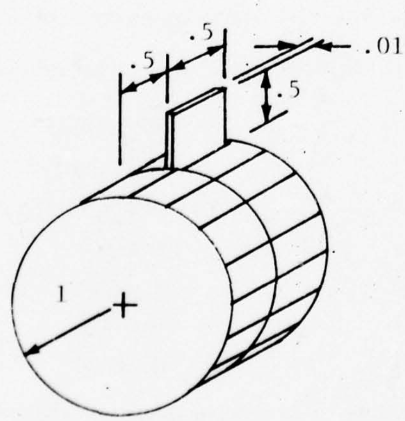

Figure A-2. Geometry of Study Problem for SOR and GEN Element Coupling

APPENDIX B

USER INFORMATION FOR THE FLUID PREPROCESSOR FLUMAS

The following includes modifications which were made under separate contract to the Naval Surface Weapons Center, Contract Number N60921-77-C-0112.

This appendix includes a copy of the users manual, and a sample input deck and subsequent output for the infinite cylindrical shell problem presented in Section 4.

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                       F L U M A S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    THIS FUNCTIONAL COMPONENT OF THE UNDERWATER SHOCK ANALYSIS CODE
    CONSTRUCTS THE FLUID MASS MATRIX FOR A STRUCTURE SUBMERGED IN AN
    INFINITE, INVISCID, INCOMPRESSIBLE FLUID BY THE BOUNDARY ELEMENT
    TECHNIQUE. IT ALSO GENERATES FLUID MESH DATA AND A SET OF
    TRANSFORMATION COEFFICIENTS THAT RELATE THE STRUCTURAL AND FLUID
    DEGREES OF FREEDOM ON THE WET SURFACE. THE CODE HAS THE CAPABILITY
    TO TREAT STRUCTURES CONTAINING BOTH SURFACE-OF-REVOLUTION (SOR)
    AND GENERAL-GEOMETRY (GEN) COMPONENTS. THE CODE CAN ALSO CONSTRUCT
    THE FLUID MASS MATRIX FOR A QUARTER-MODEL WITH ARBITRARILY
    ASSIGNED SYMMETRY OR ANTISYMMETRY CONDITIONS, AND CAN SIMULATE THE
    TWO-DIMENSIONAL PLANE STRAIN BEHAVIOR OF LONG CYLINDERS. A USEFUL
    DIAGNOSTIC TOOL CONTAINED WITHIN THE CODE IS THE ABILITY TO SOLVE
    THE FLUID BOUNDARY MODE EIGENVALUE PROBLEM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    THIS PROGRAM WAS DEVELOPED AND CODED BY JOHN A. DERUNTZ, JR.
    OF LOCKHEED MISSILES AND SPACE CO. RESEARCH LABS IN PALO ALTO
    CALIFORNIA. PLEASE CONSULT WITH AUTHOR BEFORE MAKING CHANGES
    AND ALSO REPORT ANY MALFUNCTIONS OR PROBLEMS. WRITE IN CARE OF
    LOCKHEED PALO ALTO RESEARCH LABORATORY, BLDG 205, DEPT 52-33,
    3251 HANOVER ST., PALO ALTO, CALIF., 94304 OR CALL 415-493-4411
    EXTS. 45069 OR 45133.                                  FEBRUARY, 1978

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                    M A X I M U M    V A L U E S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    MAXIMUM NUMBER OF STRUCTURAL GRID POINTS          . . . . . . . .   5 0 0

    MAXIMUM NUMBER OF GENERAL SURFACE ELEMENTS        . . . . . . . .   1 8 0

    MAXIMUM NUMBER OF SURFACE OF REVOLUTION SEGMENTS    . . . . . .       4 0

    MAXIMUM NUMBER OF SURFACE OF REVOLUTION FREEDOMS    . . . . . .       8 0

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 W A R N I N G    F R O M    T H E    P R O G R A M M E R    G E N E R A L

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    THIS CODE CONTAINS THE SPECIAL INGREDIENT DMGASP NOT FOUND IN
    OTHER BRANDS. DMGASP IS A DATA MANAGEMENT UTILITY MODULE THAT
    WILL ACTIVATE AND DEACTIVATE ALL AUXILIARY STORAGE DATA FILES
    REFERENCED BY THE CODE. HENCE THE NAMES OF SUCH FILES SHOULD NOT
    APPEAR ON ANY CONTROL CARDS IN THE RUN STREAM WHICH MIGHT NORMALLY
    ACTIVATE AND DEACTIVATE THE FILES. THE USER IS ALSO CAUTIONED THAT
    PREVIOUSLY CREATED FILES MUST ALREADY BE RESIDENT IN THE SYSTEM
```

BEFORE THE RUN IS INITIATED. IF A FILE HAS BEEN ROLLED-OUT TO TAPE DMGASP WILL ATTEMPT TO HAVE THE FILE ROLLED-IN EVERY 15 SECONDS FOR UP TO 15 MINUTES ON THE UNIVAC 1100-EXEC 8 OPERATING SYSTEM. IF AN EXISTING DATA FILE HAS NOT BEEN REFERENCED FOR SOME TIME IT IS THEREFORE GOOD POLICY TO SIMPLY ACTIVATE AND DEACTIVATE THE FILE BEFORE EXECUTION OF THIS CODE. IF THE USER ATTEMPTS TO CREATE A NEW DATA FILE WITH A NAME WHICH IS ALREADY ASSIGNED TO AN EXISTING FILE, THE UNIVAC VERSION OF DMGASP WILL MODIFY THE NAME OF THE FILE GENERATED BY THIS RUN TO AVOID ANY CONFLICT. FILE NAME DUPLICATION WILL CAUSE NO PROBLEM ON THE CDC SCOPE OPERATING SYSTEM AS SCOPE WILL SIMPLY CATALOG A NEW CYCLE OF THE SAME FILE. ON THE OTHER HAND THE CDC NOS SYSTEM IS SIMILAR TO UNIVAC IN THIS REGARD AND THE RUN WILL ABORT SINCE THE NAME-CHANGING FEATURE OF DMGASP HAS NOT BEEN IMPLEMENTED FOR NOS. QUALIFIER*FILENAME IS THE REQUIRED INPUT DATA FORMAT FOR ALL UNIVAC PERMANENT FILE NAMES. FOR CDC OPERATION QUALIFIER IS REPLACED BY THE FILE ID, WHICH IS THE USER ID BY DEFAULT

* *

P R O G R A M   S I Z E

* *

ALL ARRAYS REFERRENCED IN THIS CODE THAT ARE PROBLEM DEPENDENT RESIDE IN BLANK COMMON. THE SIZE OF BLANK COMMON IS DETERMINED BY A PARAMETER STATEMENT IN THE MAIN PROGRAM FOR THE UNIVAC 1100-OS VERSION, HENCE A RECOMPILATION IS NECESSARY TO INCREASE OR DECREASE CORE ALLOCATION. IN THE CDC 6600 VERSION RECOMPILATION IS UNNECESSARY AS THE LENGTH OF BLANK COMMON IS SET BY A FIELD LENGTH REQUEST IN THE CONTROL CARD DECK

AT THIS TIME THE CODE HAS NOT BEEN SYSTEMATICALLY OVERLAYED TO CONSERVE SPACE IN THE INSTRUCTION BANK. THIS HAS BEEN DONE TO SOME EXTENT BUT HAS NOT BEEN INCLUDED HERE AS IT IS INCOMPLETE. PLEASE CONTACT THE AUTHOR FOR INFORMATION

* *

D E F I N I T I O N   O F   I N P U T   P A R A M E T E R S

* *

INPUT VARIABLE NAMES GIVEN BELOW ARE GENERALLY THOSE WHICH ARE ALSO USED IN THE CODING AND THE VARIABLE TYPES CORRESPOND TO STANDARD FORTRAN USAGE:

A - ALPHANUMERIC
E - FLOATING POINT
F - FIXED POINT
I - INTEGER
L - LOGICAL

VARIABLE	TYPE	DESCRIPTION
NSTR	I	NUMBER OF INPUT NODE POINTS WHICH ARE USED

		TO DEFINE THE STRUCTURAL MESH. AT THE VERY LEAST THIS NUMBER MUST INCLUDE ALL THE WET NODES, IE., THOSE LYING ON THE FLUID-STRUCTURE CONTACT BOUNDARY. IF THE ULTIMATE PURPOSE OF THIS RUN IS TO CONDUCT AN UNDERWATER SHOCK ANALYSIS WITH THE USA CODE FOR THE STRUCTURE IN QUESTION THEN IT IS ADVISABLE TO INCLUDE IN THE INPUT TO THIS PROCESSOR ALL THE DRY STRUCTURAL NODE POINTS AS WELL IN ORDER TO FACILITATE POST PROCESSING OF THE TRANSIENT RESPONSE ANALYSIS FOR THE DRY STRUCTURE. THIS NUMBER MAY ALSO INCLUDE ADDITIONAL NODE POINTS THAT ARE NOT PART OF THE STRUCTURE MODEL BUT WHICH ARE NECESSARY TO DEFINE THE FLUID MESH
NGEN	I	NUMBER OF GENERAL FLUID DEGREES OF FREEDOM WHOSE ASSOCIATED ELEMENTS CANNOT BE FORMED BY AN AUTOMATIC MESH GENERATION PROCEDURE
NSOR	I	NUMBER OF SURFACE OF REVOLUTION FLUID DEGREES OF FREEDOM
NSEG	I	NUMBER OF SURFACE OF REVOLUTION SEGMENTS IN FLUID MODEL
NCYL	I	NUMBER OF GENERAL FLUID CONTROL POINTS WHICH LIE ON A RIGHT CIRCULAR CYLINDRICAL SURFACE WHOSE ASSOCIATED RECTANGULAR ELEMENTS COVER THE ENTIRE LATERAL SURFACE. SUCH ELEMENTS CAN BE FORMED BY AN AUTOMATIC MESH GENERATION SCHEME WHICH IS EMBEDDED IN THE CODE AND THE AXIS OF THIS SURFACE WILL BE ORIENTED IN THE Z DIRECTION
DENS	E,F	FLUID MASS DENSITY
CEE	E,F	FLUID SPEED OF SOUND
PRTGMT	L	TRUE IF FLUID MESH GEOMETRY DATA IS TO BE LISTED. OTHERWISE FALSE
PRTTRN	L	TRUE IF FLUID-STRUCTURE TRANSFORMATION DATA IS TO BE LISTED. OTHERWISE FALSE
PRTAMF	L	TRUE IF FLUID MASS MATRIX IS TO BE LISTED. OTHERWISE FALSE IN WHICH CASE ONLY THE DIAGONAL TERMS ARE PRINTED
CALCAM	L	TRUE IF THE FLUID MASS MATRIX IS TO BE COMPUTED. OTHERWISE FALSE AND THE RUN WILL TERMINATE AFTER THE FLUID MESH GEOMETRY DATA HAS BEEN PROCESSED. USE A VALUE OF TRUE ONLY AFTER DEBUGGING OF THE GEOMETRY DATA HAS BEEN COMPLETED

EIGMAF	L	TRUE IF EIGENVALUES AND EIGENVECTORS OF THE FLUID BOUNDARY MODE PROBLEM ARE DESIRED, OTHERWISE FALSE
TWODIM	L	TRUE IF A TWO DIMENSIONAL PLANE STRAIN FLUID MASS MATRIX IS REQUIRED, OTHERWISE FALSE
GRDCRD	L	TRUE IF GRID CARDS ARE TO APPEAR IN THE INPUT DATA DECK, OTHERWISE FALSE. THE GRID CARDS DEFINE THE GLOBAL COORDINATES OF THE STRUCTURAL NODE POINTS IN A CARTESIAN REFERENCE FRAME. GRID POINT DATA MAY ENTER THROUGH A PERMANENT FILE (SEE FRWTGR)
QUAMOD	L	TRUE IF THE FLUID MESH INPUT GEOMETRY CORRESPONDS TO A QUARTER MODEL, OTHERWISE FALSE. THE X AND Y DIRECTIONS MUST CURRENTLY BE ASSIGNED TO THE SYMMETRY AXES
PCHCDS	L	TRUE IF THE DIAGONAL GENERALIZED AREA MATRIX IS TO BE PUNCHED OUT ON CARDS FOR INPUT TO NASTRAN, OTHERWISE FALSE
NASTAM	L	TRUE IF THE FLUID MASS MATRIX OR ITS MANIPULATED FORM WHICH APPEARS IN THE DAA EQUATION IS TO BE PUT IN THE PERMANENT FILE DESIGNATED BY FLUNAM IN A FORMAT WHICH CAN BE READ BY NASTRAN, OTHERWISE FALSE
STOMAS	L	TRUE IF THE FLUID MASS MATRIX ITSELF IS TO BE PUT IN PERMANENT STORAGE, OTHERWISE FALSE
STOINV	L	TRUE IF THE MANIPULATED FORM OF THE FLUID MASS MATRIX WHICH APPEARS IN THE DAA EQUATION IS TO BE PUT IN PERMANENT STORAGE, OTHERWISE FALSE
FRWTFL	L	TRUE IF THE PERMANENT FILE CONTAINING THE FLUID MASS MATRIX OR ITS MANIPULATED FORM IS TO BE CREATED BY BUFFERED, UNFORMATTED FORTRAN WRITE STATEMENTS, OTHERWISE FALSE AND DMGASP WILL CREATE THE FILE
FRWTGE	L	TRUE IF THE PERMANENT FILE CONTAINING THE FLUID MESH GEOMETRY IS TO BE CREATED BY BUFFERED, UNFORMATTED FORTRAN WRITE STATEMENTS, OTHERWISE FALSE AND DMGASP WILL CREATE THE FILE
FRWTGR	L	TRUE IF THE PERMANENT FILE CONTAINING STRUCTURAL GRID POINT COORDINATES HAS BEEN CREATED BY BUFFERED, UNFORMATTED FORTRAN WRITE STATEMENTS, OTHERWISE FALSE IN WHICH CASE IT IS ASSUMED THAT DMGASP WAS USED TO CREATE THE FILE. CONSULT A

		LISTING OF THE SUBROUTINE READST FOR THE FILE STRUCTURE THAT IS EXPECTED WHICH DIFFERS FOR THE TWO POSSIBLE CASES. THIS FILE MUST EXIST FOR INTERFACING WITH STAGS (SEE GRDCRD)
FLUNAM	A	NAME OF PERMANENT MASS STORAGE FILE WHICH WILL CONTAIN EITHER THE FLUID MASS MATRIX OR ITS MANIPULATED DAA FORM
GEONAM	A	NAME OF PERMANENT MASS STORAGE FILE WHICH WILL CONTAIN THE FLUID MESH GEOMETRY AND FLUID-STRUCTURE TRANSFORMATION DATA
GRDNAM	A	NAME OF PERMANENT MASS STORAGE FILE WHICH CONTAINS THE GLOBAL COORDINATES OF THE STRUCTURAL GRID POINTS
NHAR	I	INDEX OF CIRCUMFERENTIAL HARMONIC FOR SOR ELEMENTS TO BE USED IN FLUID BOUNDARY MODE ANALYSIS
NVEC	I	NUMBER OF FLUID BOUNDARY MODE EIGENVECTORS DESIRED. THESE ARE ORDERED STARTING WITH THE LOWEST ORDER MODES FIRST
NUMZ	I	NUMBER OF FICTITIOUS ELEMENTS TO BE ADDED IN AXIAL DIRECTION WHICH INCREASE THE HALF LENGTH OF THE SURFACE FOR THE SIMULATION OF A TWO DIMENSIONAL PLANE STRAIN FLUID MASS MATRIX. THESE ELEMENTS DO NOT INTRODUCE NEW DEGREES OF FREEDOM
ZLEN	E,F	LENGTH OF FICTITIOUS AXIAL ELEMENTS USED IN THE SIMULATION OF A TWO DIMENSIONAL PLANE STRAIN FLUID MASS MATRIX
CQ	E,F	TAKES ON THE VALUE OF EITHER PLUS OR MINUS ONE TO DENOTE SYMMETRIC OR ANTISYMMETRIC FLOW CONDITIONS IN EACH QUADRANT OF A FLUID MESH THAT IS TO BE REPRESENTED BY A QUARTER MODEL OF THE SURFACE
NTCY	I	NUMBER OF STRUCTURAL NODE POINTS THAT COUPLE WITH A CURVED RECTANGULAR FLUID ELEMENT WHICH IS TO BE AUTOMATICALLY FORMED FOR AN AXIAL SEGMENT OF A RIGHT CIRCULAR CYLINDRICAL SURFACE. AVAILABLE OPTIONS ARE: 2 - STRUCTURAL NODES WILL BE ON MIDPOINT OF CURVED SIDES 4 - STRUCTURAL NODES WILL BE AT CORNERS
NSEQ	I	STRUCTURAL GRID POINT NUMBER
NS	I	WILL EVENTUALLY CONTAIN POINTER TO DENOTE TYPE OF COORDINATE SYSTEM GRID POINT DATA

		IS REFERRED TO. CURRENTLY ONLY GLOBAL CARTESIAN COORDINATES ARE ALLOWABLE. SET TO ZERO
XC,YC,ZC	E,F	CARTESIAN COORDINATES OF STRUCTURAL GRID POINT
NEL	I	GENERAL FLUID ELEMENT INDEX WHICH RUNS FROM 1 TO NGEN IN SEQUENTIAL ORDER
NC	I	NUMBER OF CORNER POINTS OF GENERAL FLUID ELEMENT, CURRENTLY RESTRICTED TO THE VALUES 3 OR 4. SEE FLUID ELEMENT LIBRARY. THE CORNER POINTS WILL USUALLY PARTICIPATE IN THE FLUID-STRUCTURE TRANSFORMATION
NN	I	NUMBER OF ADDITIONAL NEIGHBOR POINTS ASSOCIATED WITH A PARTICULAR GENERAL FLUID ELEMENT, CURRENTLY HAVING PERMISSIBLE VALUES OF 1, 2, 3, AND 5. SEE FLUID ELEMENT LIBRARY. THESE ADDITIONAL POINTS ALSO PARTICIPATE IN THE FLUID-STRUCTURE TRANSFORMATION
KURV	I	FLUID ELEMENT CURVATURE FLAG. ACCEPTABLE VALUES ARE: 0 - FLAT ELEMENT 1 - CURVED ELEMENT, CODE WILL DETERMINE AVERAGE CURVATURE OF ELEMENT FROM NEIGHBOR POINT LOCATIONS. DO NOT USE THIS OPTION IF NN = 0 2 - CURVED ELEMENT, USER MUST INPUT PRINCIPLE RADII OF CURVATURE. IF EITHER RADIUS IS SET TO 10000 OR GREATER THEN ITS ASSOCIATED CURVATURE WILL BE SET TO ZERO
NODE	I	NODE POINT NUMBERS OF FLUID ELEMENT CORNER POINTS TAKEN IN COUNTER CLOCKWISE DIRECTION. ASSIGN A NEGATIVE VALUE TO ANY NODE NUMBERS WHICH ARE NOT PART OF THE STRUCTURAL FINITE ELEMENT MODEL SO THEY WILL NOT PARTICIPATE IN THE FLUID-STRUCTURE TRANSFORMATION. SEE FLUID ELEMENT LIBRARY
ITEM	I	NODE POINT NUMBERS OF FLUID ELEMENT NEIGHBOR POINTS AGAIN TAKEN IN COUNTER CLOCKWISE ORDER STARTING FROM FIRST CORNER POINT. ANY INTERIOR POINTS MUST APPEAR LAST. SEE FLUID ELEMENT LIBRARY
RAD1	E,F	RADIUS OF CURVATURE OF FLUID ELEMENT IN DIRECTION FROM FIRST CORNER POINT TO SECOND CORNER POINT
RAD2	E,F	RADIUS OF CURVATURE OF FLUID ELEMENT IN

		DIRECTION PERPENDICULAR TO SIDE JOINING FIRST CORNER POINT AND SECOND CORNER POINT
NCIR	I	NUMBER OF CIRCUMFERENTIAL GENERAL ELEMENTS TO BE FORMED AUTOMATICALLY FOR AN AXIAL SEGMENT OF A RIGHT CIRCULAR CYLINDRICAL SURFACE
NLAS	I	NUMBER OF LAST FLUID ELEMENT IN SURFACE MESH WHICH PRECEEDES THE INPUT FOR THIS AXIAL SEGMENT
NSTART	I	NUMBER OF STRUCTURAL GRID NODE AT THE POINT ON THE CIRCUMFERENCE WHERE THIS SET OF CIRCUMFERENTIAL GENERAL ELEMENTS BEGIN
NDAX	I	INCREMENT TO BE APPLIED IN DESIGNATING THE NUMBER OF THE CORRESPONDING STRUCTURAL NODE AT THE OTHER AXIAL BOUNDARY OF THIS SET OF CIRCUMFERENTIAL GENERAL ELEMENTS
NDCR	I	INCREMENT TO BE APPLIED IN DESIGNATING THE NUMBER OF THE CORRESPONDING STRUCTURAL NODE ONE FLUID ELEMENT AWAY IN THE CIRCUMFERENTIAL DIRECTION
RAD	E,F	RADIUS OF CIRCULAR CYLINDRICAL SURFACE
DZ	E,F	AXIAL LENGTH OF CIRCULAL CYLINDRICAL SURFACE
ZCEN	E,F	CENTROIDAL COORDINATE IN THE Z DIRECTION FOR THIS SET OF CIRCUMFERENTIAL GENERAL ELEMENTS
NSR	I	SURFACE OF REVOLUTION ELEMENT INDEX WHICH RUNS FROM 1 TO NSOR IN SEQUENTIAL ORDER
NFREE	I	WILL HAVE THE VALUE 1, 2, OR 3 DEPENDING UPON WHETHER THE NORMAL FLUID VELOCITY OF THE SURFACE OF REVOLUTION ELEMENT IS IN THE X, Y, OR Z GLOBAL COORDINATE DIRECTION
NAXIS	I	WILL HAVE THE VALUE 1, 2, OR 3 DEPENDING UPON WHETHER THE AXIS OF REVOLUTION OF THE SURFACE OF REVOLUTION ELEMENT IS PARALLEL TO THE X, Y, OR Z GLOBAL COORDINATE DIRECTION
R1	E,F	RADIUS TO WET SURFACE FROM AXIS OF SOR ELEMENT AT STRUCTURAL GRID POINT CLOSEST TO ORIGIN OF GLOBAL COORDINATE SYSTEM
R2	E,F	RADIUS TO WET SURFACE FROM AXIS OF SOR ELEMENT AT STRUCTURAL GRID POINT FURTHEST FROM ORIGIN OF GLOBAL COORDINATE SYSTEM

```
N1             I          GRID POINT NUMBER OF STRUCTURAL NODE
                          CLOSEST TO ORIGIN OF GLOBAL COORDINATE
                          SYSTEM WHICH DEFINES ONE AXIAL BOUNDARY OF
                          THE SOR ELEMENT


N2             I          GRID POINT NUMBER OF STRUCTURAL NODE
                          FURTHEST FROM ORIGIN OF GLOBAL COORDINATE
                          SYSTEM WHICH DEFINES THE OTHER AXIAL
                          BOUNDARY OF THE SOR ELEMENT

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

            I N P U T    D A T A    C A R D    D E C K

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

ALL INPUT DATA EXCEPT ALPHANUMERIC DATA MUST BE RIGHT JUSTIFIED
IN EIGHT (8) COLUMN FIELDS WHICH CAN OCCUPY THE ENTIRE CARD.
ALPHANUMERIC DATA MUST BE LEFT JUSTIFIED IN SIXTEEN (16) COLUMN
FIELDS. FILE NAMES ARE RESTRICTED TO TWELVE (12) CHARACTERS FOR
UNIVAC OPERATION WHILE SIXTEEN (16) CHARACTERS ARE ALLOWED FOR CDC
OPERATION. HENCE A NAME LIKE ABCDE*FGHIJK IS THE LIMIT FOR UNIVAC
WHILE A CDC FILE NAME MAY HAVE FOUR (4) ADDITIONAL CHARACTERS

GENERAL PROBLEM DEFINITION (SUBROUTINE AMINPT):
----------------------------------------------

72 COLUMN ALPHANUMERIC TITLE
NSTR    NGEN    NSOR    NSEG    NCYL
DENS    CEE
PRTGMT  PRTTRN  PRTAMF  CALCAM
EIGMAF  TWODIM  GRDCRD  QUAMOD
PCHCDS  NASTAM  STOMAS  STOINV
FRWTFL  FRWTGE  FRWTGR
FLUNAM          GEONAM          GRDNAM

IF EIGMAF = .TRUE. INCLUDE THE FOLLOWING CARD

NHAR    NVEC

IF TWODIM = .TRUE. INCLUDE THE FOLLOWING TWO CARDS

NUMZ
ZLEN

IF QUAMOD = .TRUE. INCLUDE THE FOLLOWING CARD

CQ(I), I=1,4

IF NCYL IS NOT EQUAL TO ZERO READ THE FOLLOWING CARD

NTCY

STRUCTURAL NODE COORDINATES (SUBROUTINE READST):
------------------------------------------------

IF GRDCRD = .TRUE. INCLUDE THE FOLLOWING CARDS
```

```
GRID    NSEQ    N       XC      YC      ZC          )
          .     .        .       .       .          )  TOTAL = NSTR
          .     .        .       .       .          )

GENERAL ELEMENT DEFINITION (SUBROUTINE GENELM):
-----------------------------------------------

IF NGEN IS NOT EQUAL TO ZERO READ THE FOLLOWING CARDS

GEN     NEL     NC      NN      KURV        )
        NODE(I), I=1,NC                     )
        ITEM(I), I=1,NN                     )  TOTAL NUMBER OF
                                            )
IF KURV = 3 READ THE FOLLOWING CARD         )  SETS = NGEN
                                            )
        RAD1    RAD2                        )

CYLINDRICAL SURFACE GENERAL ELEMENTS (SUBROUTINE CYLGEO):
---------------------------------------------------------

IF NCYL IS NOT EQUAL TO ZERO READ THE FOLLOWING CARDS FOR EACH
AXIAL SEGMENT

NCIR    NLAS    NSTART  NDAX    NDCR
RAD     DZ      ZCEN

SURFACE-OF-REVOLUTION ELEMENT DEFINITION (SUBROUTINE SORINP):
-------------------------------------------------------------

IF NSOR IS NOT EQUAL TO ZERO READ THE FOLLOWING CARD FOR EACH
SOR DEGREE OF FREEDOM

SOR     NSR     NFREE   NAXIS   R1      R2      N1      N2
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

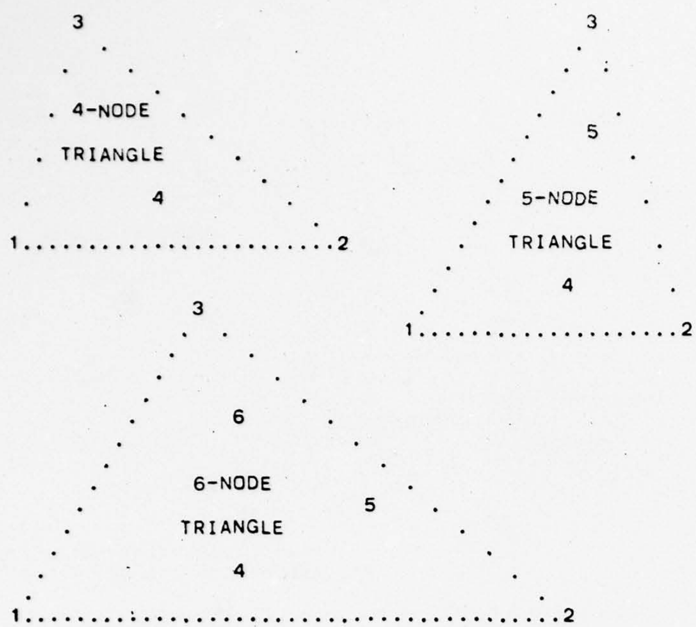
                  F L U I D     E L E M E N T     L I B R A R Y

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    THE CORNER POINTS OF EACH OF THE ELEMENT TYPES SHOWN BELOW ARE
    ASSUMED TO LIE IN THE SAME PLANE AND THE DIRECTION OF THE UNIT
    NORMAL VECTOR IS TAKEN TO BE POSITIVE AS COMING UP FROM THE PAGE
    AND OUT INTO THE FLUID REGION. THE VIEWER IS THUS PLACED IN THE
    SAME RELATIVE POSITION AS A SCUBA DIVER GAZING AT THE SIDE OF A
    SUNKEN TREASURE SHIP. THE NODE ORDER FOR INPUT MUST ALWAYS BE IN
    THE COUNTERCLOCKWISE DIRECTION AS SHOWN BECAUSE THE RIGHT HAND
    RULE IS USED INTERNALLY TO DETERMINE THE POSITIVE OUTWARD
    DIRECTION. NOTE THAT CORNER POINTS ARE TAKEN FIRST, THEN ANY OTHER
    POINTS WHICH MAY BE INVOLVED IN THE FLUID-STRUCTURE TRANSFORMATION
    FOLLOW. YOU MAY PLAY CONNECT-THE-DOTS WITH YOUR PENCIL TO MAKE THE
    FIGURES MORE LEGIBLE IF YOU WISH

                                                        3
    BASIC FLUID ELEMENT CONFIGURATIONS:               .   .
                                                     .     .
          3                                     4           .
         .  .                                  .             .
        .     .                               .   GENERAL     .
       .        .                            .                 .
      .  TRIANGLE .                         .  QUADRILATERAL    .
     .              .                      .                     .
    1.................2                   1.......................2

    BASIC FLUID ELEMENT CONFIGURATIONS    4
    WITH ADDITIONAL TRANSFORMATION         .  .
    POINTS:                               .      6
                                         .        .
                                        .       .    .
                                       .              .
          4...3                       .       .   GENERAL   .
              .                      .  6-NODE                3
         .   .                      .           .  QUADRILATERAL .
          6-NODE .                 .                              .
        6         .               1..........5.....................2
            .      .
         .     .    .
                  .  .                   4
        .   GENERAL  . .                  .   .
                       5                 .       .
       .  QUADRILATERAL  .                          .
                          .             .                7
      1....................2                           .    .
                                       .   9-NODE    .         3
                                                     .          .
                                      8..........9..........6
                                                  .             .
                                     .          .   GENERAL      . .
                                                .                  .
                                    .        .   QUADRILATERAL      .
                                             .                       .
                                   1.......5.........................2
```


3
4-NODE
TRIANGLE
4
1
2
3
5
5-NODE
TRIANGLE
4
1
2
3
6
6-NODE
5
TRIANGLE
4
1
2

The following discussion is provided as an aid to user understanding of the sample output that is included here.

First, the terms appearing under "Fluid Mesh Geometric Arrays" are defined as:

NCOR	- number of corner points for a particular fluid element
X,Y,Z	- global cartesian coordinates of the fluid element centroidal control point
NX,NY,NZ	- components of the outward unit normal vector for the fluid element
NTRA	- number of structural node points that are coupled to a particular fluid element for the purpose of force application
A00,A20,A11,A02	- area and moments and product of inertia of fluid element. Used internally for construction of the fluid mass matrix and of the fluid-structure transformation coefficients for general elements.
BII,CII	- diagonal terms of B and C matrices used for construction of fluid mass matrix (see [9])

When SOR elements are included in the fluid mesh the following terms will appear in the output:

RAD	- radius of fluid element control point from axis of revolution
NCIR	- number of integration points used in cirdumferential direction
NAXI	- see NAXIS in user manual
NFRE	- see NFREE in user manual

Local Fluid-Structure Transformation Coefficients appear next. This is a summary that indicates which structural nodes couple with a particular fluid control point and the weighting factor for each. The weighting factors must always sum to unity for any fluid control point.

The eigenvalues and eigenvectors that follow the listing of the added mass matrix correspond to the "Fluid Boundary Mode" problem [9]. For the infinite cylindrical shell problem presented here, the exact eigenvalues should behave as $1/n$ with corresponding modes $\cos n\theta$ and $\sin n\theta$. The first eigenvalue listed, .11838+04, is an approximation to ∞ for $n=0$ and it can be seen that the subsequent eigenvalues are relatively well behaved.

```
PLANE STRAIN SIMULATION OF INFINITE CYLINDER
      0       0       0       0      36
     1.      1.
      T       T       T       T
      T       T       F       F
      F       F       T       F
      F       F       F
CYL*MASS       CYL*GEOM
      0      36
    500
   .175
      2
     36       0       1       1       2
     1.    .175      0.

@XQT
```

PLANE STRAIN SIMULATION OF INFINITE CYLINDER

MAXIMUM FLUID NODES = 85

SCRATCH ALLOCATION = 15000

FLUID MASS DENSITY = .10000000+01

FLUID SOUND SPEED = .10000000+01

FLUID MESH GEOMETRIC ARRAYS:

N	NCOR	X	Y	Z	NX	NY	NZ
1	4	.10000000+01	.00000000	.00000000	.10000000+01	.00000000	.00000000
2	4	.98480775+00	.17364818+00	.00000000	.98480775+00	.17364818+00	.00000000
3	4	.93969262+00	.34202014+00	.00000000	.93969262+00	.34202014+00	.00000000
4	4	.86602541+00	.49999999+00	.00000000	.86602541+00	.49999999+00	.00000000
5	4	.76604445+00	.64278761+00	.00000000	.76604445+00	.64278761+00	.00000000
6	4	.64278762+00	.76604444+00	.00000000	.64278762+00	.76604444+00	.00000000
7	4	.50000001+00	.86602540+00	.00000000	.50000001+00	.86602540+00	.00000000
8	4	.34202016+00	.93969262+00	.00000000	.34202016+00	.93969262+00	.00000000
9	4	.17364819+00	.98480775+00	.00000000	.17364819+00	.98480775+00	.00000000
10	4	.15893255-07	.10000000+01	.00000000	.15893255-07	.10000000+01	.00000000
11	4	-.17364816+00	.98480776+00	.00000000	-.17364816+00	.98480776+00	.00000000
12	4	-.34202012+00	.93969263+00	.00000000	-.34202012+00	.93969263+00	.00000000
13	4	-.49999997+00	.86602542+00	.00000000	-.49999997+00	.86602542+00	.00000000
14	4	-.64278758+00	.76604447+00	.00000000	-.64278758+00	.76604447+00	.00000000
15	4	-.76604442+00	.64278764+00	.00000000	-.76604442+00	.64278764+00	.00000000
16	4	-.86602538+00	.50000004+00	.00000000	-.86602538+00	.50000004+00	.00000000
17	4	-.93969262+00	.34202017+00	.00000000	-.93969262+00	.34202017+00	.00000000
18	4	-.98480775+00	.17364820+00	.00000000	-.98480775+00	.17364820+00	.00000000
19	4	-.10000000+01	.31786509-07	.00000000	-.10000000+01	.31786509-07	.00000000
20	4	-.98480776+00	-.17364814+00	.00000000	-.98480776+00	-.17364814+00	.00000000
21	4	-.93969264+00	-.34202011+00	.00000000	-.93969264+00	-.34202011+00	.00000000
22	4	-.86602543+00	-.49999996+00	.00000000	-.86602543+00	-.49999996+00	.00000000
23	4	-.76604448+00	-.64278757+00	.00000000	-.76604448+00	-.64278757+00	.00000000
24	4	-.64278768+00	-.76604439+00	.00000000	-.64278768+00	-.76604439+00	.00000000
25	4	-.50000005+00	-.86602537+00	.00000000	-.50000005+00	-.86602537+00	.00000000
26	4	-.34202018+00	-.93969261+00	.00000000	-.34202018+00	-.93969261+00	.00000000
27	4	-.17364825+00	-.98480774+00	.00000000	-.17364825+00	-.98480774+00	.00000000
28	4	-.47679764-07	-.10000000+01	.00000000	-.47679764-07	-.10000000+01	.00000000
29	4	.17364810+00	-.98480777+00	.00000000	.17364810+00	-.98480777+00	.00000000
30	4	.34202009+00	-.93969264+00	.00000000	.34202009+00	-.93969264+00	.00000000
31	4	.49999992+00	-.86602545+00	.00000000	.49999992+00	-.86602545+00	.00000000
32	4	.64278756+00	-.76604449+00	.00000000	.64278756+00	-.76604449+00	.00000000
33	4	.76604442+00	-.64278764+00	.00000000	.76604442+00	-.64278764+00	.00000000

34	4	.86602537+00	-.50000007+00	.00000000	.86602537+00	-.50000007+00	.00000000
35	4	.93969260+00	-.34202019+00	.00000000	.93969260+00	-.34202019+00	.00000000
36	4	.98480774+00	-.17364826+00	.00000000	.98480774+00	-.17364826+00	.00000000

N	NTRA	A00	A20	A11	A02	BII	CII
1	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
2	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
3	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
4	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
5	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
6	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
7	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
8	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
9	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
10	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
11	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
12	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
13	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
14	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
15	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
16	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
17	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
18	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
19	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
20	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
21	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
22	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
23	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
24	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
25	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
26	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
27	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
28	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
29	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
30	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
31	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
32	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
33	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
34	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
35	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01
36	2	.30543262-01	.77533404-04	.11102230-13	.77948942-04	.61613729+00	.64372196+01

LOCAL FLUID-STRUCTURE TRANSFORMATION COEFFICIENTS:

NFLU	NSTR	
1	1	2
	.50000+00	.50000+00
2	3	4
	.50000+00	.50000+00
3	5	6
	.50000+00	.50000+00
4	7	8
	.50000+00	.50000+00
5	9	10
	.50000+00	.50000+00

6	11	12
	.50000+00	.50000+00
7	13	14
	.50000+00	.50000+00
8	15	16
	.50000+00	.50000+00
9	17	18
	.50000+00	.50000+00
10	19	20
	.50000+00	.50000+00
11	21	22
	.50000+00	.50000+00
12	23	24
	.50000+00	.50000+00
13	25	26
	.50000+00	.50000+00
14	27	28
	.50000+00	.50000+00
15	29	30
	.50000+00	.50000+00
16	31	32
	.50000+00	.50000+00
17	33	34
	.50000+00	.50000+00
18	35	36
	.50000+00	.50000+00
19	37	38
	.50000+00	.50000+00
20	39	40
	.50000+00	.50000+00
21	41	42
	.50000+00	.50000+00
22	43	44
	.50000+00	.50000+00
23	45	46
	.50000+00	.50000+00
24	47	48
	.50000+00	.50000+00
25	49	50
	.50000+00	.50000+00
26	51	52
	.50000+00	.50000+00
27	53	54
	.50000+00	.50000+00
28	55	56
	.50000+00	.50000+00
29	57	58
	.50000+00	.50000+00
30	59	60
	.50000+00	.50000+00
31	61	62
	.50000+00	.50000+00
32	63	64
	.50000+00	.50000+00
33	65	66
	.50000+00	.50000+00
34	67	68
	.50000+00	.50000+00

```
35          69           70
        .50000+00    .50000+00
36          71           72
        .50000+00    .50000+00

+++  @ ASG.UPR        CYL*GEOM.,  F/     4/ TRK/  1024
+++  @ USE      2.    CYL*GEOM.

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+          A U X I L I A R Y   S T O R A G E   T A B L E            +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                   +
+ LDI   EXT-NAME UNT EC OPT SEC  CDLOC   NEXT  LIMIT      READ WRITTEN +
+  2    CYL*GEOM   2 36 UPR  28    237    237  65536         0    6600 +
+                                                                   +
+                    1 ACTIVE DEVICES ( 0 FULL)                     +
+       0 TP-OPS,       4 WRITES,        0 READS,       6600 WORDS XFD +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

+++  @ FREE           CYL*GEOM.
```

ADDED MASS MATRIX IN FLUID COORDINATES:

	1	2	3	4	5	6	7	8	9	10
1	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01
2	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01
3	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01
4	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01
5	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01
6	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01
7	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01
8	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01
9	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01
10	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01
11	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01
12	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01
13	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01
14	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01
15	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01
16	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01
17	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01
18	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01
19	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01
20	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01
21	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01
22	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01
23	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01
24	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01
25	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01
26	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01
27	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01
28	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01
29	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01
30	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01
31	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01
32	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01
33	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01

34	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01
35	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01
36	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01
	11	12	13	14	15	16	17	18	19	20
1	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01
2	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01
3	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01
4	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01
5	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01
6	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01
7	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01
8	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01
9	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01
10	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01
11	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01
12	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01
13	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01
14	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01
15	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01
16	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01
17	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01
18	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01
19	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01
20	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01
21	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01
22	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01
23	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01
24	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01
25	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01
26	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01
27	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01
28	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01
29	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01
30	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01
31	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01
32	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01
33	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01
34	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01
35	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01
36	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01
	21	22	23	24	25	26	27	28	29	30
1	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01
2	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01
3	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01
4	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01
5	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01
6	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01
7	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01
8	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01
9	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01
10	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01
11	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01
12	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01
13	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01
14	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01
15	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01
16	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01
17	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01

18	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01
19	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01
20	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01
21	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01
22	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01
23	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01
24	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01
25	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01
26	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01
27	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01
28	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01
29	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01
30	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01
31	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01
32	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01
33	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01
34	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01
35	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01
36	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01

	31	32	33	34	35	36
1	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01
2	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01	.10062+01
3	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01	.10055+01
4	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01	.10050+01
5	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01	.10047+01
6	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01	.10044+01
7	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01	.10042+01
8	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01	.10040+01
9	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01	.10038+01
10	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01	.10037+01
11	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01	.10035+01
12	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01	.10035+01
13	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01	.10034+01
14	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01	.10033+01
15	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01	.10033+01
16	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01	.10032+01
17	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01	.10032+01
18	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01	.10032+01
19	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01	.10032+01
20	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01	.10032+01
21	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01	.10033+01
22	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01	.10033+01
23	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01	.10034+01
24	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01	.10035+01
25	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01	.10035+01
26	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01	.10037+01
27	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01	.10038+01
28	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01	.10040+01
29	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01	.10042+01
30	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01	.10044+01
31	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01	.10047+01
32	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01	.10050+01
33	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01	.10055+01
34	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01	.10062+01
35	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01	.10074+01
36	.10047+01	.10050+01	.10055+01	.10062+01	.10074+01	.10102+01

+++ @ ASG,UPR CYL=MASS., F/ 4/ TRK/ 1024

```
+++ @ USE     3,     CYL+MASS.

+++ @ ASG,T          UNIT04., F4/     4/ TRK/   256
+++ @ USE     4,     UNIT04.
```

EIGENVALUES:

1	2	3	4	5	6	7	8	9	10
.11838+04	.99860+00	.99859+00	.49810+00	.49809+00	.33073+00	.33072+00	.24668+00	.24668+00	.19609+00
11	12	13	14	15	16	17	18	19	20
.19609+00	.16237+00	.16237+00	.13840+00	.13840+00	.12060+00	.12059+00	.10695+00	.10694+00	.96271-01
21	22	23	24	25	26	27	28	29	30
.96269-01	.87829-01	.87827-01	.81150-01	.81147-01	.75908-01	.75907-01	.71879-01	.71874-01	.68889-01
31	32	33	34	35	36				
.68887-01	.66821-01	.66818-01	.65607-01	.65606-01	.65207-01				

EIGENVECTORS:

	1	2	3	4	5	6	7	8	9	10
1	.95365+00	.13455+01	.91100-01	.12370+01	-.61289+00	-.12886+01	-.39697+00	.97952+00	-.92341+00	.83940-01
2	.95365+00	.13090+01	.32336+00	.13463+01	-.16504+00	-.13152+01	.30066+00	.13465+01	-.75511-01	.10853+01
3	.95365+00	.12326+01	.54582+00	.12930+01	.30273+00	-.98898+00	.91773+00	.10830+01	.80769+00	.13109+01
4	.95365+00	.11188+01	.75168+00	.10839+01	.73397+00	-.39798+00	.12889+01	.31296+00	.13130+01	.60012+00
5	.95365+00	.97099+00	.93471+00	.74401+00	.10767+01	.29963+00	.13147+01	-.60348+00	.12039+01	-.53934+00
6	.95365+00	.79371+00	.10893+01	.31441+00	.12895+01	.91696+00	.98825+00	-.12375+01	.53152+00	-.12935+01
7	.95365+00	.59230+00	.12109+01	-.15313+00	.13469+01	.12886+01	.39698+00	-.12926+01	-.38958+00	-.11236+01
8	.95365+00	.37290+00	.12956+01	-.60218+00	.12417+01	.13150+01	-.30066+00	-.74280+00	-.11284+01	-.15096+00
9	.95365+00	.14218+00	.13410+01	-.97859+00	.98682+00	.98898+00	-.91773+00	.15458+00	-.13392+01	.92960+00
10	.95365+00	-.92870-01	.13456+01	-.12370+01	.61288+00	.39800+00	-.12889+01	.97961+00	-.92341+00	.13460+01
11	.95365+00	-.32509+00	.13093+01	-.13462+01	.16503+00	-.29964+00	-.13147+01	.13463+01	-.75526-01	.60080+00
12	.95365+00	-.54744+00	.12333+01	-.12930+01	-.30273+00	-.91698+00	-.98825+00	.10830+01	.80769+00	-.31649+00
13	.95365+00	-.75316+00	.11198+01	-.10839+01	-.73397+00	-.12886+01	-.39699+00	.31301+00	.13130+01	-.12077+01
14	.95365+00	-.93593+00	.97223+00	-.74401+00	-.10767+01	-.13150+01	.30065+00	-.60347+00	.12039+01	-.12361+01
15	.95365+00	-.10904+01	.79515+00	-.31442+00	-.12895+01	-.98897+00	.91772+00	-.12376+01	.53151+00	-.38145+00
16	.95365+00	-.12116+01	.59391+00	.15310+00	-.13469+01	-.39802+00	.12889+01	-.12926+01	-.38959+00	.74576+00
17	.95365+00	-.12961+01	.37462+00	.60217+00	-.12417+01	.29958+00	.13147+01	-.74279+00	-.11284+01	.13402+01
18	.95365+00	-.13412+01	.14395+00	.97858+00	-.98681+00	.91695+00	.98828+00	.15450+00	-.13392+01	.97711+00
19	.95365+00	-.13455+01	-.91092-01	.12370+01	-.61289+00	.12886+01	.39701+00	.97958+00	-.92340+00	-.83950-01
20	.95365+00	-.13089+01	-.32337+00	.13462+01	-.16503+00	.13150+01	-.30063+00	.13463+01	-.75524-01	-.10851+01
21	.95365+00	-.12326+01	-.54582+00	.12930+01	.30273+00	.98899+00	-.91773+00	.10831+01	.80769+00	-.13110+01
22	.95365+00	-.11188+01	-.75168+00	.10839+01	.73397+00	.39805+00	-.12889+01	.31304+00	.13130+01	-.60037+00
23	.95365+00	-.97100+00	-.93471+00	.74402+00	.10767+01	-.29956+00	-.13148+01	-.60343+00	.12039+01	.53923+00
24	.95365+00	-.79371+00	-.10893+01	.31443+00	.12895+01	-.91692+00	-.98828+00	-.12375+01	.53151+00	.12936+01
25	.95365+00	-.59231+00	-.12109+01	-.15307+00	.13469+01	-.12886+01	-.39700+00	-.12926+01	-.38958+00	.11238+01
26	.95365+00	-.37291+00	-.12956+01	-.60213+00	.12417+01	-.13150+01	.30065+00	-.74284+00	-.11284+01	.15116+00
27	.95365+00	-.14219+00	-.13410+01	-.97858+00	.98682+00	-.98900+00	.91773+00	.15443+00	-.13392+01	-.92953+00
28	.95365+00	.92858-01	-.13456+01	-.12370+01	.61289+00	-.39805+00	.12889+01	.97946+00	-.92341+00	-.13461+01
29	.95365+00	.32509+00	-.13093+01	-.13462+01	.16504+00	.29954+00	.13148+01	.13462+01	-.75516-01	-.80098+00
30	.95365+00	.54743+00	-.12333+01	-.12930+01	-.30272+00	.91690+00	.98826+00	.10831+01	.80770+00	.31632+00
31	.95365+00	.75315+00	-.11198+01	-.10839+01	-.73397+00	.12886+01	.39700+00	.31313+00	.13130+01	.12077+01
32	.95365+00	.93598+00	-.97223+00	-.74404+00	-.10767+01	.13149+01	-.30064+00	-.60329+00	.12039+01	.12363+01
33	.95365+00	.10904+01	-.79515+00	-.31444+00	-.12895+01	.98900+00	-.91774+00	-.12374+01	.53153+00	.38167+00
34	.95365+00	.12116+01	-.59391+00	.15307+00	-.13469+01	.39810+00	-.12889+01	-.12926+01	-.38959+00	-.74569+00
35	.95365+00	.12961+01	-.37462+00	.60214+00	-.12417+01	-.29951+00	-.13147+01	-.74295+00	-.11284+01	-.13403+01
36	.95365+00	.13411+01	-.14395+00	.97855+00	-.98682+00	-.91684+00	-.98829+00	.15431+00	-.13392+01	-.97738+00

	11	12	13	14	15	16	17	18	19	20
1	.13473+01	-.70567+00	.11491+01	-.71234+00	-.11153+01	-.48015+00	-.12417+01	-.59091+00	.12130+01	.13866+00
2	.81747+00	-.13485+01	-.36482-01	-.13201+01	.33064+00	-.13249+01	.30239+00	-.12125+01	-.58800+00	-.13453+01

3	-.29628+00	-.64215+00	-.11858+01	-.18996+00	.13418+01	.21103-01	.13468+01	.59251+00	-.12139+01	.32955+00
4	-.11984+01	.70602+00	-.11493+01	.11898+01	.58709+00	.13318+01	.16535+00	.12118+01	.58843+00	.12304+01
5	-.12443+01	.13481+01	.36570-01	.10038+01	-.94019+00	.44139+00	-.12894+01	-.59247+00	.12139+01	-.75689+00
6	-.40126+00	.64215+00	.11858+01	-.50315+00	-.12302+01	-.11785+01	-.61313+00	-.12120+01	-.58851+00	-.96757+00
7	.72840+00	-.70590+00	.11493+01	-.13479+01	.98600-01	-.85060+00	.10764+01	.59252+00	-.12137+01	.10931+01
8	.13377+01	-.13482+01	-.36548-01	-.41900+00	.12977+01	.88287+00	.98705+00	.12119+01	.58847+00	.58783+00
9	.99134+00	-.64232+00	-.11859+01	.10612+01	.78908+00	.11571+01	-.73356+00	-.59250+00	.12136+01	-.12973+01
10	-.63299-01	.70584+00	-.11493+01	.11450+01	-.75798+00	-.48077+00	-.12418+01	-.12118+01	-.58845+00	-.13726+00
11	-.10727+01	.13482+01	.36590-01	-.27794+00	-.13075+01	-.13242+01	.30229+00	.59230+00	-.12136+01	.13449+01
12	-.13157+01	.64236+00	.11859+01	-.13351+01	-.13641+00	.20846-01	.13469+01	.12119+01	.58852+00	-.32967+00
13	-.61877+00	-.70577+00	.11493+01	-.63537+00	.12142+01	.13314+01	.16538+00	-.59221+00	.12135+01	-.12304+01
14	.52023+00	-.13482+01	-.36596-01	.90050+00	.96699+00	.44166+00	-.12894+01	-.12120+01	-.58855+00	.75694+00
15	.12876+01	-.64233+00	-.11859+01	.12515+01	-.55280+00	-.11780+01	-.61322+00	.59214+00	-.12135+01	.96764+00
16	.11350+01	.70571+00	-.11493+01	-.44532-01	-.13451+01	-.85097+00	.10765+01	.12119+01	.58852+00	-.10931+01
17	.17165+00	.13481+01	.36591-01	-.12820+01	-.36722+00	.88231+00	.98714+00	-.59205+00	.12135+01	-.58817+00
18	-.91440+00	.64254+00	.11859+01	-.83227+00	.10938+01	.11576+01	-.73378+00	-.12118+01	-.58849+00	.12976+01
19	-.13472+01	-.70568+00	.11493+01	.71247+00	.11155+01	-.48036+00	-.12419+01	.59171+00	-.12136+01	.13738+00
20	-.81749+00	-.13482+01	-.36593-01	.13197+01	-.33078+00	-.13244+01	.30242+00	.12119+01	.58866+00	-.13452+01
21	.29623+00	-.64257+00	-.11859+01	.19027+00	-.13417+01	.20220-01	.13469+01	-.59166+00	.12135+01	.32959+00
22	.11983+01	.70563+00	-.11493+01	-.11895+01	-.58701+00	.13315+01	.16529+00	-.12119+01	-.58867+00	.12309+01
23	.12443+01	.13482+01	.36571-01	-.10040+01	.94019+00	.44221+00	-.12895+01	.59150+00	-.12134+01	-.75707+00
24	.40131+00	.64259+00	.11859+01	.50263+00	.12301+01	-.11779+01	-.61308+00	.12119+01	.58866+00	-.96803+00
25	-.72833+00	-.70562+00	.11493+01	.13479+01	-.98697-01	-.85142+00	.10766+01	-.59136+00	.12134+01	.10931+01
26	-.13377+01	-.13482+01	-.36598-01	.41946+00	-.12977+01	.88226+00	.98697+00	-.12119+01	-.58871+00	.58858+00
27	-.99138+00	-.64253+00	-.11858+01	-.10609+01	-.78899+00	.11580+01	-.73386+00	.59128+00	-.12133+01	-.12974+01
28	.63216-01	.70557+00	-.11493+01	-.11452+01	.75807+00	-.48012+00	-.12418+01	.12120+01	.58868+00	-.13816+00
29	.10727+01	.13481+01	.36581-01	.27738+00	.13075+01	-.13248+01	.30262+00	-.59123+00	.12132+01	.13452+01
30	.13157+01	.64261+00	.11858+01	.13351+01	.13630+00	.20061-01	.13469+01	-.12119+01	-.58868+00	-.32870+00
31	.61883+00	-.70549+00	.11492+01	.63584+00	-.12143+01	.13317+01	.16519+00	.59102+00	-.12132+01	-.12312+01
32	-.52017+00	-.13482+01	-.36591-01	-.90019+00	-.96689+00	.44243+00	-.12895+01	.12119+01	.58867+00	.75614+00
33	-.12876+01	-.64267+00	-.11858+01	-.12516+01	.55287+00	-.11779+01	-.61303+00	-.59086+00	.12133+01	.96870+00
34	-.11351+01	.70555+00	-.11492+01	.44048-01	.13450+01	-.85149+00	.10766+01	-.12118+01	-.58864+00	-.10923+01
35	-.17167+00	.13481+01	.36624-01	.12817+01	.36719+00	.88203+00	.98696+00	-.59067+00	-.12133+01	-.58957+00
36	.91441+00	.64274+00	.11858+01	.83281+00	-.10939+01	.11580+01	-.73389+00	.12120+01	.58880+00	.12971+01
	21	22	23	24	25	26	27	28	29	30
1	-.13413+01	-.69815+00	.11824+01	.55539+00	-.12377+01	-.65568-01	.13464+01	-.80572-01	.13451+01	.70929+00
2	.94490-01	.13232+01	.20513+00	-.13420+01	.15544+00	-.98934+00	-.91388+00	-.80317+00	-.10820+01	-.11870+01
3	.13086+01	-.20785+00	-.13227+01	.78802+00	.10826+01	.13379+01	-.17153+00	.13122+01	.31177+00	.13478+01
4	-.54900+00	-.11803+01	.69958+00	.55333+00	-.12382+01	-.73084+00	.11342+01	-.12076+01	.60464+00	-.11477+01
5	-.11179+01	.10154+01	.84413+00	-.13414+01	.15560+00	-.39852+00	-.12867+01	.53782+00	-.12383+01	.63989+00
6	.93728+00	.48605+00	-.12771+01	.78791+00	.10825+01	.12432+01	.51999+00	.38363+00	.12928+01	.39536-01
7	.79233+00	-.13481+01	.29444-01	.55385+00	-.12382+01	-.11995+01	.61848+00	-.11254+01	-.74244+00	-.70815+00
8	-.12124+01	.43619+00	.12569+01	-.13419+01	.15581+00	.29865+00	-.13154+01	.13404+01	-.15548+00	.11867+01
9	-.37122+00	.10499+01	-.88922+00	.78775+00	.10824+01	.81540+00	.10726+01	-.92821+00	.98056+00	-.13473+01
10	.13413+01	-.11545+01	-.64864+00	.55451+00	-.12383+01	-.13468+01	-.63459-01	.81708-01	-.13468+01	.11470+01
11	-.94582-01	-.26015+00	.13329+01	-.13424+01	.15589+00	.91590+00	-.99104+00	.80296+00	.10831+01	-.63934+00
12	-.13085+01	.13323+01	-.26310+00	.78775+00	.10823+01	.16943+00	.13376+01	-.13119+01	-.31273+00	-.39565-01
13	.54902+00	-.65114+00	-.11530+01	.55470+00	-.12381+01	-.11337+01	-.72864+00	.12069+01	-.60385+00	.70785+00
14	.11178+01	-.88702+00	.10518+01	-.13423+01	.15581+00	.12881+01	-.40091+00	-.53706+00	.12380+01	-.11864+01
15	-.93719+00	.12578+01	.43360+00	.78752+00	.10823+01	-.52206+00	.12442+01	-.38404+00	-.12930+01	.13471+01
16	-.79229+00	.26860-01	-.13484+01	.55466+00	-.12381+01	-.61708+00	-.11988+01	.11253+01	.74298+00	-.11470+01
17	.12124+01	-.12760+01	.48875+00	-.13422+01	.15583+00	.13153+01	.29698+00	-.13401+01	.15446+00	.63937+00
18	.37121+00	.84565+00	.10140+01	.78756+00	.10822+01	-.10736+01	.81720+00	.92786+00	-.97937+00	.39896-01
19	-.13413+01	.69794+00	-.11824+01	.55438+00	-.12379+01	.64649-01	-.13478+01	-.81643-01	.13458+01	-.70879+00
20	.94656-01	-.13232+01	-.20518+00	-.13417+01	.15566+00	.99057+00	.91560+00	-.80262+00	-.10826+01	.11879+01
21	.13084+01	.20721+00	.13228+01	.78700+00	.10823+01	-.13382+01	.17065+00	.13112+01	.31286+00	-.13486+01
22	-.54914+00	.11813+01	-.69970+00	.55492+00	-.12380+01	.72987+00	-.11349+01	-.12062+01	.60336+00	.11481+01
23	-.11176+01	-.10151+01	-.84415+00	-.13419+01	.15579+00	.39978+00	.12883+01	.53657+00	-.12375+01	-.63989+00

24	.93728+00	-.48706+00	.12772+01	.78668+00	.10822+01	-.12439+01	-.52131+00	.38408+00	.12928+01	-.39849-01
25	.79212+00	.13483+01	-.29538-01	.55534+00	-.12381+01	.11992+01	-.61818+00	-.11250+01	-.74341+00	.70883+00
26	-.12124+01	-.43530+00	-.12570+01	-.13419+01	.15535+00	-.29771+00	.13161+01	.13396+01	-.15348+00	-.11876+01
27	-.37110+00	-.10506+01	.88933+00	.78646+00	.10822+01	-.81641+00	-.10737+01	-.92716+00	.97666+00	.13483+01
28	.13413+01	.11540+01	.64864+00	.55538+00	-.12381+01	.13472+01	.64125-01	.80695-01	-.13462+01	-.11477+01
29	-.94698-01	.26148+00	-.13330+01	-.13419+01	.15589+00	-.91552+00	.99104+00	.80347+00	.10839+01	.63926+00
30	-.13085+01	-.13331+01	.26314+00	.78648+00	.10822+01	-.17018+00	-.13380+01	-.13115+01	-.31447+00	.40797-01
31	.54916+00	.65049+00	.11530+01	.55539+00	-.12380+01	.11342+01	.72909+00	.12057+01	-.60223+00	-.71008+00
32	.11178+01	.88821+00	-.10519+01	-.13419+01	.15585+00	-.12890+01	.40059+00	-.53584+00	.12372+01	.11889+01
33	-.93740+00	-.12581+01	-.43347+00	.78643+00	.10821+01	.52166+00	-.12440+01	-.38468+00	-.12933+01	-.13489+01
34	-.79224+00	-.27863-01	.13483+01	.55581+00	-.12380+01	.61744+00	.11989+01	.11252+01	.74465+00	.11475+01
35	.12126+01	.12773+01	-.48882+00	-.13424+01	.15597+00	-.13156+01	-.29743+00	-.13392+01	.15212+00	-.63868+00
36	.37109+00	-.84591+00	-.10140+01	.78656+00	.10819+01	.10740+01	-.81636+00	.92652+00	-.97756+00	-.41190-01

	31	32	33	34	35	36
1	.11386+01	.37644+00	-.12761+01	-.72628+00	.11543+01	-.96128+00
2	-.62444+00	-.79595+00	.10505+01	.91157+00	-.10148+01	.96067+00
3	-.57249-01	.11200+01	-.69752+00	-.10698+01	.84465+00	-.95932+00
4	.72362+00	-.13093+01	.26047+00	.11958+01	-.64894+00	.95781+00
5	-.11962+01	.13403+01	.20801+00	-.12853+01	.43336+00	-.95636+00
6	.13484+01	-.12096+01	-.65151+00	.13355+01	-.20459+00	.95499+00
7	-.11392+01	.93307+00	.10161+01	-.13453+01	-.30146-01	-.95395+00
8	.62470+00	-.54419+00	-.12579+01	.13144+01	.26371+00	.95325+00
9	.56961-01	.89491-01	.13483+01	-.12433+01	-.48948+00	-.95256+00
10	-.72324+00	.37619+00	-.12765+01	.11343+01	.70061+00	.95189+00
11	.11956+01	-.79660+00	.10511+01	-.99062+00	-.89053+00	-.95125+00
12	-.13476+01	.11211+01	-.69906+00	.81685+00	.10534+01	.95066+00
13	.11386+01	-.13104+01	.26276+00	-.61825+00	-.11843+01	-.95017+00
14	-.62449+00	.13416+01	.20520+00	.40074+00	.12791+01	.94979+00
15	-.56878-01	-.12108+01	-.64856+00	-.17112+00	-.13350+01	-.94969+00
16	.72290+00	.93384+00	.10141+01	-.63464-01	.13503+01	.95000+00
17	-.11953+01	-.54420+00	-.12574+01	.29612+00	-.13247+01	-.95038+00
18	.13477+01	.89110-01	.13488+01	-.51996+00	.12593+01	.95061+00
19	-.11393+01	.37656+00	-.12775+01	.72826+00	-.11560+01	-.95061+00
20	.62576+00	-.79674+00	.10521+01	-.91460+00	.10179+01	.95055+00
21	.55373-01	.11208+01	-.69985+00	.10732+01	-.84895+00	-.95054+00
22	-.72162+00	-.13095+01	.26307+00	-.11993+01	.65441+00	.95054+00
23	.11945+01	.13403+01	.20546+00	.12890+01	-.44008+00	-.95063+00
24	-.13473+01	-.12094+01	-.64909+00	-.13394+01	.21234+00	.95093+00
25	.11391+01	.93258+00	.10146+01	.13492+01	.21790-01	-.95122+00
26	-.62563+00	-.54314+00	-.12580+01	-.13181+01	-.25510+00	.95150+00
27	-.55360-01	.88254-01	.13498+01	.12470+01	.48079+00	-.95205+00
28	.72141+00	.37725+00	-.12789+01	-.11378+01	-.69208+00	.95277+00
29	-.11942+01	-.79739+00	.10541+01	.99404+00	.88227+00	-.95349+00
30	.13472+01	.11215+01	-.70275+00	-.82020+00	-.10454+01	.95418+00
31	-.11393+01	-.13105+01	.26698+00	.62147+00	.11768+01	-.95498+00
32	.62618+00	.13413+01	.20090+00	-.40379+00	-.12726+01	.95608+00
33	.54761-01	-.12102+01	-.64458+00	.17376+00	.13299+01	-.95739+00
34	-.72089+00	.93318+00	.10104+01	.61418-01	-.13468+01	.95864+00
35	.11938+01	-.54367+00	-.12542+01	-.29455+00	.13225+01	-.95978+00
36	-.13469+01	.88711-01	.13466+01	.51859+00	-.12578+01	.96081+00

+++ @ FREE UNIT04.

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+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+          A U X I L I A R Y   S T O R A G E   T A B L E            +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                   +
+ LDI   EXT-NAME UNT EC OPT SEC  CDLOC   NEXT  LIMIT    READ WRITTEN +
```

```
+ 3    CYL•MASS    3 36 UPR  28      47      47  65536         0     1296 +
+                                                                        +
+                    1 ACTIVE DEVICES ( 0 FULL)                          +
+       0 TP-OPS,        6 WRITES,        1 READS,     10488 WORDS XFD   +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

+++  • FREE            CYL•MASS.
```

APPENDIX C

USER INFORMATION FOR THE AUGMENTED MATRIX PREPROCESSOR AUGMAT

The following includes modifications which were made under separate contract to the Naval Surface Weapons Center, Contract Number N60921-77-C-0112.

This appendix includes a copy of the users manual, and a sample input deck and subsequent output for the infinite cylindrical shell problem presented in Section 4.

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                              A U G M A T

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      THIS FUNCTIONAL COMPONENT OF THE UNDERWATER SHOCK ANALYSIS CODE
      ACCEPTS DATA FROM THE FLUID MASS MATRIX PROCESSOR AND THE
      STRUCTURAL ANALYZER TO CONSTRUCT THE SPECIFIC CONSTANTS AND ARRAYS
      THAT ARE USED IN THE STAGGERED SOLUTION PROCEDURE FOR THE
      TRANSIENT RESPONSE ANALYSIS OF SUBMERGED STRUCTURES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      THIS PROGRAM WAS DEVELOPED AND CODED BY JOHN A. DERUNTZ, JR.
      OF LOCKHEED MISSILES AND SPACE CO. RESEARCH LABS IN PALO ALTO
      CALIFORNIA. PLEASE CONSULT WITH AUTHOR BEFORE MAKING CHANGES
      AND ALSO REPORT ANY MALFUNCTIONS OR PROBLEMS. WRITE IN CARE OF
      LOCKHEED PALO ALTO RESEARCH LABORATORY, BLDG 205, DEPT 52-33,
      3251 HANOVER ST., PALO ALTO, CALIF., 94304 OR CALL 415-493-4411
      EXTS. 45069 OR 45133.                            FEBRUARY, 1978

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  W A R N I N G     F R O M     T H E     P R O G R A M M E R     G E N E R A L

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      THIS CODE CONTAINS THE SPECIAL INGREDIENT DMGASP NOT FOUND IN
      OTHER BRANDS. DMGASP IS A DATA MANAGEMENT UTILITY MODULE THAT
      WILL ACTIVATE AND DEACTIVATE ALL AUXILIARY STORAGE DATA FILES
      REFERENCED BY THE CODE. HENCE THE NAMES OF SUCH FILES SHOULD NOT
      APPEAR ON ANY CONTROL CARDS IN THE RUN STREAM WHICH MIGHT NORMALLY
      ACTIVATE AND DEACTIVATE THE FILES. THE USER IS ALSO CAUTIONED THAT
      PREVIOUSLY CREATED FILES MUST ALREADY BE RESIDENT IN THE SYSTEM
      BEFORE THE RUN IS INITIATED. IF A FILE HAS BEEN ROLLED-OUT TO TAPE
      DMGASP WILL ATTEMPT TO HAVE THE FILE ROLLED-IN EVERY 15 SECONDS
      FOR UP TO 15 MINUTES ON THE UNIVAC 1100-EXEC 8 OPERATING SYSTEM.
      IF AN EXISTING DATA FILE HAS NOT BEEN REFERENCED FOR SOME TIME IT
      IS THEREFORE GOOD POLICY TO SIMPLY ACTIVATE AND DEACTIVATE THE
      FILE BEFORE EXECUTION OF THIS CODE. IF THE USER ATTEMPTS TO CREATE
      A NEW DATA FILE WITH A NAME WHICH IS ALREADY ASSIGNED TO AN
      EXISTING FILE, THE UNIVAC VERSION OF DMGASP WILL MODIFY THE NAME
      OF THE FILE GENERATED BY THIS RUN TO AVOID ANY CONFLICT. FILE NAME
      DUPLICATION WILL CAUSE NO PROBLEM ON THE CDC SCOPE OPERATING
      SYSTEM AS SCOPE WILL SIMPLY CATALOG A NEW CYCLE OF THE SAME FILE.
      ON THE OTHER HAND THE CDC NOS SYSTEM IS SIMILAR TO UNIVAC IN THIS
      REGARD AND THE RUN WILL ABORT SINCE THE NAME-CHANGING FEATURE OF
      DMGASP HAS NOT BEEN IMPLEMENTED FOR NOS. QUALIFIER*FILENAME IS THE
      REQUIRED INPUT DATA FORMAT FOR ALL UNIVAC PERMANENT FILE NAMES.
      FOR CDC OPERATION QUALIFIER IS REPLACED BY THE FILE ID, WHICH IS
      THE USER ID BY DEFAULT

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                         P R O G R A M     S I Z E
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         ALL ARRAYS REFERRENCED IN THIS CODE THAT ARE PROBLEM DEPENDENT
         RESIDE IN BLANK COMMON. THE SIZE OF BLANK COMMON IS DETERMINED BY
         A PARAMETER STATEMENT IN THE MAIN PROGRAM FOR THE UNIVAC 1100-OS
         VERSION. HENCE A RECOMPILATION IS NECESSARY TO INCREASE OR
         DECREASE CORE ALLOCATION. IN THE CDC 6600 VERSION RECOMPILATION IS
         UNNECESSARY AS THE LENGTH OF BLANK COMMON IS SET BY A FIELD LENGTH
         REQUEST IN THE CONTROL CARD DECK

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

         D E F I N I T I O N    O F    I N P U T    P A R A M E T E R S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

         INPUT VARIABLE NAMES GIVEN BELOW ARE GENERALLY THOSE WHICH ARE
         ALSO USED IN THE CODING AND THE VARIABLE TYPES CORRESPOND TO
         STANDARD FORTRAN USAGE:

                        A    -    ALPHANUMERIC
                        E    -    FLOATING POINT
                        F    -    FIXED POINT
                        I    -    INTEGER
                        L    -    LOGICAL

         --------      ----                ------------
         VARIABLE      TYPE                DESCRIPTION
         --------      ----                ------------

         NSTR           I         NUMBER OF NODE POINTS IN STRUCTURAL MODEL

         NGEN           I         NUMBER OF GENERAL FLUID DEGREES OF FREEDOM

         NSOR           I         NUMBER OF SURFACE OF REVOLUTION FLUID
                                  DEGREES OF FREEDOM

         NSEG           I         NUMBER OF SURFACE OF REVOLUTION SEGMENTS
                                  IN FLUID MODEL

         NSFR           I         NUMBER OF STRUCTURAL DEGREES OF FREEDOM.
                                  WHEN INTERFACING WITH THE NONLINEAR
                                  STRUCTURAL ANALYZER STAGS THIS PARAMETER
                                  IS ALWAYS ONE LARGER THAN THE NUMBER OF
                                  ACTUAL DEGREES OF FREEDOM SINCE STAGS ADDS
                                  ONE FICTITIOUS EQUATION AND DEGREE OF
                                  FREEDOM TO THE SYSTEM FOR SOME STRANGE
                                  REASON KNOWN ONLY TO BO ALMROTH AND FRANK
                                  BROGAN. THIS EXTRA FREEDOM ALWAYS APPEARS
                                  FIRST IN THE EQUATION SET

         NFRE           I         THE LARGEST DEGREE OF FREEDOM INDEX AT ANY
                                  STRUCTURAL NODE WHICH IS REFERENCED IN THE
                                  ANALYSIS. FREEDOMS 1, 2, AND 3 ARE ASSUMED
                                  TO BE TRANSLATIONAL WHILE 4, 5, AND 6 ARE
                                  RESERVED FOR ROTATIONS

         NFTR           I         THE LARGEST TRANSLATIONAL DEGREE OF
```

		FREEDOM INDEX AT ANY NODE WHICH IS REFERENCED IN THE ANALYSIS
NMOD	I	THE LARGEST NUMBER OF RIGID BODY FLUID DEGREES OF FREEDOM ASSOCIATED WITH ANY ONE SURFACE OF REVOLUTION SEGMENT (MAXIMUM OF TWO)
NSETLC	I	NUMBER OF DATA SETS REQUIRED TO DEFINE THE TYPE OF STRUCTURAL COORDINATE SYSTEM WITH WHICH ANY PARTICULAR FLUID ELEMENT MUST INTERACT
NDICOS	I	DESIGNATES THE TYPE OF COORDINATE SYSTEM USED IN THE STRUCTURAL SOLUTION. ACCEPTABLE VALUES ARE: 0 - GLOBAL COORDINATES 1 - LOCAL COORDINATES WITH THE FIRST DEGREE OF FREEDOM NORMAL TO THE FLUID-STRUCTURE CONTACT BOUNDARY 2 - LOCAL COORDINATES WITH THE SECOND DEGREE OF FREEDOM NORMAL TO THE FLUID-STRUCTURE CONTACT BOUNDARY 3 - LOCAL COORDINATES WITH THE THIRD DEGREE OF FREEDOM NORMAL TO THE FLUID-STRUCTURE CONTACT BOUNDARY AT THIS TIME OPTIONS 1, 2, OR 3 MAY BE USED ONLY FOR RIGHT CIRCULAR CYLINDERS OR SPHERES. MORE LATITUDE IN THESE CHOICES IS ULTIMATELY PLANNED
JSTART	I	FIRST OF ONE OR MORE FLUID ELEMENTS HAVING THE SAME VALUE OF NDICOS
JSTOP	I	LAST OF ONE OR MORE FLUID ELEMENTS HAVING THE SAME VALUE OF NDICOS
JINC	I	INCREMENT TO BE APPLIED IN ASSIGNING THE VALUE OF NDICOS TO FLUID ELEMENTS IN THE RANGE FROM JSTART TO JSTOP
FRWTGE	L	TRUE IF THE PERMANENT FILE CONTAINING THE FLUID MESH GEOMETRY WAS CREATED BY BUFFERED FORTRAN WRITE STATEMENTS. OTHERWISE FALSE
FRWTST	L	TRUE IF THE PERMANENT FILE CONTAINING THE STRUCTURAL MASS AND STIFFNESS MATRICES WAS CREATED BY BUFFERED FORTRAN WRITE STATEMENTS. OTHERWISE FALSE
FRWTFL	L	TRUE IF THE PERMANENT FILE CONTAINING THE FLUID MASS MATRIX WAS CREATED BY BUFFERED FORTRAN WRITE STATEMENTS. OTHERWISE FALSE
FLUSKY	L	TRUE IF THE FLUID MASS MATRIX HAS BEEN

```
                                   STORED IN SKYLINE FORM. OTHERWISE FALSE

           DAAFRM        L         TRUE IF THE STORED FLUID MATRIX CONSISTS
                                   OF THE INVERTED FLUID MASS MATRIX WHICH
                                   HAS BEEN PRE- AND POST-MULTIPLIED BY THE
                                   DIAGONAL FLUID ELEMENT AREA MATRIX AND
                                   THEN MULTIPLIED BY BOTH THE MASS DENSITY
                                   AND THE SPEED OF SOUND OF THE FLUID. THE
                                   RESULTING MATRIX IS THE MOST CONVENIENT
                                   FORM FOR USE IN THE DAA EQUATION. IF FALSE
                                   THEN THIS PROCESSOR WILL DO THE JOB

           PRTGMT        L         TRUE IF FLUID MESH GEOMETRY DATA IS TO BE
                                   LISTED. OTHERWISE FALSE

           PRTTRN        L         TRUE IF FLUID-STRUCTURE TRANSFORMATION
                                   DATA IS TO BE LISTED. OTHERWISE FALSE

           RHO           E,F       FLUID MASS DENSITY

           CEE           E,F       FLUID SPEED OF SOUND

           STRNAM        A         NAME OF PERMANENT MASS STORAGE FILE WHICH
                                   CONTAINS THE STRUCTURAL MASS AND STIFFNESS
                                   MATRICES AS WELL AS BOOKEEPING INFORMATION
                                   RELATING THE INTERNAL AND EXTERNAL DEGREES
                                   OF FREEDOM. WHEN INTERFACING WITH THE
                                   NONLINEAR STRUCTURAL ANALYZER STAGS THE
                                   STIFFNESS MATRIX IS NOT PRESENT

           FLUNAM        A         NAME OF PERMANENT MASS STORAGE FILE WHICH
                                   CONTAINS EITHER THE FLUID MASS MATRIX OR
                                   ITS MANIPULATED DAA FORM

           GEONAM        A         NAME OF PERMANENT MASS STORAGE FILE WHICH
                                   CONTAINS THE FLUID MESH GEOMETRY AND
                                   FLUID-STRUCTURE TRANSFORMATION DATA

           PRENAM        L         NAME OF PERMANENT MASS STORAGE FILE
                                   CREATED BY THIS PROCESSOR WHICH CONTAINS
                                   ALL THE INFORMATION REQUIRED TO CONDUCT
                                   THE UNDERWATER SHOCK ANALYSIS OF THE
                                   STRUCTURE IN QUESTION EXCEPT FOR THE
                                   EXCITATION AND INTEGRATION DATA

   * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                 I N P U T     D A T A     C A R D     D E C K

   * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

           ALL INPUT DATA EXCEPT ALPHANUMERIC DATA MUST BE RIGHT JUSTIFIED
           IN EIGHT (8) COLUMN FIELDS WHICH CAN OCCUPY THE ENTIRE CARD.
           ALPHANUMERIC DATA MUST BE LEFT JUSTIFIED IN SIXTEEN (16) COLUMN
           FIELDS. FILE NAMES ARE RESTRICTED TO TWELVE (12) CHARACTERS FOR
           UNIVAC OPERATION WHILE SIXTEEN (16) CHARACTERS ARE ALLOWED FOR CDC
           OPERATION. HENCE A NAME LIKE ABCDE*FGHIJK IS THE LIMIT FOR UNIVAC
           WHILE A CDC FILE NAME MAY HAVE FOUR (4) ADDITIONAL CHARACTERS
```

```
GENERAL PROBLEM DEFINITION (MAIN PROGRAM PREPROC):
--------------------------------------------------

72 COLUMN ALPHANUMERIC TITLE
NSTR     NGEN     NSOR     NSEG
NSFR     NFRE     NFTR     NMOD
NSETLC
NDICOS   JSTART   JSTOP    JINC      )
   .        .        .        .      )   TOTAL = NSETLC
   .        .        .        .      )
FRWTGE   FRWTST   FRWTFL
FLUSKY   DAAFRM
PRTGMT   PRTTRN
RHO      CEE
STRNAM            FLUNAM            GEONAM            PRENAM
```

The following discussion is provided as an aid to user understanding of the sample output that is included here.

After a summary of the fluid mesh geometry arrays (see Appendix B) the first item needing explanation is that entitled "Fluid Element Wetted Freedom Indicator". This is simply a listing of the input variable NDICOS (see user manual) for each fluid element.

The section "Structural Grid Point Numbers Associated With Internal Sequence Numbers" contains a correspondence table that relates the internal sequence numbers assigned by the fluid mass processor with the external structural node number assigned by the user.

The next item entitled "Grid Point and Freedom Number for Each Row of Stiffness Matrix" identifies an integer vector that is constructed by the user in the Skyline Utility (see Figure 3-1, also Appendix F). For each structural equation the entry in the vector consists of ten times the structural node number plus the local degree of freedom number.

The last item requiring explanation is the "Freedom/Equation Correspondence Table". This is an integer matrix of 6 rows and as many columns as there are structural node points. Any particular row corresponds to a local degree of freedom number while a column corresponds to the internal sequence number for a particular external node number. The matrix entry for any particular set of row and column is the structural equation number for that pair.

```
PRE-PROCESSING RUN FOR INFINITE CYLINDER SIMULATION
       72        36         0         0
      432         6         3         0
        1
        1         1        36         1
        F         F         F
        F         F
        T         T
       1.        1.
INF*CYLSKY    CYL*MASS      CYL*GEOM      CYL*PREPN

@XQT
```

PRE-PROCESSING RUN FOR INFINITE CYLINDER SIMULATION

FLUID MASS DENSITY =   .10000000+01

FLUID SOUND SPEED =   .10000000+01

```
+++  @ ASG,UPR        CYL*PREPN.,  F/    4/ TRK/  1024
+++  @ USE     16,    CYL*PREPN.

+++  @ ASG,AX          CYL*GEOM.
+++  @ USE     14,     CYL*GEOM.

+++  @ FREE            CYL*GEOM.
```

FLUID MESH GEOMETRIC ARRAYS:

N	NTRA	X	Y	Z	NX	NY	NZ	A00
1	2	.10000000+01	.00000000	.00000000	.10000000+01	.00000000	.00000000	.30543262-01
2	2	.98480775+00	.17364818+00	.00000000	.98480775+00	.17364818+00	.00000000	.30543262-01
3	2	.93969262+00	.34202014+00	.00000000	.93969262+00	.34202014+00	.00000000	.30543262-01
4	2	.86602541+00	.49999999+00	.00000000	.86602541+00	.49999999+00	.00000000	.30543262-01
5	2	.76604445+00	.64278761+00	.00000000	.76604445+00	.64278761+00	.00000000	.30543262-01
6	2	.64278762+00	.76604444+00	.00000000	.64278762+00	.76604444+00	.00000000	.30543262-01
7	2	.50000001+00	.86602540+00	.00000000	.50000001+00	.86602540+00	.00000000	.30543262-01
8	2	.34202016+00	.93969262+00	.00000000	.34202016+00	.93969262+00	.00000000	.30543262-01
9	2	.17364819+00	.98480775+00	.00000000	.17364819+00	.98480775+00	.00000000	.30543262-01
10	2	.15893255-07	.10000000+01	.00000000	.15893255-07	.10000000+01	.00000000	.30543262-01
11	2	-.17364816+00	.98480776+00	.00000000	-.17364816+00	.98480776+00	.00000000	.30543262-01
12	2	-.34202012+00	.93969263+00	.00000000	-.34202012+00	.93969263+00	.00000000	.30543262-01
13	2	-.49999997+00	.86602542+00	.00000000	-.49999997+00	.86602542+00	.00000000	.30543262-01
14	2	-.64278758+00	.76604447+00	.00000000	-.64278758+00	.76604447+00	.00000000	.30543262-01
15	2	-.76604442+00	.64278764+00	.00000000	-.76604442+00	.64278764+00	.00000000	.30543262-01
16	2	-.86602538+00	.50000004+00	.00000000	-.86602538+00	.50000004+00	.00000000	.30543262-01
17	2	-.93969262+00	.34202017+00	.00000000	-.93969262+00	.34202017+00	.00000000	.30543262-01
18	2	-.98480775+00	.17364820+00	.00000000	-.98480775+00	.17364820+00	.00000000	.30543262-01
19	2	-.10000000+01	.31786509-07	.00000000	-.10000000+01	.31786509-07	.00000000	.30543262-01
20	2	-.98480776+00	-.17364814+00	.00000000	-.98480776+00	-.17364814+00	.00000000	.30543262-01
21	2	-.93969264+00	-.34202011+00	.00000000	-.93969264+00	-.34202011+00	.00000000	.30543262-01
22	2	-.86602543+00	-.49999996+00	.00000000	-.86602543+00	-.49999996+00	.00000000	.30543262-01
23	2	-.76604448+00	-.64278757+00	.00000000	-.76604448+00	-.64278757+00	.00000000	.30543262-01
24	2	-.64278768+00	-.76604439+00	.00000000	-.64278768+00	-.76604439+00	.00000000	.30543262-01
25	2	-.50000005+00	-.86602537+00	.00000000	-.50000005+00	-.86602537+00	.00000000	.30543262-01
26	2	-.34202018+00	-.93969261+00	.00000000	-.34202018+00	-.93969261+00	.00000000	.30543262-01
27	2	-.17364825+00	-.98480774+00	.00000000	-.17364825+00	-.98480774+00	.00000000	.30543262-01
28	2	-.47679764-07	-.10000000+01	.00000000	-.47679764-07	-.10000000+01	.00000000	.30543262-01
29	2	.17364810+00	-.98480777+00	.00000000	.17364810+00	-.98480777+00	.00000000	.30543262-01
30	2	.34202009+00	-.93969264+00	.00000000	.34202009+00	-.93969264+00	.00000000	.30543262-01

31	2	.49999992+00	-.86602545+00	.00000000	.49999992+00	-.86602545+00	.00000000	.30543262-01
32	2	.64278756+00	-.76604449+00	.00000000	.64278756+00	-.76604449+00	.00000000	.30543262-01
33	2	.76604442+00	-.64278764+00	.00000000	.76604442+00	-.64278764+00	.00000000	.30543262-01
34	2	.86602537+00	-.50000007+00	.00000000	.86602537+00	-.50000007+00	.00000000	.30543262-01
35	2	.93969260+00	-.34202019+00	.00000000	.93969260+00	-.34202019+00	.00000000	.30543262-01
36	2	.98480774+00	-.17364826+00	.00000000	.98480774+00	-.17364826+00	.00000000	.30543262-01

LOCAL FLUID-STRUCTURE TRANSFORMATION COEFFICIENTS:

NFLU	NSTR	
1	1	2
	.50000+00	.50000+00
2	3	4
	.50000+00	.50000+00
3	5	6
	.50000+00	.50000+00
4	7	8
	.50000+00	.50000+00
5	9	10
	.50000+00	.50000+00
6	11	12
	.50000+00	.50000+00
7	13	14
	.50000+00	.50000+00
8	15	16
	.50000+00	.50000+00
9	17	18
	.50000+00	.50000+00
10	19	20
	.50000+00	.50000+00
11	21	22
	.50000+00	.50000+00
12	23	24
	.50000+00	.50000+00
13	25	26
	.50000+00	.50000+00
14	27	28
	.50000+00	.50000+00
15	29	30
	.50000+00	.50000+00
16	31	32
	.50000+C0	.50000+00
17	33	34
	.50000+00	.50000+00
18	35	36
	.50000+00	.50000+00
19	37	38
	.50000+00	.50000+00
20	39	40
	.50000+00	.50000+00
21	41	42
	.50000+00	.50000+00
22	43	44
	.50000+00	.50000+00
23	45	46
	.50000+00	.50000+00
24	47	48

```
          .50000+00    .50000+00
   25        49           50
          .50000+00    .50000+00
   26        51           52
          .50000+00    .50000+00
   27        53           54
          .50000+00    .50000+00
   28        55           56
          .50000+00    .50000+00
   29        57           58
          .50000+00    .50000+00
   30        59           60
          .50000+00    .50000+00
   31        61           62
          .50000+00    .50000+00
   32        63           64
          .50000+00    .50000+00
   33        65           66
          .50000+00    .50000+00
   34        67           68
          .50000+00    .50000+00
   35        69           70
          .50000+00    .50000+00
   36        71           72
          .50000+00    .50000+00

 FLUID ELEMENT WETTED FREEDOM INDICATOR:

       1       2       3       4       5       6       7       8       9      10
       1       1       1       1       1       1       1       1       1       1

      11      12      13      14      15      16      17      18      19      20
       1       1       1       1       1       1       1       1       1       1

      21      22      23      24      25      26      27      28      29      30
       1       1       1       1       1       1       1       1       1       1

      31      32      33      34      35      36
       1       1       1       1       1       1

 GENERALIZED FLUID AREAS:

       1           2           3           4           5           6           7           8           9          10
 .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01
      11          12          13          14          15          16          17          18          19          20
 .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01
      21          22          23          24          25          26          27          28          29          30
 .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01
      31          32          33          34          35          36
 .30543-01   .30543-01   .30543-01   .30543-01   .30543-01   .30543-01

+++  @ ASG,AX       INF*CYLSKY.
+++  @ USE     18,  INF*CYLSKY.

 DIAGONAL STRUCTURAL MASS MATRIX:

       1       2       3       4       5       6       7       8       9      10
```

.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
11	12	13	14	15	16	17	18	19	20
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
21	22	23	24	25	26	27	28	29	30
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
31	32	33	34	35	36	37	38	39	40
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
41	42	43	44	45	46	47	48	49	50
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
51	52	53	54	55	56	57	58	59	60
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
61	62	63	64	65	66	67	68	69	70
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
71	72	73	74	75	76	77	78	79	80
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
81	82	83	84	85	86	87	88	89	90
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
91	92	93	94	95	96	97	98	99	100
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
101	102	103	104	105	106	107	108	109	110
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
111	112	113	114	115	116	117	118	119	120
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
121	122	123	124	125	126	127	128	129	130
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
131	132	133	134	135	136	137	138	139	140
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
141	142	143	144	145	146	147	148	149	150
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
151	152	153	154	155	156	157	158	159	160
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
161	162	163	164	165	166	167	168	169	170
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
171	172	173	174	175	176	177	178	179	180
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
181	182	183	184	185	186	187	188	189	190
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
191	192	193	194	195	196	197	198	199	200
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
201	202	203	204	205	206	207	208	209	210
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
211	212	213	214	215	216	217	218	219	220
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
221	222	223	224	225	226	227	228	229	230
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
231	232	233	234	235	236	237	238	239	240
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
241	242	243	244	245	246	247	248	249	250
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
251	252	253	254	255	256	257	258	259	260
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
261	262	263	264	265	266	267	268	269	270
.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000
271	272	273	274	275	276	277	278	279	280
.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02	.11973-02	.00000
281	282	283	284	285	286	287	288	289	290
.00000	.00000	.11973-02	.11973-02	.11973-02	.00000	.00000	.00000	.11973-02	.11973-02
291	292	293	294	295	296	297	298	299	300

```
.11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000
   301         302         303         304         305         306         307         308         309         310
.11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000
   311         312         313         314         315         316         317         318         319         320
.00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02
   321         322         323         324         325         326         327         328         329         330
.11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000
   331         332         333         334         335         336         337         338         339         340
.11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000
   341         342         343         344         345         346         347         348         349         350
.00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02
   351         352         353         354         355         356         357         358         359         360
.11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000
   361         362         363         364         365         366         367         368         369         370
.11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000
   371         372         373         374         375         376         377         378         379         380
.00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02
   381         382         383         384         385         386         387         388         389         390
.11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000
   391         392         393         394         395         396         397         398         399         400
.11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000
   401         402         403         404         405         406         407         408         409         410
.00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02
   411         412         413         414         415         416         417         418         419         420
.11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000      .00000      .00000
   421         422         423         424         425         426         427         428         429         430
.11973-02   .11973-02   .11973-02   .00000      .00000      .00000      .11973-02   .11973-02   .11973-02   .00000
   431         432
.00000      .00000

+++  @ FREE        INF*CYLSKY.

  STRUCTURAL GRID POINT NUMBERS ASSOCIATED WITH INTERNAL SEQUENCE NUMBERS:

      1         2         3         4         5         6         7         8         9        10
      1         2         3         4         5         6         7         8         9        10

     11        12        13        14        15        16        17        18        19        20
     11        12        13        14        15        16        17        18        19        20

     21        22        23        24        25        26        27        28        29        30
     21        22        23        24        25        26        27        28        29        30

     31        32        33        34        35        36        37        38        39        40
     31        32        33        34        35        36        37        38        39        40

     41        42        43        44        45        46        47        48        49        50
     41        42        43        44        45        46        47        48        49        50

     51        52        53        54        55        56        57        58        59        60
     51        52        53        54        55        56        57        58        59        60

     61        62        63        64        65        66        67        68        69        70
     61        62        63        64        65        66        67        68        69        70

     71        72
     71        72
```

GRID POINT AND FREEDOM NUMBER FOR EACH ROW OF STIFFNESS MATRIX:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	21	22	23	24
11	12	13	14	15	16	17	18	19	20
25	26	31	32	33	34	35	36	41	42
21	22	23	24	25	26	27	28	29	30
43	44	45	46	51	52	53	54	55	56
31	32	33	34	35	36	37	38	39	40
61	62	63	64	65	66	71	72	73	74
41	42	43	44	45	46	47	48	49	50
75	76	81	82	83	84	85	86	91	92
51	52	53	54	55	56	57	58	59	60
93	94	95	96	101	102	103	104	105	106
61	62	63	64	65	66	67	68	69	70
111	112	113	114	115	116	121	122	123	124
71	72	73	74	75	76	77	78	79	80
125	126	131	132	133	134	135	136	141	142
81	82	83	84	85	86	87	88	89	90
143	144	145	146	151	152	153	154	155	156
91	92	93	94	95	96	97	98	99	100
161	162	163	164	165	166	171	172	173	174
101	102	103	104	105	106	107	108	109	110
175	176	181	182	183	184	185	186	191	192
111	112	113	114	115	116	117	118	119	120
193	194	195	196	201	202	203	204	205	206
121	122	123	124	125	126	127	128	129	130
211	212	213	214	215	216	221	222	223	224
131	132	133	134	135	136	137	138	139	140
225	226	231	232	233	234	235	236	241	242
141	142	143	144	145	146	147	148	149	150
243	244	245	246	251	252	253	254	255	256
151	152	153	154	155	156	157	158	159	160
261	262	263	264	265	266	271	272	273	274
161	162	163	164	165	166	167	168	169	170
275	276	281	282	283	284	285	286	291	292
171	172	173	174	175	176	177	178	179	180
293	294	295	296	301	302	303	304	305	306
181	182	183	184	185	186	187	188	189	190

311	312	313	314	315	316	321	322	323	324
191 325	192 326	193 331	194 332	195 333	196 334	197 335	198 336	199 341	200 342
201 343	202 344	203 345	204 346	205 351	206 352	207 353	208 354	209 355	210 356
211 361	212 362	213 363	214 364	215 365	216 366	217 371	218 372	219 373	220 374
221 375	222 376	223 381	224 382	225 383	226 384	227 385	228 386	229 391	230 392
231 393	232 394	233 395	234 396	235 401	236 402	237 403	238 404	239 405	240 406
241 411	242 412	243 413	244 414	245 415	246 416	247 421	248 422	249 423	250 424
251 425	252 426	253 431	254 432	255 433	256 434	257 435	258 436	259 441	260 442
261 443	262 444	263 445	264 446	265 451	266 452	267 453	268 454	269 455	270 456
271 461	272 462	273 463	274 464	275 465	276 466	277 471	278 472	279 473	280 474
281 475	282 476	283 481	284 482	285 483	286 484	287 485	288 486	289 491	290 492
291 493	292 494	293 495	294 496	295 501	296 502	297 503	298 504	299 505	300 506
301 511	302 512	303 513	304 514	305 515	306 516	307 521	308 522	309 523	310 524
311 525	312 526	313 531	314 532	315 533	316 534	317 535	318 536	319 541	320 542
321 543	322 544	323 545	324 546	325 551	326 552	327 553	328 554	329 555	330 556
331 561	332 562	333 563	334 564	335 565	336 566	337 571	338 572	339 573	340 574
341 575	342 576	343 581	344 582	345 583	346 584	347 585	348 586	349 591	350 592
351 593	352 594	353 595	354 596	355 601	356 602	357 603	358 604	359 605	360 606
361 611	362 612	363 613	364 614	365 615	366 616	367 621	368 622	369 623	370 624
371 625	372 626	373 631	374 632	375 633	376 634	377 635	378 636	379 641	380 642

381	382	383	384	385	386	387	388	389	390
643	644	645	646	651	652	653	654	655	656
391	392	393	394	395	396	397	398	399	400
661	662	663	664	665	666	671	672	673	674
401	402	403	404	405	406	407	408	409	410
675	676	681	682	683	684	685	686	691	692
411	412	413	414	415	416	417	418	419	420
693	694	695	696	701	702	703	704	705	706
421	422	423	424	425	426	427	428	429	430
711	712	713	714	715	716	721	722	723	724
431	432								
725	726								

FREEDOM/EQUATION CORRESPONDENCE TABLE:

	1	2	3	4	5	6	7	8	9	10
1	1	7	13	19	25	31	37	43	49	55
2	2	8	14	20	26	32	38	44	50	56
3	3	9	15	21	27	33	39	45	51	57
4	4	10	16	22	28	34	40	46	52	58
5	5	11	17	23	29	35	41	47	53	59
6	6	12	18	24	30	36	42	48	54	60
	11	12	13	14	15	16	17	18	19	20
1	61	67	73	79	85	91	97	103	109	115
2	62	68	74	80	86	92	98	104	110	116
3	63	69	75	81	87	93	99	105	111	117
4	64	70	76	82	88	94	100	106	112	118
5	65	71	77	83	89	95	101	107	113	119
6	66	72	78	84	90	96	102	108	114	120
	21	22	23	24	25	26	27	28	29	30
1	121	127	133	139	145	151	157	163	169	175
2	122	128	134	140	146	152	158	164	170	176
3	123	129	135	141	147	153	159	165	171	177
4	124	130	136	142	148	154	160	166	172	178
5	125	131	137	143	149	155	161	167	173	179
6	126	132	138	144	150	156	162	168	174	180
	31	32	33	34	35	36	37	38	39	40
1	181	187	193	199	205	211	217	223	229	235
2	182	188	194	200	206	212	218	224	230	236
3	183	189	195	201	207	213	219	225	231	237
4	184	190	196	202	208	214	220	226	232	238
5	185	191	197	203	209	215	221	227	233	239
6	186	192	198	204	210	216	222	228	234	240
	41	42	43	44	45	46	47	48	49	50
1	241	247	253	259	265	271	277	283	289	295
2	242	248	254	260	266	272	278	284	290	296
3	243	249	255	261	267	273	279	285	291	297

4	244	250	256	262	268	274	280	286	292	298
5	245	251	257	263	269	275	281	287	293	299
6	246	252	258	264	270	276	282	288	294	300
	51	52	53	54	55	56	57	58	59	60
1	301	307	313	319	325	331	337	343	349	355
2	302	308	314	320	326	332	338	344	350	356
3	303	309	315	321	327	333	339	345	351	357
4	304	310	316	322	328	334	340	346	352	358
5	305	311	317	323	329	335	341	347	353	359
6	306	312	318	324	330	336	342	348	354	360
	61	62	63	64	65	66	67	68	69	70
1	361	367	373	379	385	391	397	403	409	415
2	362	368	374	380	386	392	398	404	410	416
3	363	369	375	381	387	393	399	405	411	417
4	364	370	376	382	388	394	400	406	412	418
5	365	371	377	383	389	395	401	407	413	419
6	366	372	378	384	390	396	402	408	414	420
	71	72								
1	421	427								
2	422	428								
3	423	429								
4	424	430								
5	425	431								
6	426	432								

```
+++  @ ASG,AX          CYL*MASS.
+++  @ USE     12,     CYL*MASS.

+++  @ FREE            CYL*MASS.

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+           A U X I L I A R Y    S T O R A G E    T A B L E           +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                     +
+ LDI    EXT-NAME UNT EC OPT SEC   CDLOC    NEXT  LIMIT     READ WRITTEN +
+ 14    CYL*PREPN  16 36 UPR  28       2      86  65536       73    2247 +
+                                                                     +
+                      1 ACTIVE DEVICES ( 0 FULL)                     +
+        0 TP-OPS,        9 WRITES,       11 READS,      11082 WORDS XFD +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

+++  @ FREE           CYL*PREPN.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
       SUMMARY OF DATA STORED ON PERMANENT FILE
             ***  CYL*PREPN           ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RECORD      RECORD DESCRIPTION       SECTOR        NUMBER
                                    LOCATION      OF WORDS
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

   1     FILE LIBRARY DATA             0             31
```

2	FLUID GEOMETRY AND TRANSFORMATION DATA	2	540
3	GENERALIZED FLUID AREAS	22	36
4	FREEDOM/EQUATION CORRESPONDENCE TABLE	24	432
5	DIAGONAL STRUCTURAL MASS INV	40	432
6	DIAGONAL POINTERS FOR DAA STRUCTURAL MASS INV	56	37
7	SKYLINE ENTRIES FOR DAA STRUCTURAL MASS INV	58	36
8	DIAGONAL POINTERS FOR DAA VIRTUAL MASS INV	60	37
9	SKYLINE ENTRIES FOR DAA VIRTUAL MASS INV	62	666

APPENDIX D

USER INFORMATION FOR THE TIME INTEGRATION PROCESSOR TIMINT

The following includes modifications which were made under separate contract to the Naval Surface Weapons Center, Contract Number N60921-77-C-0112.

This appendix includes a copy of the users manual, and a sample input deck and subsequent output for the infinite cylindrical shell problem presented in Section 4.

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* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                              T I M I N T

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      THIS FUNCTIONAL COMPONENT OF THE UNDERWATER SHOCK ANALYSIS CODE
      CONDUCTS A STEP-BY-STEP DIRECT NUMERICAL TIME INTEGRATION OF THE
      GOVERNING EQUATIONS OF SUBMERGED STRUCTURES EXPOSED TO SPHERICAL
      SHOCK WAVES OF ARBITRARY PRESSURE PROFILE AND SOURCE LOCATION. THE
      FLUID EQUATIONS UTILIZE THE WELL-KNOWN DOUBLY ASYMPTOTIC
      APPROXIMATION (DAA) WHILE THE STRUCTURE ITSELF MAY BE TREATED BY A
      VARIETY OF LINEAR OR NONLINEAR PROGRAM MODULES THAT CARRY OUT THE
      SPATIAL ANALYSIS AT EACH TIME STEP. THE CODE USES THE STAGGERED
      SOLUTION PROCEDURE WHEREIN THE STRUCTURAL RESPONSE EQUATIONS AND
      THE FLUID RESPONSE EQUATIONS ARE SOLVED SEPARATELY AT EACH TIME
      STEP THROUGH EXTRAPOLATION OF THE TERMS WHICH COUPLE THE TWO
      SYSTEMS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      THIS PROGRAM WAS DEVELOPED AND CODED BY JOHN A. DERUNTZ, JR.
      OF LOCKHEED MISSILES AND SPACE CO. RESEARCH LABS IN PALO ALTO
      CALIFORNIA. PLEASE CONSULT WITH AUTHOR BEFORE MAKING CHANGES
      AND ALSO REPORT ANY MALFUNCTIONS OR PROBLEMS. WRITE IN CARE OF
      LOCKHEED PALO ALTO RESEARCH LABORATORY, BLDG 205, DEPT 52-33,
      3251 HANOVER ST., PALO ALTO, CALIF., 94304 OR CALL 415-493-4411
      EXTS. 45069 OR 45133.                                FEBRUARY, 1978

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                      M A X I M U M     V A L U E S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      MAXIMUM NUMBER OF INPUT PRESSURE DATA POINTS   . . . . . . . . .   2 0 1

      MAXIMUM NUMBER OF DIFFERENT TIME STEP SIZES    . . . . . . . . .     1 0

      MAXIMUM NUMBER OF TRANSIENT RESPONSE DISPLAYS  . . . . . . . . .   1 0 0

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                 R U N     T I M E     I N F O R M A T I O N

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      THE FOLLOWING INFORMATION IS PROVIDED FOR THE ESTIMATION OF CPU
      TIME IN SECONDS TO WHICH MUST BE ADDED INPUT/OUTPUT CHARGES,
      CORE-BLOCK TIME, EXECUTIVE REQUESTS, FILE CHARGES, ETC. THE RULE
      TO FOLLOW IS TO ESTIMATE CPU TIME AND THEN INCREASE THIS TO ARRIVE
      AT AN APPROXIMATE SYSTEM CHARGE ESTIMATE. FOR SMALL PROBLEMS THE
      SYSTEM CHARGES CAN EASILY DOMINATE AND A LARGE FACTOR WOULD HAVE
      TO BE APPLIED TO THE RUN TIME COMPUTED BELOW. FOR FAIRLY LARGE
      PROBLEMS (2500 DOF) THIS FACTOR DROPS DOWN TO ABOUT TWO (2) FOR
      UNIVAC OPERATION
```

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THE ESTIMATES FOR STRUCTURAL FACTORIZATION AND ADVANCEMENT TIMES
GIVEN BELOW DO NOT APPLY TO THE USA-STAGS SYSTEM. PLEASE CONSULT A
STAGS MANUAL

DEFINITION OF VARIABLES REQUIRED FOR RUN TIME COMPUTATION:

     NSTEP     NUMBER OF TIME STEPS

     NTINC     NUMBER OF DIFFERENT TIME STEP INCREMENTS

     NDISP     NUMBER OF DEGREES OF FREEDOM FOR WHICH TRANSIENT
               RESPONSE HISTORIES ARE TO BE DISPLAYED AT CONCLUSION
               OF RUN

     NSFR      NUMBER OF DEGREES OF FREEDOM OF STRUCTURAL SYSTEM

     NFLU      NUMBER OF DEGREES OF FREEDOM OF FLUID SYSTEM

     BAVE      AVERAGE HALF BAND WIDTH OF STRUCTURAL STIFFNESS
               MATRIX

     BRMS      ROOT MEAN SQUARE HALF BAND WIDTH OF STRUCTURAL
               STIFFNESS MATRIX. USE AVERAGE HALF BAND WIDTH IF
               THIS QUANTITY IS NOT READILY AVAILABLE

     TCPU      TOTAL CENTRAL PROCESSING UNIT TIME REQUIRED FOR
               LISTED ITEMS BELOW

               TCPU = TPRE + NTINC*(TFS+TFF) + NSTEP*(TAS+TAF) + TDISP

     TPRE      CPU TIME SPENT ON PRE-PROCESSING BEFORE TIME
               INTEGRATION COMMENCES

               TPRE = 1000.*CS*(NSFR+NFLU)

     TFS       TIME REQUIRED TO FACTOR STRUCTURAL EQUATION SYSTEM

               TFS = CS*NSFR*BRMS**2/2.

     TAS       TIME REQUIRED FOR ADVANCEMENT OF ONE TIME STEP FOR
               STRUCTURAL SYSTEM

               TAS = 3.*CS*NSFR*BAVE

     TFF       TIME REQUIRED TO FACTOR FLUID EQUATION SYSTEM

               TFF = CS*NFLU**3/6.

     TAF       TIME REQUIRED FOR ADVANCEMENT OF ONE TIME STEP FOR
               FLUID SYSTEM

               TAF = CS*NFLU**2

     TDISP     CPU TIME SPENT ON DISPLAY OF RESPONSE HISTORIES

               TDISP = 500.*CS*NSTEP*NDISP

     CS        UNIT OPERATION CONSTANT IN SECONDS, CONSISTING OF A
```

FLOATING ADDITION, A FLOATING MULTIPLY, AND INDEXING

V A L U E S   O F   C O N S T A N T   C S
- - - - - -   - -   - - - - - - - -   - -

O P E R A T I N G   S Y S T E M

PRECISION	UNIVAC 1108	UNIVAC 1110	CDC 6600
SINGLE	5.5X10-6	3.2X10-6	1.5X10-6
DOUBLE	9.0X10-6	4.5X10-6	- - -

AT THIS TIME THE CODE OPERATES ONLY IN SINGLE PRECISION

IN ADDITION TO BILLABLE CHARGES DUE TO EXECUTION OF THIS CODE THERE WILL PROBABLY BE A DAILY CHARGE FOR PERMANENT FILE STORAGE. RESPONSE AND RESTART FILES CREATED BY THIS CODE CAN BE EXTREMELY LENGTHY HENCE SUCH OUTPUT FROM LARGE RUNS SHOULD BE TRANSFERRED TO TAPE AT THE EARLIEST OPPORTUNITY TO MINIMIZE THESE CHARGES

* *

W A R N I N G   F R O M   T H E   P R O G R A M M E R   G E N E R A L

* *

THIS CODE CONTAINS THE SPECIAL INGREDIENT DMGASP NOT FOUND IN OTHER BRANDS. DMGASP IS A DATA MANAGEMENT UTILITY MODULE THAT WILL ACTIVATE AND DEACTIVATE ALL AUXILIARY STORAGE DATA FILES REFERENCED BY THE CODE. HENCE THE NAMES OF SUCH FILES SHOULD NOT APPEAR ON ANY CONTROL CARDS IN THE RUN STREAM WHICH MIGHT NORMALLY ACTIVATE AND DEACTIVATE THE FILES. THE USER IS ALSO CAUTIONED THAT PREVIOUSLY CREATED FILES MUST ALREADY BE RESIDENT IN THE SYSTEM BEFORE THE RUN IS INITIATED. IF A FILE HAS BEEN ROLLED-OUT TO TAPE DMGASP WILL ATTEMPT TO HAVE THE FILE ROLLED-IN EVERY 15 SECONDS FOR UP TO 15 MINUTES ON THE UNIVAC 1100-EXEC 8 OPERATING SYSTEM. IF AN EXISTING DATA FILE HAS NOT BEEN REFERENCED FOR SOME TIME IT IS THEREFORE GOOD POLICY TO SIMPLY ACTIVATE AND DEACTIVATE THE FILE BEFORE EXECUTION OF THIS CODE. IF THE USER ATTEMPTS TO CREATE A NEW DATA FILE WITH A NAME WHICH IS ALREADY ASSIGNED TO AN EXISTING FILE, THE UNIVAC VERSION OF DMGASP WILL MODIFY THE NAME OF THE FILE GENERATED BY THIS RUN TO AVOID ANY CONFLICT. FILE NAME DUPLICATION WILL CAUSE NO PROBLEM ON THE CDC SCOPE OPERATING SYSTEM AS SCOPE WILL SIMPLY CATALOG A NEW CYCLE OF THE SAME FILE. ON THE OTHER HAND THE CDC NOS SYSTEM IS SIMILAR TO UNIVAC IN THIS REGARD AND THE RUN WILL ABORT SINCE THE NAME-CHANGING FEATURE OF DMGASP HAS NOT BEEN IMPLEMENTED FOR NOS. QUALIFIER*FILENAME IS THE REQUIRED INPUT DATA FORMAT FOR ALL UNIVAC PERMANENT FILE NAMES. FOR CDC OPERATION QUALIFIER IS REPLACED BY THE FILE ID, WHICH IS THE USER ID BY DEFAULT

* *

P R O G R A M   S I Z E

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      ALL ARRAYS REFERRENCED IN THIS CODE THAT ARE PROBLEM DEPENDENT
      RESIDE IN BLANK COMMON. THE SIZE OF BLANK COMMON IS DETERMINED BY
      A PARAMETER STATEMENT IN THE MAIN PROGRAM FOR THE UNIVAC 1100-OS
      VERSION. HENCE A RECOMPILATION IS NECESSARY TO INCREASE OR
      DECREASE CORE ALLOCATION. IN THE CDC 6600 VERSION RECOMPILATION IS
      UNNECESSARY AS THE LENGTH OF BLANK COMMON IS SET BY A FIELD LENGTH
      REQUEST IN THE CONTROL CARD DECK

      AT THIS TIME THE CODE HAS NOT BEEN SYSTEMATICALLY OVERLAYED TO
      CONSERVE SPACE IN THE INSTRUCTION BANK. THIS HAS BEEN DONE TO SOME
      EXTENT BUT HAS NOT BEEN INCLUDED HERE AS IT IS INCOMPLETE. PLEASE
      CONTACT THE AUTHOR FOR INFORMATION

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      D E F I N I T I O N    O F    I N P U T    P A R A M E T E R S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      INPUT VARIABLE NAMES GIVEN BELOW ARE GENERALLY THOSE WHICH ARE
      ALSO USED IN THE CODING AND THE VARIABLE TYPES CORRESPOND TO
      STANDARD FORTRAN USAGE:

                     A    -    ALPHANUMERIC
                     E    -    FLOATING POINT
                     F    -    FIXED POINT
                     I    -    INTEGER
                     L    -    LOGICAL

      --------    ----                     -----------
      VARIABLE    TYPE                     DESCRIPTION
      --------    ----                     -----------

      XC,YC,ZC     E,F      CARTESIAN COORDINATES OF THE LOCATION OF
                            SPHERICAL CHARGE IN FLUID MESH SYSTEM

      SC           E,F      CHARGE STANDOFF, ABSOLUTE VALUE OF THE
                            SHORTEST DISTANCE BETWEEN THE CHARGE
                            LOCATION AND THE STRUCTURE. THE INTEGATION
                            PROCESS STARTS AT TIME EQUAL TO ZERO WITH
                            THE SPHERICAL WAVE JUST TOUCHING THE
                            STRUCTURE AT THE POINT ASSOCIATED WITH
                            THIS MINIMUM DISTANCE

      JPHIST       I        NUMBER OF EQUALLY SPACED INCIDENT PRESSURE
                            HISTORY DATA POINTS. SEE ABOVE FOR MAXIMUM
                            NUMBER ALLOWED BY CORE ALLOCATION

      DTHIST       E,F      TIME INTERVAL ASSOCIATED WITH ANY TWO
                            SUCCESSIVE INCIDENT PRESSURE HISTORY DATA
                            POINTS

      PNORM        E,F      CONSTANT MULTIPLICATIVE FACTOR TO BE
                            APPLIED TO THE INPUT PRESSURE HISTORY DATA
                            POINTS
```

PHIST		INCIDENT PRESSURE HISTORY DATA POINTS. THE VALUES USED IN THE TIME INTEGRATION PROCESS ARE THE PRODUCT OF PHIST AND PNORM TO ALLOW FOR THE POSSIBILITY THAT THE INPUT DATA MAY HAVE BEEN EXPERIMENTALLY OBTAINED AT A POINT WHICH IS NOT EQUAL TO SC ABOVE. PNORM MUST THEREFORE REFLECT THE 1/R SCALING DIFFERENCE BETWEEN SC AND THE LOCATION OF THE PRESSURE SENSOR DURING THE PULSE CHARACTERIZATION EXPERIMENT. IF THE INCIDENT PRESSURE GOES TO ZERO AT SOME POINT AND REMAINS THERE THEN DATA NEED ONLY BE PROVIDED FOR THAT TIME SPAN AND THE CODE WILL AUTOMATICALLY ENSURE THAT THE INCIDENT PRESSURE REMAINS ZERO THEREAFTER. WHEN RESTARTING THE TRANSIENT ANALYSIS THE REQUIRED INCIDENT PRESSURE DATA IS IDENTICAL TO THAT USED IN THE INITIAL RUN
NTINT	I	NUMBER OF TIME STEP SIZES TO BE USED IN THE INTEGRATION PROCESS. SEE ABOVE FOR MAXIMUM NUMBER ALLOWED BY CORE ALLOCATION
STRTIM	E,F	THE STARTING TIME AT WHICH ANY PARTICULAR STEP SIZE IS TO BE USED UNTIL IT IS EITHER SUPERCEEDED BY ANOTHER STEP SIZE OR, THE ENTIRE TRANSIENT ANALYSIS HAS BEEN COMPLETED
DELTIM		TIME STEP SIZE ASSOCIATED WITH STRTIM ABOVE
FINTIM		TIME AT WHICH THE PRESENT ANALYSIS IS TO BE TERMINATED
PRENAM	A	NAME OF PRE-PROCESSED MASS STORAGE FILE CONTAINING ALL FLUID AND STRUCTURE DATA WHICH DOES NOT DEPEND UPON ABOVE LOAD AND INTEGRATION PARAMETERS
POSNAM	A	NAME OF MASS STORAGE FILE AVAILABLE FOR POST-PROCESSING WHICH CONTAINS SYSTEM RESPONSES
RESNAM	A	NAME OF MASS STORAGE FILE WHICH CONTAINS INFORMATION FOR RESTARTING THE TRANSIENT RESPONSE ANALYSIS
NSAVER	I	FREQUENCY OF SAVING SYSTEM RESPONSES ON PERMANENT FILE POSNAM. NSAVER EXPRESSED IN NUMBER OF TIME STEPS
NRESET	I	FREQUENCY OF SAVING RESTART INFORMATION ON PERMANENT FILE RESNAM. NRESET EXPRESSED IN NUMBER OF TIME STEPS
LOCBEG	I	LOCATION IN POSNAM FILE WHERE RESPONSES

		FROM CURRENT RUN ARE TO BE PLACED. THIS LOCATION IS MEASURED EITHER IN SECTORS (28 WORDS) ON UNIVAC SYSTEMS OR PHYSICAL RECORD UNITS (PRU OF 64 WORDS) ON CDC HARDWARE. A ZERO VALUE IS THE DESIGNATION OF THE BEGINNING OF THE FILE FOR EITHER SYSTEM IN THIS CODE. IF LOCBEG = 0, A NEW PERMANENT FILE IS ASSIGNED FOR THE RUN WITH THE NAME DENOTED BY POSNAM, OTHERWISE POSNAM IS TAKEN TO BE AN EXISTING FILE. UNDER RESTART CONDITIONS THE APPROPRIATE VALUE OF LOCBEG IS ASCERTAINED FROM OUTPUT GENERATED DURING PRECEEDING RUNS
LOCRES	I	LOCATION IN PERMANENT FILE RESNAM WHERE RESTART DATA IS TO BE FOUND. SEE LOCBEG FOR DEFINITION OF LOCATION. SET EQUAL TO ZERO IN CURRENT RUN IS NOT A RESTART. OTHERWISE APPROPRIATE VALUE OF LOCRES IS ASCERTAINED FROM OUTPUT GENERATED DURING PRECEEDING RUNS
LOCWRT	I	LOCATION IN PERMANENT FILE RESNAM WHERE NEW RESTART DATA GENERATED IN THE CURRENT RUN IS TO BE WRITTEN. SEE LOCBEG FOR DEFINITION OF LOCATION. IF LOCWRT = 0, A NEW PERMANENT FILE IS ASSIGNED FOR THE RUN WITH THE NAME DENOTED BY RESNAM, OTHERWISE RESNAM IS TAKEN TO BE AN EXISTING FILE. UNDER RESTART CONDITIONS THE APPROPRIATE VALUE OF LOCWRT IS ASCERTAINED FROM OUTPUT GENERATED DURING PRECEEDING RUNS
FORWRT	L	TRUE IF PERMANENT FILE DENOTED BY POSNAM IS TO BE CREATED USING UNFORMATTED FORTRAN WRITE. OTHERWISE FILE WILL BE CREATED BY DIRECT TRANSFER USING THE DATA MANAGEMENT SYSTEM DMGASP
DISPLA	L	TRUE IF SELECTED TRANSIENT RESPONSE HISTORIES ARE TO BE DISPLAYED, OTHERWISE FALSE
NPREVT	I	NUMBER OF TIME STEPS PREVIOUSLY COMPUTED WITH RESPONSES SAVED IN PERMANENT FILE DENOTED BY POSNAM. NPREVT WILL BE NONZERO ONLY FOR RESTART RUNS. IT ENSURES THAT ANY RESPONSE DISPLAY MADE IN CONJUNCTION WITH THE TIME INTEGRATION RUN WILL INCLUDE THE ENTIRE HISTORY AVAILABLE FROM THAT FILE AND NOT JUST THE PORTION COMPUTED DURING THE CURRENT RUN
LISTRE	L	TRUE IF TRANSIENT RESPONSE HISTORIES ARE TO BE LISTED IN TABULAR FORM, OTHERWISE FALSE
PRTPLT	L	TRUE IF PRINTER PLOTS ARE TO BE GENERATED FOR TRANSIENT RESPONSE HISTORIES,

		OTHERWISE FALSE
NWETHS	I	NUMBER OF STRUCTURAL HISTORIES (EITHER DISPLACEMENTS OR VELOCITIES) TO BE DISPLAYED FOR WHICH THE APPROPRIATE STRUCTURAL FREEDOMS CAN BE IDENTIFIED INTERNALLY THROUGH THE FREEDOM/EQUATION CORRESPONDENCE TABLE. ALL STRUCTURAL NODES WHICH PARTICIPATE IN THE FLUID-STRUCTURE TRANSFORMATION WILL FALL INTO THIS CATEGORY AS WELL AS ANY OTHERS WHOSE GRID POINT COORDIATES WERE ENTERED AS DATA FOR THE FLUID MASS PROCESSOR
NDRYHS	I	NUMBER OF STRUCTURAL HISTORIES (EITHER DISPLACEMENTS OR VELOCITIES) TO BE DISPLAYED FOR WHICH THE APPROPRIATE STRUCTURAL FREEDOMS CANNOT BE IDENTIFIED INTERNALLY THROUGH THE FREEDOM/EQUATION CORRESPONDENCE TABLE. DRY STRUCTURE NODE POINTS CAN FALL INTO THIS CATEGORY IF THE USER DID NOT INCLUDE THEM IN THE DATA STREAM FOR THE FLUID MASS PROCESSOR. IN THIS CASE ONE MUST IDENTIFY THE INTERNAL SEQUENCE NUMBER APPROPRIATE TO THE DESIRED DEGREE OF FREEDOM BY A MYSTICAL PROCESS WHICH INVOLVES THE INTIMATE KNOWLEDGE OF THE ELIMINATION ORDER AND ANY REDUCTION OF THE NUMBER OF ACTIVE FREEDOMS DUE TO THE APPLICATION OF CONSTRAINTS. MORAL OF THE STORY - RUN ALL STRUCTURAL GRID POINTS THROUGH THE FLUID MASS PROCESSOR EVEN IF THEY NEVER GET WET
NODOUT	I	EXTERNAL INDENTIFICATION NUMBER OF STRUCTURAL NODE FOR WHICH A TIME HISTORY DISPLAY IS DESIRED
NFROUT	I	STRUCTURAL DEGREE OF FREEDOM NUMBER FOR WHICH A TIME HISTORY DISPLAY IS DESIRED
NEQHST	I	INTERNAL SEQUENCE NUMBER DETERMINED BY HAND FOR STRUCTURAL DEGREES OF FREEDOM WHICH ARE TO BE DISPLAYED AND ARE NOT INCLUDED IN THE FREEDOM/EQUATION CORRESPONDENCE TABLE FOR REASONS KNOWN ONLY TO THE USER
NPREHS	I	NUMBER OF FLUID PRESSURE HISTORIES TO BE DISPLAYED
NEQHPR	I	FLUID CONTROL POINT NUMBER FOR WHICH A TIME HISTORY DISPLAY IS DESIRED FOR THE TOTAL PRESSURE
SCALEF	L	TRUE IF A MULTIPLICATIVE CONSTANT FACTOR IS TO BE APPLIED TO THE DISPLAYED VALUES

```
                         OF THE STRUCTURAL DISPLACEMENT AND
                         VELOCITY HISTORIES, OTHERWISE FALSE

     FACTOR      E,F     VALUE OF MULTIPLICATIVE LENGTH CONVERSION
                         FACTOR TO BE APPLIED TO THE DISPLAYED
                         STRUCTURAL TRANSIENT RESPONSE HISTORIES

     SHSPEC      L       TRUE IF PSEUDO-VELOCITY SHOCK SPECTRA ARE
                         ALSO DESIRED FOR STRUCTURAL FREEDOMS WHOSE
                         VELOCITY RESPONSE IS TO BE DISPLAYED,
                         OTHERWISE FALSE

     SHLIST      L       TRUE IF PSEUDO-VELOCITY SHOCK SPECTRA ARE
                         TO BE LISTED IN TABULAR FORM, OTHERWISE
                         FALSE

     SHPRPL      L       TRUE IF PRINTER PLOTS ARE TO BE GENERATED
                         FOR PSEUDO-VELOCITY SHOCK SPECTRA,
                         OTHERWISE FALSE

     FREQLW      E,F     LOWER LIMIT OF FREQUENCY RANGE TO BE
                         SCANNED FOR PSEUDO-VELOCITY SHOCK SPECTRA

     FREQUP      E,F     UPPER LIMIT OF FREQUENCY RANGE TO BE
                         SCANNED FOR PSEUDO-VELOCITY SHOCK SPECTRA

     DFREQ       E,F     FREQUENCY INCREMENT TO BE USED IN
                         GENERATING PSEUDO-VELOCITY SHOCK SPECTRA

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

           I N P U T    D A T A    C A R D    D E C K

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

     ALL INPUT DATA EXCEPT ALPHANUMERIC DATA MUST BE RIGHT JUSTIFIED
     IN EIGHT (8) COLUMN FIELDS WHICH CAN OCCUPY THE ENTIRE CARD.
     ALPHANUMERIC DATA MUST BE LEFT JUSTIFIED IN SIXTEEN (16) COLUMN
     FIELDS. FILE NAMES ARE RESTRICTED TO TWELVE (12) CHARACTERS FOR
     UNIVAC OPERATION WHILE SIXTEEN (16) CHARACTERS ARE ALLOWED FOR CDC
     OPERATION. HENCE A NAME LIKE ABCDE·FGHIJK IS THE LIMIT FOR UNIVAC
     WHILE A CDC FILE NAME MAY HAVE FOUR (4) ADDITIONAL CHARACTERS

     GENERAL PROBLEM DEFINITION (SUBROUTINE INPDAT):
     -----------------------------------------------

     72 COLUMN ALPHNUMERIC TITLE
     XC      YC      ZC      SC
     JPHIST
     DTHIST  PNORM
     PHIST(I), I=1,JPHIST
     NTINT
     STRTIM  DELTIM         )
        .       .           )   TOTAL = NTINT
        .       .           )
     FINTM
     PRENAM          POSNAM          RESNAM
     NSAVER  NRESET
```

```
LOCBEG  LOCRES  LOCWRT
FORWRT

POST PROCESSING (SUBROUTINE POSTRE):
------------------------------------


DISPLA

IF DISPLA = .FALSE. THIS TERMINATES THE INPUT DATA DECK

NPREVT

POST PROCESSING (SUBROUTINE RESDSP):
------------------------------------

LISTRE  PRTPLT

POST PROCESSING (SUBROUTINE STRDSP):
------------------------------------

NWETHS  NDRYHS                         )
NODOUT  NFROUT         )               )
   .       .           )  TOTAL = NWETHS )  THIS SET FOR
   .       .           )               )
NODOUT  NFROUT  NEQHST )               )  DISPLACEMENTS
   .       .       .   )  TOTAL = NDRYHS )
   .       .       .   )               )

NWETHS  NDRYHS                         )
NODOUT  NFROUT         )               )
   .       .           )  TOTAL = NWETHS )  THIS SET FOR
   .       .           )               )
NODOUT  NFROUT  NEQHST )               )  VELOCITIES
   .       .       .   )  TOTAL = NDRYHS )
   .       .           )               )

POST PROCESSING (SUBROUTINE RESDSP):
------------------------------------

NPREHS
NEQHPR                 )
   .                   )  TOTAL = NPREHS
   .                   )

POST PROCESSING (SUBROUTINE FILBUF):
------------------------------------

SCALEF

IF SCALEF = .TRUE. READ THE FOLLOWING CARD

FACTOR

POST PROCESSING (SUBROUTINE RESDSP):
------------------------------------

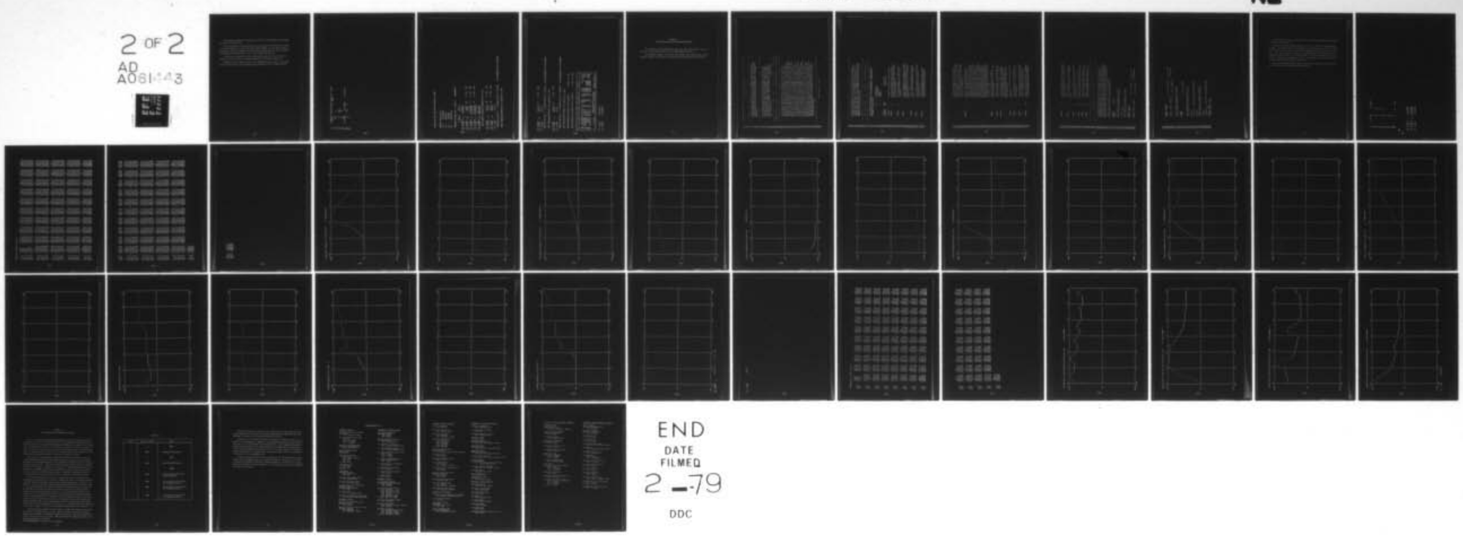
SHSPEC
```

```
IF SHSPEC = .TRUE. READ THE FOLLOWING CARDS

SHLIST   SHPRPL
FREQLW   FREQUP   DFREQ
```

AD-A061 443 LOCKHEED MISSILES AND SPACE CO INC PALO ALTO CALIF PA--ETC F/G 19/4
THE UNDERWATER SHOCK ANALYSIS (USA) CODE, A REFERENCE MANUAL.(U)
FEB 78 J A DERUNTZ, T L GEERS, C A FELIPPA DNA001-76-C-0285
UNCLASSIFIED LMSC/D624328 DNA-4524F NL

2 OF 2
AD
A061443



END
DATE
FILMED
2-79
DDC

The following discussion is provided as an aid to user understanding of the sample output that is included here.

First, the amount of storage required for the run given in the output refers solely to the blank common that is set in the main program, UNWASH. An error exit is taken if insufficient storage is available and the user must see that more is provided either by a recompilation on UNIVAC 1100-OS or by a field length request on CDC.

Sector address information for the response and restart files that is listed at various places in the output is extremely important for subsequent restart runs.

Although transient response results can be displayed as part of the run such output has been deferred to the post processing phase in Appendix E for this sample problem.

```
PLANE STEP WAVE SIDE ON TO INFINITE CYLINDER
  10000.      0.       0.   9999.
      2
    50.     1.
     1.     1.
      3
     0.   .025
     1.    .05
     2.     .1
     5.
CYL*PREPN     CYL*RESPON     CYL*RESTAR
      1     30
      0      0       0
      F
      F
```

```
PLANE STEP WAVE SIDE ON TO INFINITE CYLINDER


CHARGE LOCATION DATA:

XC =      .10000000+05

YC =      .00000000

ZC =      .00000000

SC =      .99990000+04

PRESSURE HISTORY DATA:    DTHIST =     .50000000+02

            1            2
        .10000+01    .10000+01

+++  @ ASG,AX          CYL*PREPN.
+++  @ USE      16,    CYL*PREPN.

+++  @ ASG,T              POOL01., F4/      4/ TRK/    256
+++  @ USE      20,       POOL01.

+++  @ ASG,UP          CYL*RESPON.,  F/     4/ TRK/   1024
+++  @ USE      12,    CYL*RESPON.

+++  @ ASG,UP          CYL*RESTAR.,  F/     4/ TRK/   1024
+++  @ USE      14,    CYL*RESTAR.

+++  @ ASG,AX          INF*CYLSKY.
+++  @ USE      22,    INF*CYLSKY.

  12314 WORDS OF STORAGE REQUIRED FOR THIS RUN


+++  @ ASG,T              UNIT13., F4/      4/ TRK/    256
+++  @ USE      13,       UNIT13.

+++  @ ASG,T              UNIT18., F4/      4/ TRK/    256
+++  @ USE      18,       UNIT18.

+++  @ FREE               UNIT13.

RESTART DATA FOR T =     .750000 WRITTEN AT LOCATION      0 ON PERMANENT FILE CYL*RESTAR

POST PROCESSING RESPONSE FILE LOCATION IS  1054
```

```
+++  @ ASG,T             UNIT13., F4/     4/ TRK/   256
+++  @ USE    13,        UNIT13.

+++  @ FREE              UNIT13.

   RESTART DATA FOR T =   2.000000 WRITTEN AT LOCATION   121 ON PERMANENT FILE CYL*RESTAR

   POST PROCESSING RESPONSE FILE LOCATION IS  2074

+++  @ ASG,T             UNIT13., F4/     4/ TRK/   256
+++  @ USE    13,        UNIT13.

+++  @ FREE              UNIT13.
   RESTART DATA FOR T =   5.000000 WRITTEN AT LOCATION   242 ON PERMANENT FILE CYL*RESTAR

   POST PROCESSING RESPONSE FILE LOCATION IS  3094

   SECTOR ADDRESS OF RESTART FILE CYL*RESTAR          AT EXIT IS   363

   SECTOR ADDRESS OF RESPONSE FILE CYL*RESPON         AT EXIT IS  3094

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+            A U X I L I A R Y   S T O R A G E   T A B L E               +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                        +
+ LDI   EXT-NAME UNT EC OPT SEC  CDLOC   NEXT  LIMIT      READ WRITTEN +
+ 10  CYL*RESPON  12 36 UP   28   3094   3094  65536         0   82173 +
+ 12  CYL*RESTAR  14 36 UP   28    363    363  65536         0    9939 +
+ 14   CYL*PREPN  16 36 AX   28     56    128  65536    151956       0 +
+ 16      UNIT18  18 32 T    28     96    576  16384   2733696   48384 +
+ 18      POOL01  20 32 T    28     74     74  16384    247068  120045 +
+ 20  INF*CYLSKY  22 36 AX   28    613    640  65536   1500367       0 +
+                                                                        +
+                   6 ACTIVE DEVICES ( 0 FULL)                           +
+       0 TP-OPS,     585 WRITES,    2776 READS,    4896220 WORDS XFD   +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

+++  @ FREE         CYL*RESTAR.

+++  @ FREE         CYL*RESPON.
```

APPENDIX E

USER INFORMATION FOR THE POSTPROCESSOR POSTPR

The following includes modifications which were made under separate contract to the Naval Surface Weapons Center, Contract Number N60921-77-C-0112.

This appendix includes a copy of the users manual, and a sample input deck and subsequent output for the infinte cylindrical shell problem presented in Section 4.

```
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                              P O S T P R

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   THIS FUNCTIONAL COMPONENT OF THE UNDERWATER SHOCK ANALYSIS CODE
   IS RESPONSIBLE FOR THE TABULATION AND PRINTER-PLOT GRAPHIC DISPLAY
   OF SELECTED TRANSIENT RESPONSES AND PSEUDO-VELOCITY SHOCK SPECTRA
   UPON COMPLETION OF AN UNDERWATER SHOCK ANALYSIS OF A SUBMERGED
   STRUCTURE

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   THIS PROGRAM WAS DEVELOPED AND CODED BY JOHN A. DERUNTZ, JR.
   OF LOCKHEED MISSILES AND SPACE CO. RESEARCH LABS IN PALO ALTO
   CALIFORNIA. PLEASE CONSULT WITH AUTHOR BEFORE MAKING CHANGES
   AND ALSO REPORT ANY MALFUNCTIONS OR PROBLEMS. WRITE IN CARE OF
   LOCKHEED PALO ALTO RESEARCH LABORATORY, BLDG 205, DEPT 52-33,
   3251 HANOVER ST., PALO ALTO, CALIF., 94304 OR CALL 415-493-4411
   EXTS. 45069 OR 45133.                             FEBRUARY, 1978

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 W A R N I N G    F R O M    T H E    P R O G R A M M E R    G E N E R A L

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   THIS CODE CONTAINS THE SPECIAL INGREDIENT DMGASP NOT FOUND IN
   OTHER BRANDS. DMGASP IS A DATA MANAGEMENT UTILITY MODULE THAT
   WILL ACTIVATE AND DEACTIVATE ALL AUXILIARY STORAGE DATA FILES
   REFERENCED BY THE CODE. HENCE THE NAMES OF SUCH FILES SHOULD NOT
   APPEAR ON ANY CONTROL CARDS IN THE RUN STREAM WHICH MIGHT NORMALLY
   ACTIVATE AND DEACTIVATE THE FILES. THE USER IS ALSO CAUTIONED THAT
   PREVIOUSLY CREATED FILES MUST ALREADY BE RESIDENT IN THE SYSTEM
   BEFORE THE RUN IS INITIATED. IF A FILE HAS BEEN ROLLED-OUT TO TAPE
   DMGASP WILL ATTEMPT TO HAVE THE FILE ROLLED-IN EVERY 15 SECONDS
   FOR UP TO 15 MINUTES ON THE UNIVAC 1100-EXEC 8 OPERATING SYSTEM.
   IF AN EXISTING DATA FILE HAS NOT BEEN REFERENCED FOR SOME TIME IT
   IS THEREFORE GOOD POLICY TO SIMPLY ACTIVATE AND DEACTIVATE THE
   FILE BEFORE EXECUTION OF THIS CODE. IF THE USER ATTEMPTS TO CREATE
   A NEW DATA FILE WITH A NAME WHICH IS ALREADY ASSIGNED TO AN
   EXISTING FILE, THE UNIVAC VERSION OF DMGASP WILL MODIFY THE NAME
   OF THE FILE GENERATED BY THIS RUN TO AVOID ANY CONFLICT. FILE NAME
   DUPLICATION WILL CAUSE NO PROBLEM ON THE CDC SCOPE OPERATING
   SYSTEM AS SCOPE WILL SIMPLY CATALOG A NEW CYCLE OF THE SAME FILE.
   ON THE OTHER HAND THE CDC NOS SYSTEM IS SIMILAR TO UNIVAC IN THIS
   REGARD AND THE RUN WILL ABORT SINCE THE NAME-CHANGING FEATURE OF
   DMGASP HAS NOT BEEN IMPLEMENTED FOR NOS. QUALIFIER*FILENAME IS THE
   REQUIRED INPUT DATA FORMAT FOR ALL UNIVAC PERMANENT FILE NAMES.
   FOR CDC OPERATION QUALIFIER IS REPLACED BY THE FILE ID, WHICH IS
   THE USER ID BY DEFAULT

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                         P R O G R A M    S I Z E
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* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      ALL ARRAYS REFERRENCED IN THIS CODE THAT ARE PROBLEM DEPENDENT
      RESIDE IN BLANK COMMON. THE SIZE OF BLANK COMMON IS DETERMINED BY
      A PARAMETER STATEMENT IN THE MAIN PROGRAM FOR THE UNIVAC 1100-OS
      VERSION. HENCE A RECOMPILATION IS NECESSARY TO INCREASE OR
      DECREASE CORE ALLOCATION. IN THE CDC 6600 VERSION RECOMPILATION IS
      UNNECESSARY AS THE LENGTH OF BLANK COMMON IS SET BY A FIELD LENGTH
      REQUEST IN THE CONTROL CARD DECK

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      D E F I N I T I O N     O F     I N P U T     P A R A M E T E R S

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      INPUT VARIABLE NAMES GIVEN BELOW ARE GENERALLY THOSE WHICH ARE
      ALSO USED IN THE CODING AND THE VARIABLE TYPES CORRESPOND TO
      STANDARD FORTRAN USAGE:

                     A    -    ALPHANUMERIC
                     E    -    FLOATING POINT
                     F    -    FIXED POINT
                     I    -    INTEGER
                     L    -    LOGICAL

      --------       ----                   -----------
      VARIABLE       TYPE                   DESCRIPTION
      --------       ----                   -----------

      JFINTM         I         NUMBER OF TIME POINTS TO BE DISPLAYED

      PRENAM         A         NAME OF PRE-PROCESSED MASS STORAGE FILE
                               CONTAINING ALL FLUID AND STRUCTURE DATA
                               WHICH DOES NOT DEPEND UPON ABOVE LOAD AND
                               INTEGRATION PARAMETERS

      POSNAM         A         NAME OF MASS STORAGE FILE AVAILABLE FOR
                               POST-PROCESSING WHICH CONTAINS SYSTEM
                               RESPONSES

      FORWRT         L         TRUE IF PERMANENT FILE DENOTED BY POSNAM
                               HAS BEEN CREATED USING UNFORMATTED FORTRAN
                               WRITE. OTHERWISE FILE WAS CREATED BY
                               DIRECT TRANSFER USING THE DATA MANAGEMENT
                               SYSTEM DMGASP

      LISTRE         L         TRUE IF TRANSIENT RESPONSE HISTORIES ARE
                               TO BE LISTED IN TABULAR FORM, OTHERWISE
                               FALSE

      PRTPLT         L         TRUE IF PRINTER PLOTS ARE TO BE GENERATED
                               FOR TRANSIENT RESPONSE HISTORIES,
                               OTHERWISE FALSE

      NWETHS         I         NUMBER OF STRUCTURAL HISTORIES (EITHER
                               DISPLACEMENTS OR VELOCITIES) TO BE
                               DISPLAYED FOR WHICH THE APPROPRIATE
```

```
                                STRUCTURAL FREEDOMS CAN BE IDENTIFIED
                                INTERNALLY THROUGH THE FREEDOM/EQUATION
                                CORRESPONDENCE TABLE. ALL STRUCTURAL NODES
                                WHICH PARTICIPATE IN THE FLUID-STRUCTURE
                                TRANSFORMATION WILL FALL INTO THIS
                                CATEGORY AS WELL AS ANY OTHERS WHOSE GRID
                                POINT COORDIATES WERE ENTERED AS DATA FOR
                                THE FLUID MASS PROCESSOR

NDRYHS          I               NUMBER OF STRUCTURAL HISTORIES (EITHER
                                DISPLACEMENTS OR VELOCITIES) TO BE
                                DISPLAYED FOR WHICH THE APPROPRIATE
                                STRUCTURAL FREEDOMS CANNOT BE IDENTIFIED
                                INTERNALLY THROUGH THE FREEDOM/EQUATION
                                CORRESPONDENCE TABLE. DRY STRUCTURE NODE
                                POINTS CAN FALL INTO THIS CATEGORY IF THE
                                USER DID NOT INCLUDE THEM IN THE DATA
                                STREAM FOR THE FLUID MASS PROCESSOR. IN
                                THIS CASE ONE MUST IDENTIFY THE INTERNAL
                                SEQUENCE NUMBER APPROPRIATE TO THE DESIRED
                                DEGREE OF FREEDOM BY A MYSTICAL PROCESS
                                WHICH INVOLVES THE INTIMATE KNOWLEDGE OF
                                THE ELIMINATION ORDER AND ANY REDUCTION
                                OF THE NUMBER OF ACTIVE FREEDOMS DUE TO
                                THE APPLICATION OF CONSTRAINTS. MORAL OF
                                THE STORY - RUN ALL STRUCTURAL GRID POINTS
                                THROUGH THE FLUID MASS PROCESSOR EVEN IF
                                THEY NEVER GET WET

NODOUT          I               EXTERNAL INDENTIFICATION NUMBER OF
                                STRUCTURAL NODE FOR WHICH A TIME HISTORY
                                DISPLAY IS DESIRED

NFROUT          I               STRUCTURAL DEGREE OF FREEDOM NUMBER FOR
                                WHICH A TIME HISTORY DISPLAY IS DESIRED

NEQHST          I               INTERNAL SEQUENCE NUMBER DETERMINED BY
                                HAND FOR STRUCTURAL DEGREES OF FREEDOM
                                WHICH ARE TO BE DISPLAYED AND ARE NOT
                                INCLUDED IN THE FREEDOM/EQUATION
                                CORRESPONDENCE TABLE FOR REASONS KNOWN
                                ONLY TO THE USER

NPREHS          I               NUMBER OF FLUID PRESSURE HISTORIES TO BE
                                DISPLAYED

NEQHPR          I               FLUID CONTROL POINT NUMBER FOR WHICH A
                                TIME HISTORY DISPLAY IS DESIRED FOR THE
                                TOTAL PRESSURE

SCALEF          L               TRUE IF A MULTIPLICATIVE CONSTANT FACTOR
                                IS TO BE APPLIED TO THE DISPLAYED VALUES
                                OF THE STRUCTURAL DISPLACEMENT AND
                                VELOCITY HISTORIES, OTHERWISE FALSE

FACTOR          E,F             VALUE OF MULTIPLICATIVE LENGTH CONVERSION
                                FACTOR TO BE APPLIED TO THE DISPLAYED
                                STRUCTURAL TRANSIENT RESPONSE HISTORIES
```

```
        SHSPEC       L         TRUE IF PSEUDO-VELOCITY SHOCK SPECTRA ARE
                               ALSO DESIRED FOR STRUCTURAL FREEDOMS WHOSE
                               VELOCITY RESPONSE IS TO BE DISPLAYED,
                               OTHERWISE FALSE

        SHLIST       L         TRUE IF PSEUDO-VELOCITY SHOCK SPECTRA ARE
                               TO BE LISTED IN TABULAR FORM, OTHERWISE
                               FALSE

        SHPRPL       L         TRUE IF PRINTER PLOTS ARE TO BE GENERATED
                               FOR PSEUDO-VELOCITY SHOCK SPECTRA,
                               OTHERWISE FALSE

        FREQLW       E,F       LOWER LIMIT OF FREQUENCY RANGE TO BE
                               SCANNED FOR PSEUDO-VELOCITY SHOCK SPECTRA

        FREQUP       E,F       UPPER LIMIT OF FREQUENCY RANGE TO BE
                               SCANNED FOR PSEUDO-VELOCITY SHOCK SPECTRA

        DFREQ        E,F       FREQUENCY INCREMENT TO BE USED IN
                               GENERATING PSEUDO-VELOCITY SHOCK SPECTRA

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

               I N P U T    D A T A    C A R D    D E C K

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

        ALL INPUT DATA EXCEPT ALPHANUMERIC DATA MUST BE RIGHT JUSTIFIED
        IN EIGHT (8) COLUMN FIELDS WHICH CAN OCCUPY THE ENTIRE CARD.
        ALPHANUMERIC DATA MUST BE LEFT JUSTIFIED IN SIXTEEN (16) COLUMN
        FIELDS. FILE NAMES ARE RESTRICTED TO TWELVE (12) CHARACTERS FOR
        UNIVAC OPERATION WHILE SIXTEEN (16) CHARACTERS ARE ALLOWED FOR CDC
        OPERATION. HENCE A NAME LIKE ABCDE-FGHIJK IS THE LIMIT FOR UNIVAC
        WHILE A CDC FILE NAME MAY HAVE FOUR (4) ADDITIONAL CHARACTERS

        GENERAL DISPLAY DEFINITION (MAIN PROGRAM POSTPR):
        ------------------------------------------------


        JFINTM
        PRENAM          POSNAM
        FORWRT

        POST PROCESSING (SUBROUTINE RESDSP):
        ------------------------------------

        LISTRE  PRTPLT

        POST PROCESSING (SUBROUTINE STRDSP):
        ------------------------------------

        NWETHS  NDRYHS                                  )
        NODOUT  NFROUT           )                      )
          .       .              )   TOTAL = NWETHS     )     THIS SET FOR
          .       .              )                      )
        NODOUT  NFROUT  NEQHST   )                      )     DISPLACEMENTS
          .               .      )   TOTAL = NDRYHS     )
```

```
       .      .      .    )                        )

NWETHS  NDRYHS                                     )
NODOUT  NFROUT            )                        )
   .      .               )   TOTAL = NWETHS       )   THIS SET FOR
   .      .               )                        )
NODOUT  NFROUT  NEQHST    )                        )   VELOCITIES
   .      .       .       )   TOTAL = NDRYHS       )
   .      .               )                        )

POST PROCESSING (SUBROUTINE RESDSP):
------------------------------------

NPREHS
NEQHPR                    )
   .                      )   TOTAL = NPREHS
   .                      )

POST PROCESSING (SUBROUTINE FILBUF):
------------------------------------

SCALEF

IF SCALEF = .TRUE. READ THE FOLLOWING CARD

FACTOR

POST PROCESSING (SUBROUTINE RESDSP):
------------------------------------

SHSPEC

IF SHSPEC = .TRUE. READ THE FOLLOWING CARDS

SHLIST  SHPRPL
FREQLW  FREQUP  DFREQ
```

The following discussion is provided as an aid to user understanding of the sample output that is included here.

Perhaps the only item needing discussion is the transient response tabular listings. The desired responses are displayed in matrix form so that each row contains the entire history of a particular degree of freedom except for the first row which is time. Each column therefore contains the instantaneous values of the complete set of response variables desired at a particular time. Each row is identified by the structural or fluid node and its degree of freedom. The letters D, V, and P stand for displacement, velocity, and pressure, respectively.

Essentially the same format is used for the pseudo-velocity shock spectra except that the first row is now frequency rather than time.

```
 1          91
 2     CYL*PREPN       CYL*RESPON
 3           F
 4           T        T
 5           2        0
 6          19        1
 7          19        2
 8           4        0
 9           1        1
10          19        1
11          19        2
12          37        1
13           3
14           1
15          10
16          19
17           F
18           T
19           T        T
20          0.       3.     .025

@XQT

+++  @ ASG,AX          CYL*PREPN.
+++  @ USE     16,     CYL*PREPN.

+++  @ ASG,AX        CYL*RESPON.
+++  @ USE     12,   CYL*RESPON.

+++  @ FREE            CYL*PREPN.
```

TRANSIENT RESPONSE HISTORIES:

	1	2	3	4	5	6	7	8	9	10
	-.00000	.25000-01	.50000-01	.75000-01	.10000+00	.12500+00	.15000+00	.17500+00	.20000+00	.22500+00
19/1 D	.00000	-.12753-05	-.77224-05	-.23777-04	-.51038-04	-.87027-04	-.12574-03	-.15885-03	-.17670-03	-.16889-03
19/2 D	.00000	.29236-08	.29659-07	.15176-06	.53017-06	.14413-05	.32893-05	.66442-05	.12424-04	.22524-04
1/1 V	.00000	-.27908+00	-.73153+00	-.10611+01	-.12968+01	-.14663+01	-.15894+01	-.16799+01	-.17468+01	-.17966+01
19/1 V	.00000	-.10202-03	-.41375-03	-.87059-03	-.13103-02	-.15688-02	-.15284-02	-.11204-02	-.30774-03	.93239-03
19/2 V	.00000	.23388-06	.19049-05	.78632-05	.22409-04	.50478-04	.97367-04	.17102-03	.29135-03	.51665-03
37/1 V	.00000	-.50264-04	-.20279-03	-.42395-03	-.63343-03	-.75075-03	-.71896-03	-.50667-03	-.99344-04	.50879-03
1/0 P	.11765+00	.16364+01	.12208+01	.89650+00	.67491+00	.52977+00	.43563+00	.37507+00	.33664+00	.31318+00
10/0 P	-.00000	.64211-03	.13266-02	.15793-02	.12674-02	.51319-03	-.51817-03	-.16963-02	-.29549-02	-.42601-02
19/0 P	-.00000	.31632-03	.64677-03	.75973-03	.59625-03	.21450-03	-.30061-03	-.88081-03	-.14982-02	-.21359-02

	11	12	13	14	15	16	17	18	19	20
	.25000+00	.27500+00	.30000+00	.32500+00	.35000+00	.37500+00	.40000+00	.42500+00	.45000+00	.47500+00
19/1 D	-.12468-03	-.33284-04	.11673-03	.33923-03	.65309-03	.10853-02	.16751-02	.24783-02	.35705-02	.50459-02
19/2 D	.41557-04	.80926-04	.16707-03	.35588-03	.75424-03	.15467-02	.30205-02	.55762-02	.97110-02	.15963-01
1/1 V	-.18337+01	-.18616+01	-.18827+01	-.18987+01	-.19107+01	-.19198+01	-.19266+01	-.19320+01	-.19363+01	-.19399+01
19/1 V	.26046-02	.47071-02	.72938-02	.10507-01	.14602-01	.19976-01	.27207-01	.37051-01	.50322-01	.67713-01
19/2 V	.10060-02	.21436-02	.47480-02	.10357-01	.21512-01	.41886-01	.76013-01	.12845+00	.20234+00	.29782+00
37/1 V	.13107-02	.22867-02	.34199-02	.46970-02	.61007-02	.76049-02	.91797-02	.10801-01	.12450-01	.14108-01
1/0 P	.30042+00	.29529+00	.29521+00	.29860+00	.30449+00	.31230+00	.32132+00	.33097+00	.34080+00	.35064+00
10/0 P	-.54643-02	-.64894-02	-.73561-02	-.78268-02	-.75895-02	-.60410-02	-.26846-02	.31091-02	.12001-01	.24398-01
19/0 P	-.27410-02	-.32975-02	-.38479-02	-.43822-02	-.48936-02	-.53403-02	-.57484-02	-.61354-02	-.65133-02	-.68839-02

	21	22	23	24	25	26	27	28	29	30
	.50000+00	.52500+00	.55000+00	.57500+00	.60000+00	.62500+00	.65000+00	.67500+00	.70000+00	.72500+00
19/1 D	.70125-02	.95814-02	.12854-01	.16908-01	.21792-01	.27523-01	.34093-01	.41485-01	.49680-01	.58673-01
19/2 D	.24821-01	.36618-01	.51450-01	.69152-01	.89355-01	.11161+00	.13551+00	.16086+00	.18760+00	.21585+00
1/1 V	-.19428+01	-.19453+01	-.19475+01	-.19496+01	-.19518+01	-.19544+01	-.19572+01	-.19601+01	-.19628+01	-.19654+01
19/1 V	.89611-01	.11590+00	.14588+00	.17844+00	.21228+00	.24620+00	.27945+00	.31187+00	.34376+00	.37567+00
19/2 V	.41079+00	.53296+00	.65361+00	.76259+00	.85365+00	.92645+00	.98622+00	.10411+01	.10985+01	.11614+01
37/1 V	.15760-01	.17385-01	.18957-01	.20457-01	.21873-01	.23199-01	.24451-01	.25671-01	.26953-01	.28471-01
1/0 P	.36038+00	.37009+00	.37962+00	.38874+00	.39726+00	.40518+00	.41254+00	.41963+00	.42657+00	.43336+00
10/0 P	.40222-01	.59207-01	.80372-01	.10236+00	.12391+00	.14412+00	.16207+00	.17789+00	.19175+00	.20410+00
19/0 P	-.72627-02	-.76020-02	-.79074-02	-.81906-02	-.84383-02	-.86033-02	-.86646-02	-.84981-02	-.79680-02	-.68358-02

	31	32	33	34	35	36	37	38	39	40
	.75000+00	.77500+00	.80000+00	.82500+00	.85000+00	.87500+00	.90000+00	.92500+00	.95000+00	.97500+00
19/1 D	.68471-01	.79093-01	.90568-01	.10293+00	.11624+00	.13053+00	.14589+00	.16230+00	.17937+00	.19641+00
19/2 D	.24572+00	.27724+00	.31035+00	.34489+00	.38074+00	.41785+00	.45624+00	.49598+00	.53711+00	.57958+00
1/1 V	-.19680+01	-.19708+01	-.19740+01	-.19778+01	-.19818+01	-.19859+01	-.19898+01	-.19935+01	-.19972+01	-.20012+01
19/1 V	.40815+00	.44161+00	.47637+00	.51285+00	.55138+00	.59238+00	.63649+00	.67625+00	.68944+00	.67359+00
19/2 V	.12281+01	.12939+01	.13545+01	.14089+01	.14592+01	.15093+01	.15620+01	.16174+01	.16729+01	.17246+01
37/1 V	.30514-01	.33522-01	.38112-01	.45086-01	.55394-01	.70052-01	.90004-01	.11592+00	.14801+00	.18582+00
1/0 P	.43984+00	.44577+00	.45103+00	.45569+00	.46000+00	.46422+00	.46849+00	.47276+00	.47679+00	.48036+00
10/0 P	.21527+00	.22498+00	.23254+00	.23712+00	.23969+00	.23941+00	.23659+00	.28201+00	.41764+00	.47729+00
19/0 P	-.47574-02	-.12426-02	.43564-02	.12816-01	.25006-01	.41737-01	.63648-01	.91014-01	.12358+00	.16046+00

	41	42	43	44	45	46	47	48	49	50
	.10000+01	.10500+01	.11000+01	.11500+01	.12000+01	.12500+01	.13000+01	.13500+01	.14000+01	.14500+01
19/1 D	.21255+00	.23953+00	.25837+00	.26878+00	.27197+00	.26993+00	.26408+00	.25557+00	.24544+00	.23453+00
19/2 D	.62326+00	.71376+00	.80806+00	.90588+00	.10065+01	.11082+01	.12092+01	.13076+01	.14016+01	.14898+01
1/1 V	-.20056+01	-.20148+01	-.20238+01	-.20327+01	-.20426+01	-.20540+01	-.20661+01	-.20775+01	-.20884+01	-.20997+01
19/1 V	.61773+00	.46115+00	.29254+00	.12395+00	.36494-02	-.85187-01	-.14908+00	-.19103+00	-.21411+00	-.22255+00
19/2 V	.17703+01	.18495+01	.19228+01	.19899+01	.20329+01	.20377+01	.20036+01	.19317+01	.18253+01	.17050+01
37/1 V	.22819+00	.32560+00	.41620+00	.48444+00	.54146+00	.59348+00	.64543+00	.69647+00	.74335+00	.78584+00

1/0 P	.48338+00	.48843+00	.49360+00	.49876+00	.50277+00	.50515+00	.50686+00	.50900+00	.51160+00	.51401+00
10/0 P	.68044+00	.63747+00	.73945+00	.65715+00	.61509+00	.59371+00	.58605+00	.59083+00	.60688+00	.63137+00
19/0 P	.20016+00	.27911+00	.34677+00	.39782+00	.43517+00	.46655+00	.49693+00	.52523+00	.54825+00	.56570+00

	51	52	53	54	55	56	57	58	59	60
	.15000+01	.15500+01	.16000+01	.16500+01	.17000+01	.17500+01	.18000+01	.18500+01	.19000+01	.19500+01
19/1 D	.22342+00	.21240+00	.20145+00	.19036+00	.17891+00	.16707+00	.15499+00	.14278+00	.13053+00	.11822+00
19/2 D	.15726+01	.16516+01	.17291+01	.18068+01	.18850+01	.19629+01	.20389+01	.21126+01	.21852+01	.22582+01
1/1 V	-.21114+01	-.21225+01	-.21311+01	-.21356+01	-.21338+01	-.21228+01	-.20997+01	-.20639+01	-.20182+01	-.19698+01
19/1 V	-.22189+00	-.21876+00	-.21909+00	-.22481+00	-.23323+00	-.24009+00	-.24345+00	-.24456+00	-.24549+00	-.24690+00
19/2 V	.16063+01	.15542+01	.15466+01	.15609+01	.15679+01	.15450+01	.14959+01	.14540+01	.14492+01	.14705+01
37/1 V	.82717+00	.86966+00	.91221+00	.95321+00	.99368+00	.10363+01	.10826+01	.11319+01	.11852+01	.12475+01
1/0 P	.51619+00	.51950+00	.52568+00	.53641+00	.55369+00	.57979+00	.61654+00	.66353+00	.71661+00	.76831+00
10/0 P	.65875+00	.68372+00	.70149+00	.71100+00	.71596+00	.72093+00	.72776+00	.73511+00	.74077+00	.74407+00
19/0 P	.58021+00	.59436+00	.60699+00	.61587+00	.62194+00	.62671+00	.63050+00	.63064+00	.62528+00	.60940+00

	61	62	63	64	65	66	67	68	69	70
	.20000+01	.21000+01	.22000+01	.23000+01	.24000+01	.25000+01	.26000+01	.27000+01	.28000+01	.29000+01
19/1 D	.10587+00	.81879-01	.60223-01	.42058-01	.27701-01	.16760-01	.77386-02	-.10276-02	-.96763-02	-.17404-01
19/2 D	.23320+01	.24800+01	.26326+01	.27987+01	.29806+01	.31720+01	.33656+01	.35544+01	.37381+01	.39234+01
1/1 V	-.19266+01	-.18708+01	-.18589+01	-.18487+01	-.18217+01	-.18166+01	-.18299+01	-.18303+01	-.18223+01	-.18310+01
19/1 V	-.24721+00	-.23263+00	-.20049+00	-.16282+00	-.12433+00	-.94482-01	-.85949-01	-.89375-01	-.83599-01	-.70953-01
19/2 V	.14810+01	.14797+01	.15708+01	.17517+01	.18860+01	.19437+01	.19276+01	.18483+01	.18247+01	.18822+01
37/1 V	.13090+01	.13842+01	.14106+01	.14193+01	.14244+01	.14344+01	.14602+01	.15032+01	.15586+01	.16132+01
1/0 P	.80997+00	.85045+00	.86017+00	.86809+00	.88455+00	.89267+00	.88632+00	.88181+00	.88384+00	.88063+00
10/0 P	.74494+00	.75460+00	.77830+00	.81181+00	.84819+00	.87635+00	.88609+00	.88285+00	.88306+00	.89138+00
19/0 P	.63839+00	.71348+00	.74690+00	.76222+00	.77211+00	.78568+00	.81198+00	.85412+00	.90791+00	.95939+00

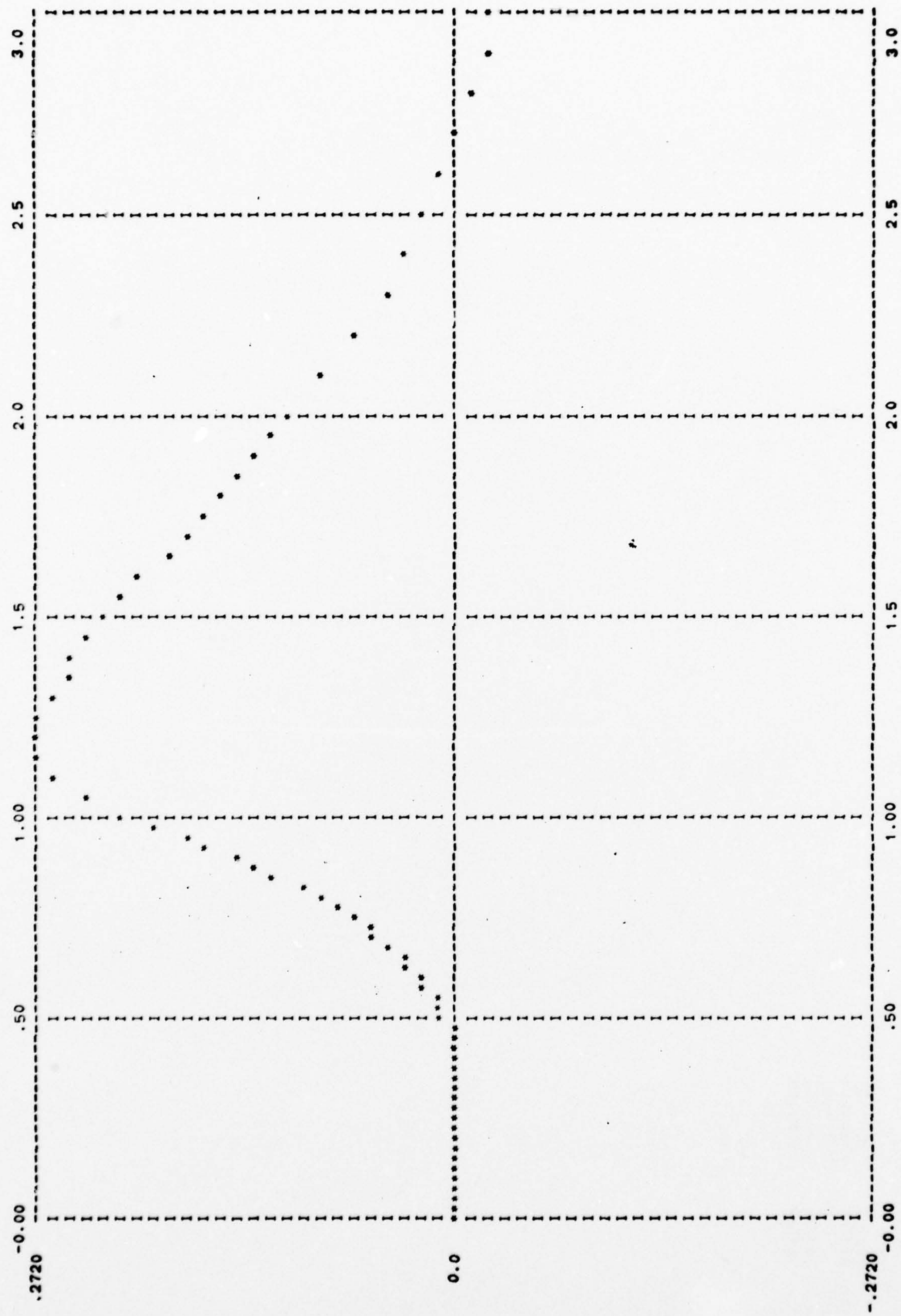
	71	72	73	74	75	76	77	78	79	80
	.30000+01	.31000+01	.32000+01	.33000+01	.34000+01	.35000+01	.36000+01	.37000+01	.38000+01	.39000+01
19/1 D	-.24176-01	-.30355-01	-.35606-01	-.39271-01	-.41266-01	-.42588-01	-.44682-01	-.47855-01	-.51302-01	-.54542-01
19/2 D	.41109+01	.42912+01	.44600+01	.46209+01	.47778+01	.49325+01	.50897+01	.52534+01	.54217+01	.55896+01
1/1 V	-.18427+01	-.18357+01	-.18271+01	-.18281+01	-.18203+01	-.18003+01	-.17790+01	-.17497+01	-.17150+01	-.17013+01
19/1 V	-.64492-01	-.59076-01	-.45945-01	-.27358-01	-.12553-01	-.13886-01	-.28000-01	-.35451-01	-.33480-01	-.31329-01
19/2 V	.18667+01	.17409+01	.16337+01	.15860+01	.15503+01	.15446+01	.16001+01	.16729+01	.16941+01	.16639+01
37/1 V	.16427+01	.16398+01	.16256+01	.16237+01	.16377+01	.16491+01	.16424+01	.16296+01	.16311+01	.16441+01
1/0 P	.87477+00	.87829+00	.88710+00	.89367+00	.90385+00	.92189+00	.94494+00	.97388+00	.10037+01	.10173+01
10/0 P	.90092+00	.90996+00	.92265+00	.94031+00	.95623+00	.95939+00	.95026+00	.94253+00	.94338+00	.94977+00
19/0 P	.98789+00	.98480+00	.96453+00	.95080+00	.95370+00	.96086+00	.95590+00	.94178+00	.93452+00	.93915+00

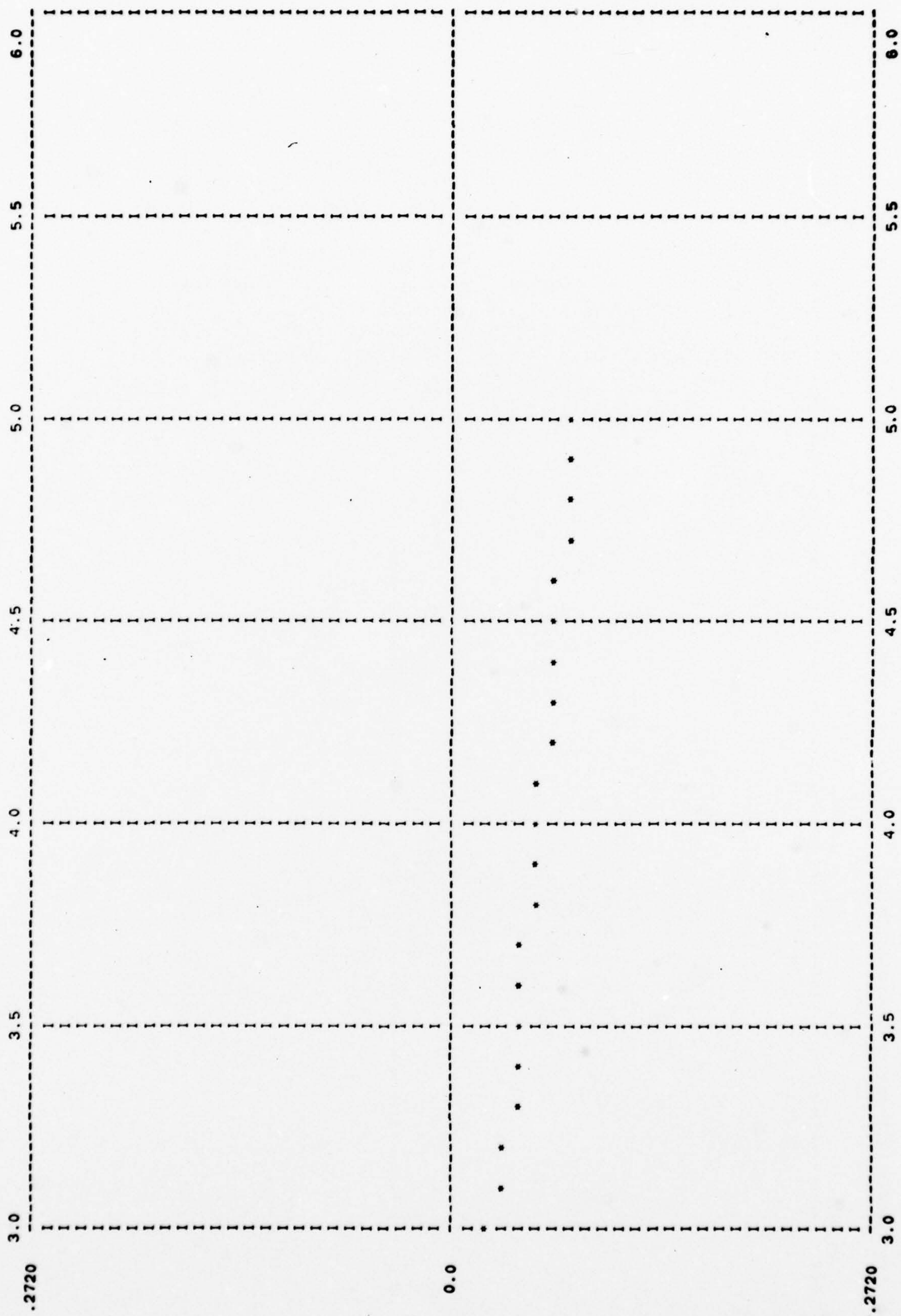
	81	82	83	84	85	86	87	88	89	90
	.40000+01	.41000+01	.42000+01	.43000+01	.44000+01	.45000+01	.46000+01	.47000+01	.48000+01	.49000+01
19/1 D	-.57413-01	-.59651-01	-.61445-01	-.63129-01	-.64571-01	-.65986-01	-.68261-01	-.71559-01	-.74743-01	-.76830-01
19/2 D	.57567+01	.59294+01	.61117+01	.62978+01	.64815+01	.66611+01	.68364+01	.70087+01	.71806+01	.73514+01
1/1 V	-.17130+01	-.17281+01	-.17396+01	-.17459+01	-.17386+01	-.17299+01	-.17399+01	-.17560+01	-.17562+01	-.17464+01
19/1 V	-.26093-01	-.18668-01	-.17204-01	-.16490-01	-.12332-01	-.15969-01	-.29544-01	-.36408-01	-.27277-01	-.14461-01
19/2 V	.16763+01	.17792+01	.18660+01	.18570+01	.18154+01	.17766+01	.17299+01	.17158+01	.17222+01	.16939+01
37/1 V	.16504+01	.16473+01	.16542+01	.16769+01	.16938+01	.17025+01	.17235+01	.17497+01	.17574+01	.17477+01
1/0 P	.10083+01	.98889+00	.97146+00	.96321+00	.96779+00	.97517+00	.97050+00	.95784+00	.95298+00	.95944+00
10/0 P	.95942+00	.96902+00	.97425+00	.97733+00	.98058+00	.97878+00	.96980+00	.96336+00	.96876+00	.98075+00
19/0 P	.94442+00	.94325+00	.94584+00	.95959+00	.97420+00	.98419+00	.99815+00	.10150+01	.10211+01	.10114+01

	91
	.50000+01
19/1 D	-.78088-01
19/2 D	.75195+01
1/1 V	-.17399+01
19/1 V	-.10706-01

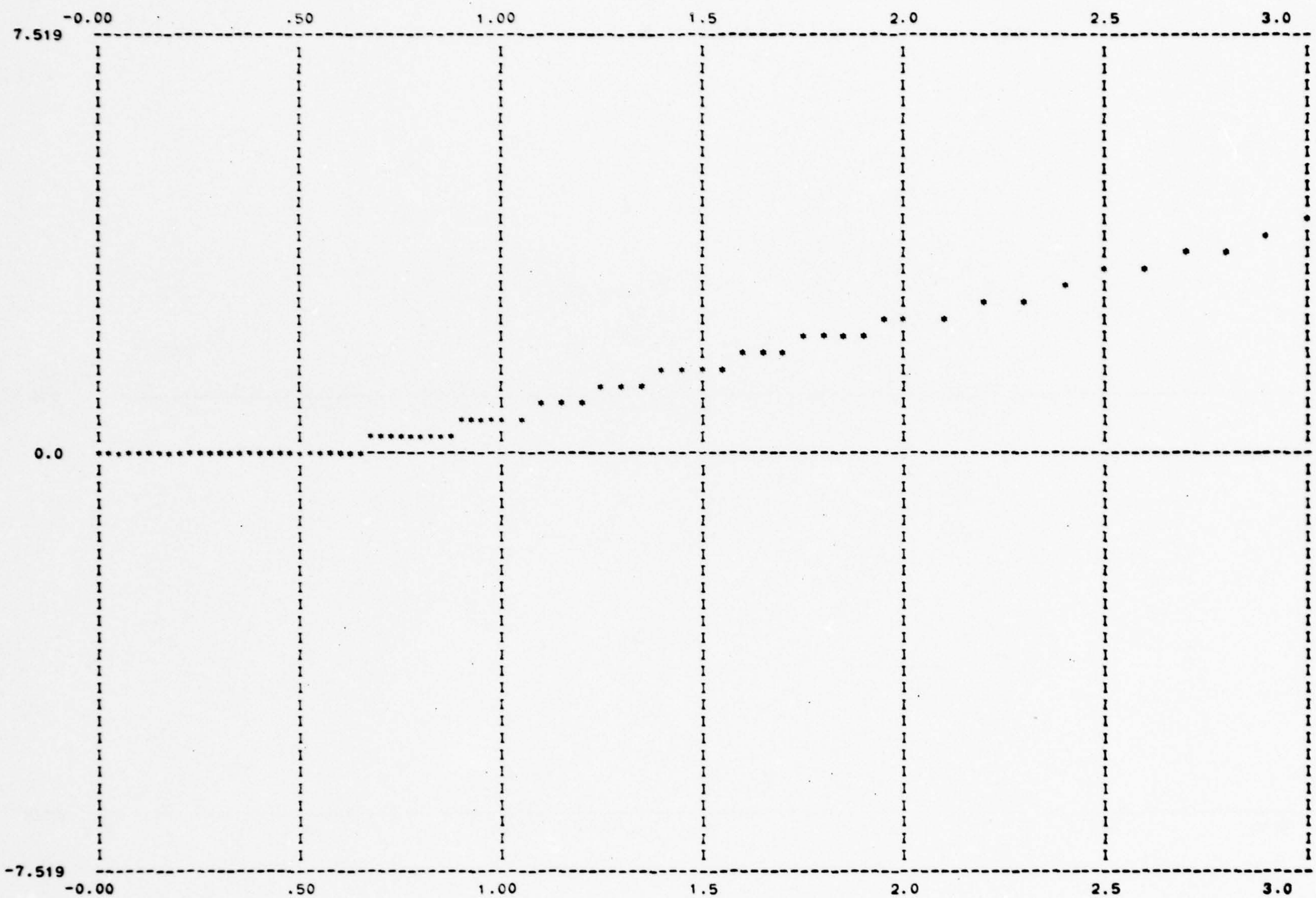
19/2	V	.16681+01
37/1	V	.17340+01
1/0	P	.96874+00
10/0	P	.98798+00
19/0	P	.99333+00

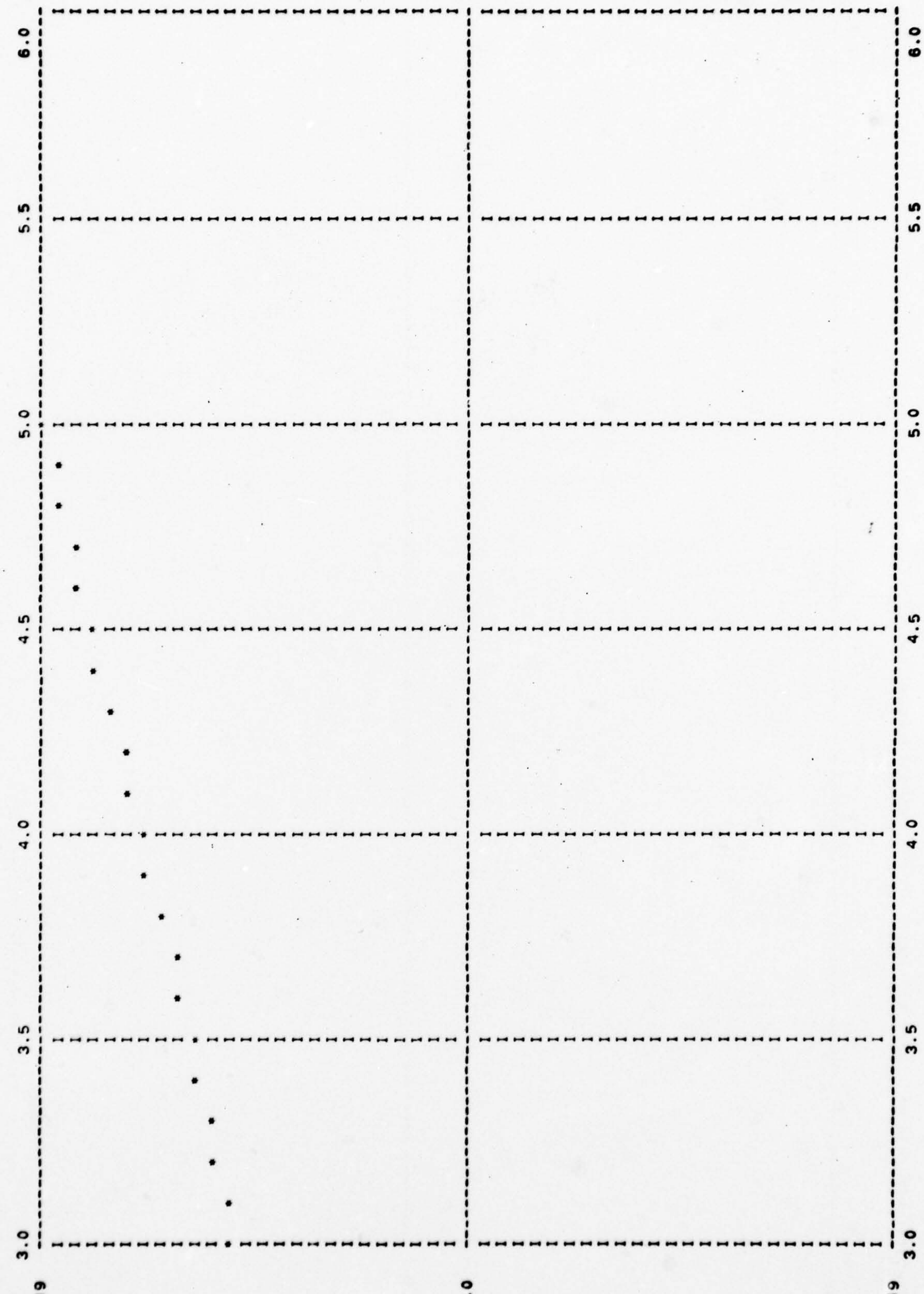
DISPLACEMENT RESPONSE OF STRUCTURAL NODE 19, FREEDOM NUMBER 1:



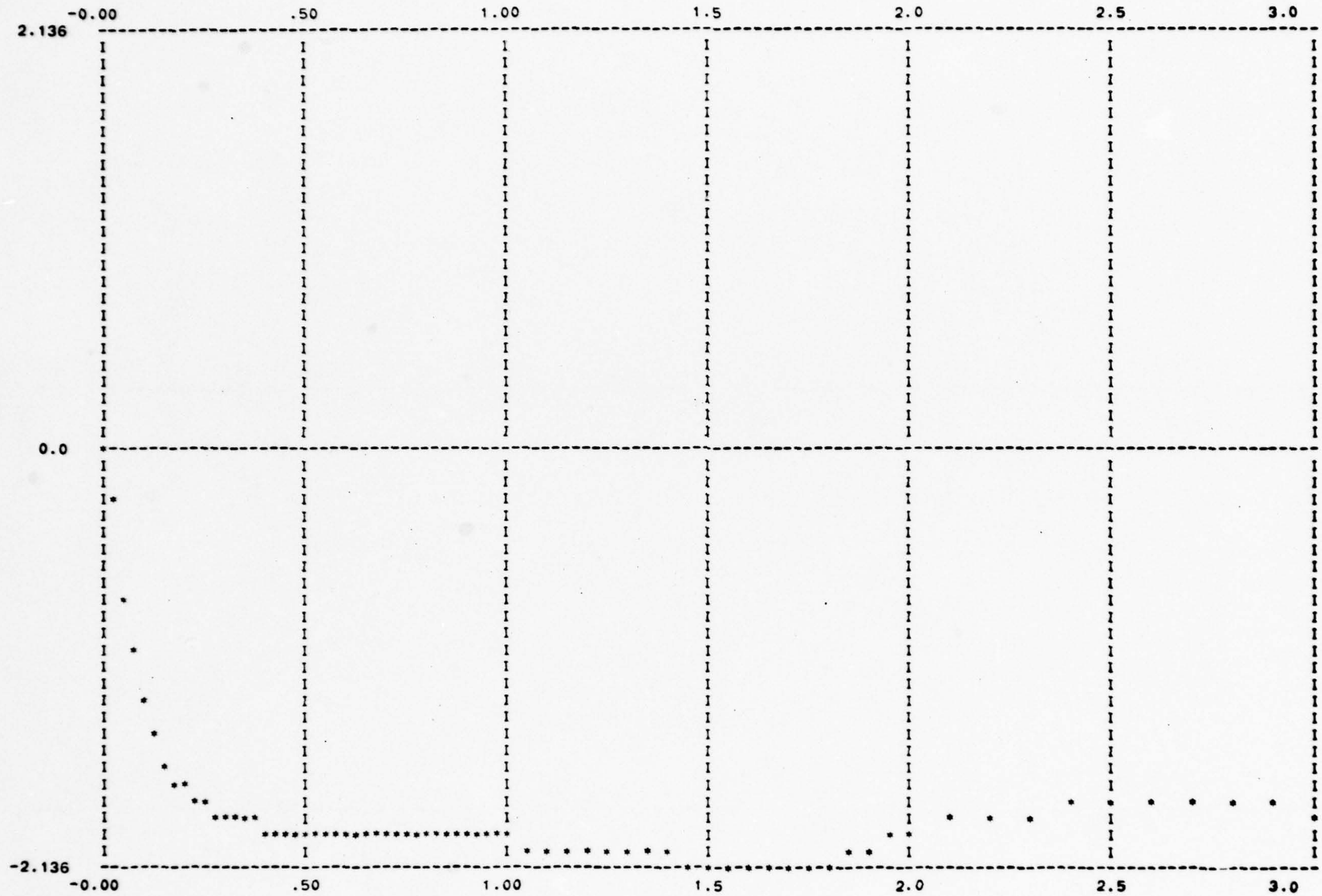

3.0
3.5
4.0
4.5
5.0
5.5
6.0
.2720
0.0
-.2720

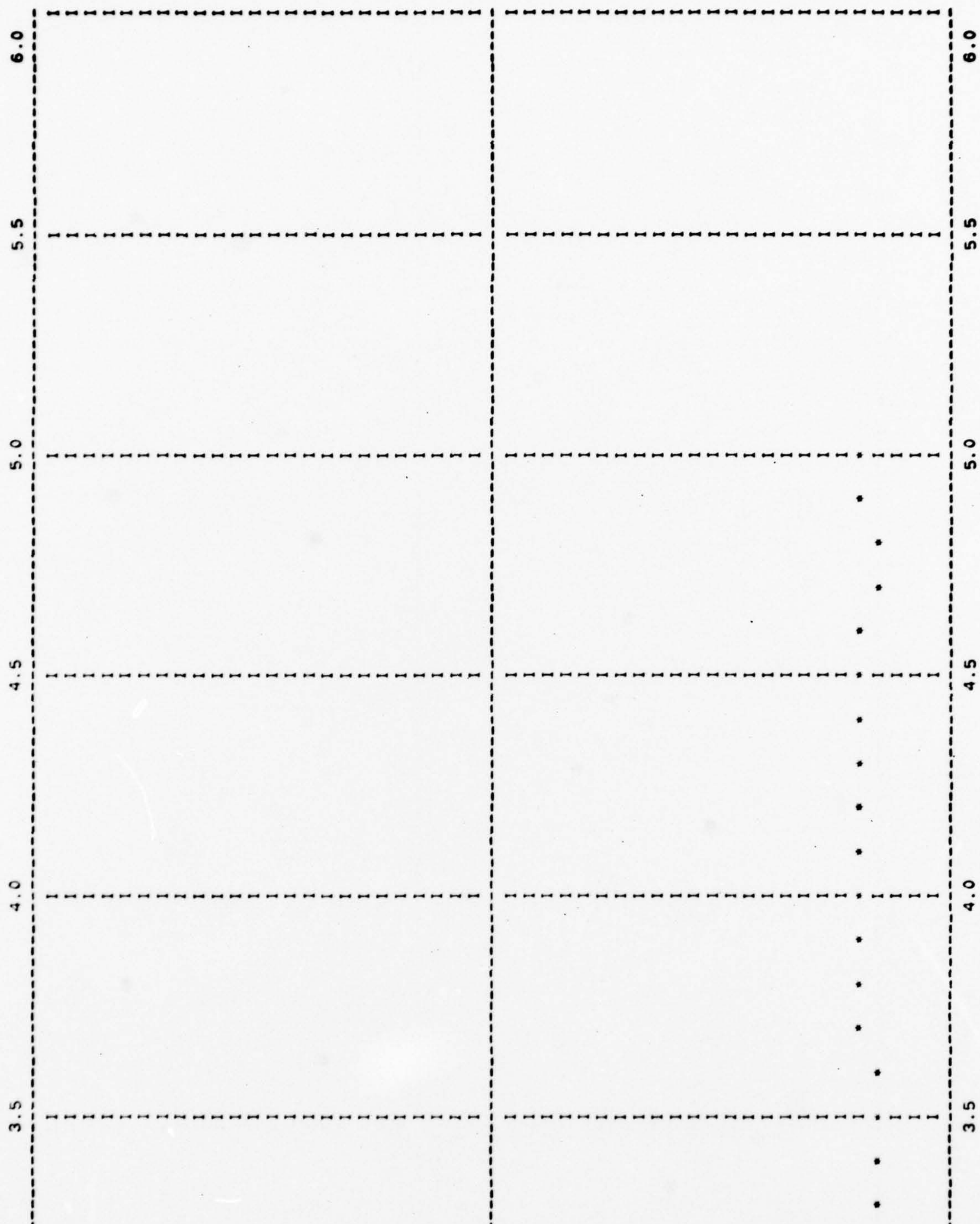
DISPLACEMENT RESPONSE OF STRUCTURAL NODE 19, FREEDOM NUMBER 2:




3.0
3.5
4.0
4.5
5.0
5.5
6.0
7.519
0.0
-7.519

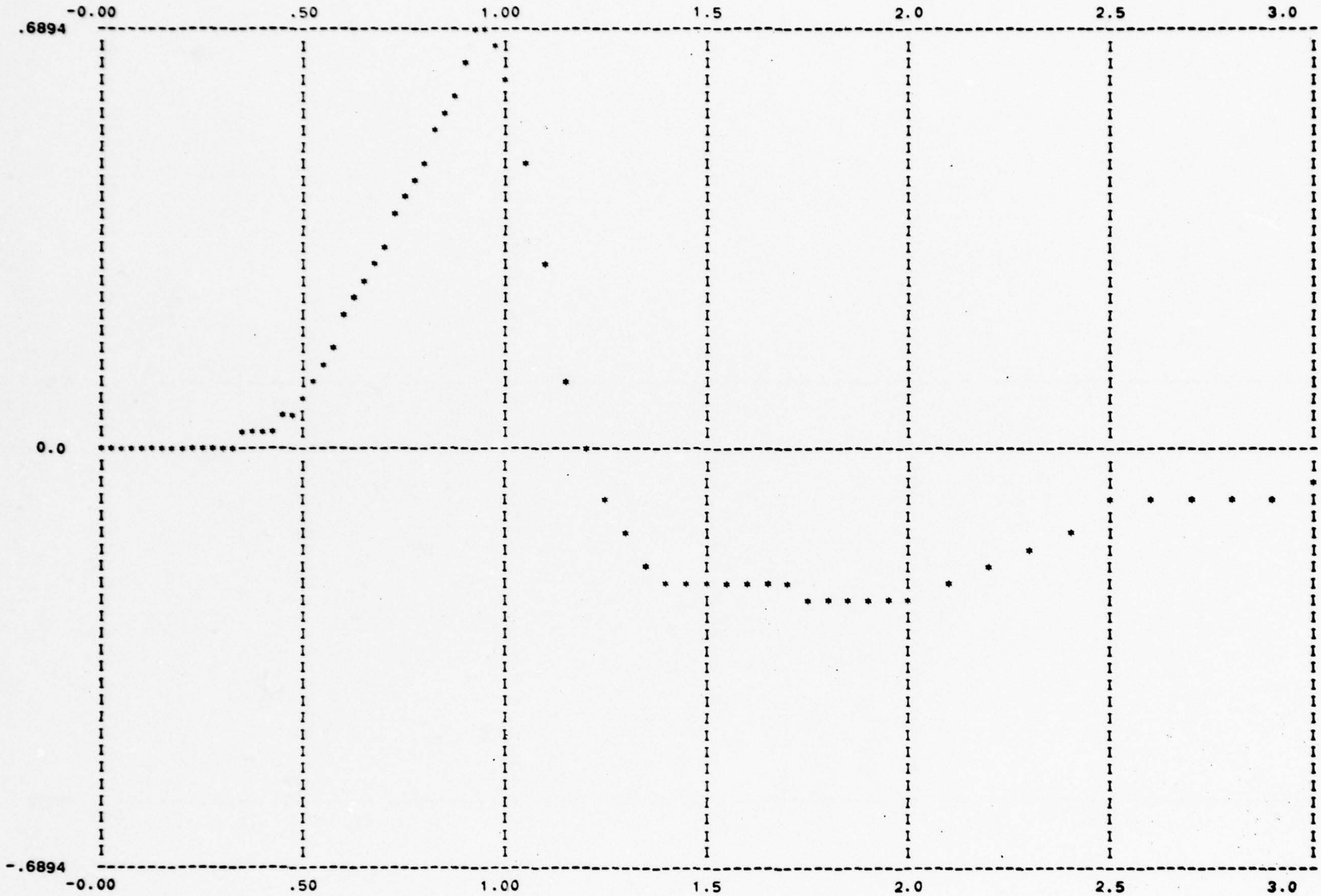
VELOCITY RESPONSE OF STRUCTURAL NODE 1, FREEDOM NUMBER 1:

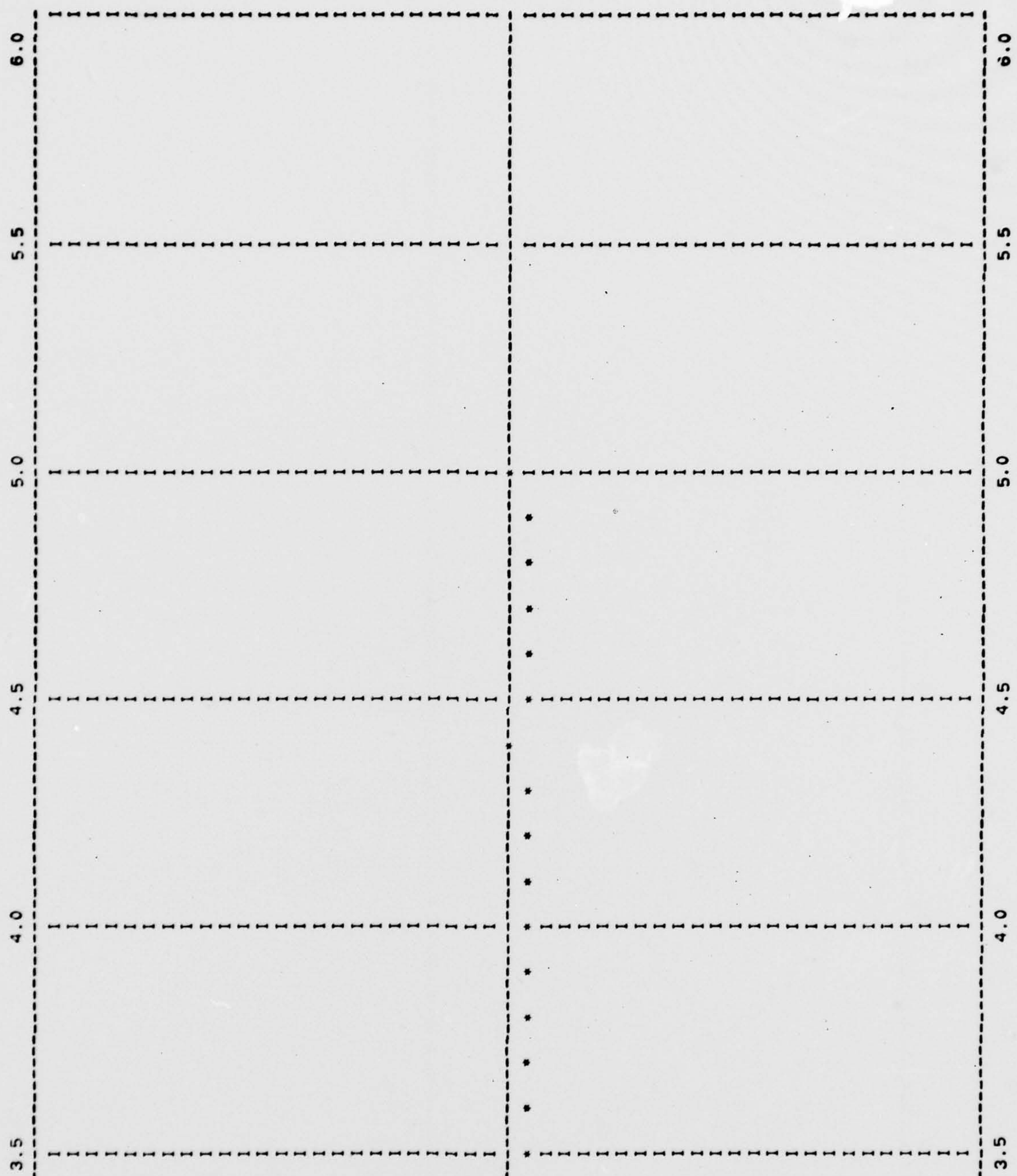




3.0
3.5
4.0
4.5
5.0
5.5
6.0
2.136
0.0
-2.136

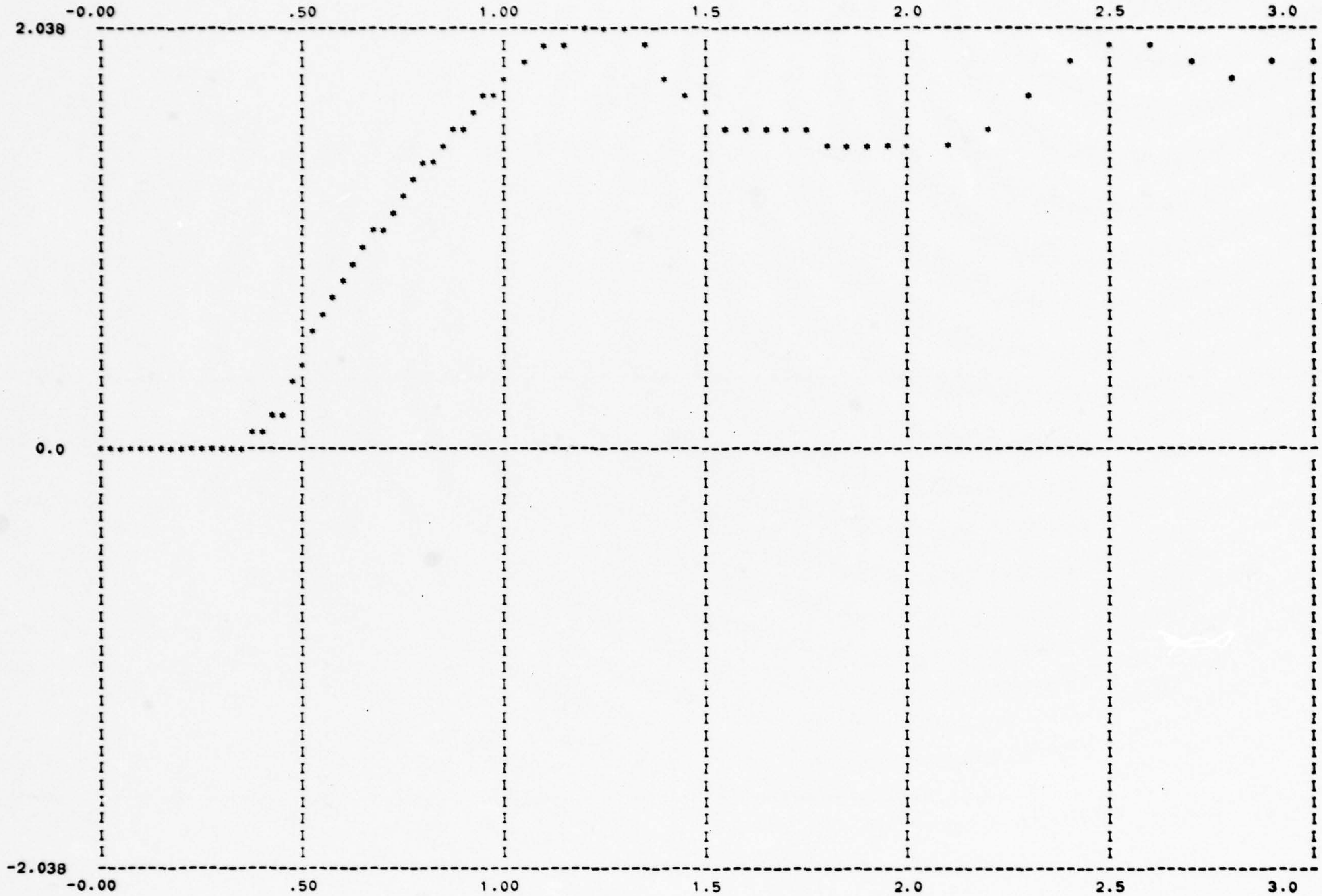
VELOCITY RESPONSE OF STRUCTURAL NODE 19, FREEDOM NUMBER 1:

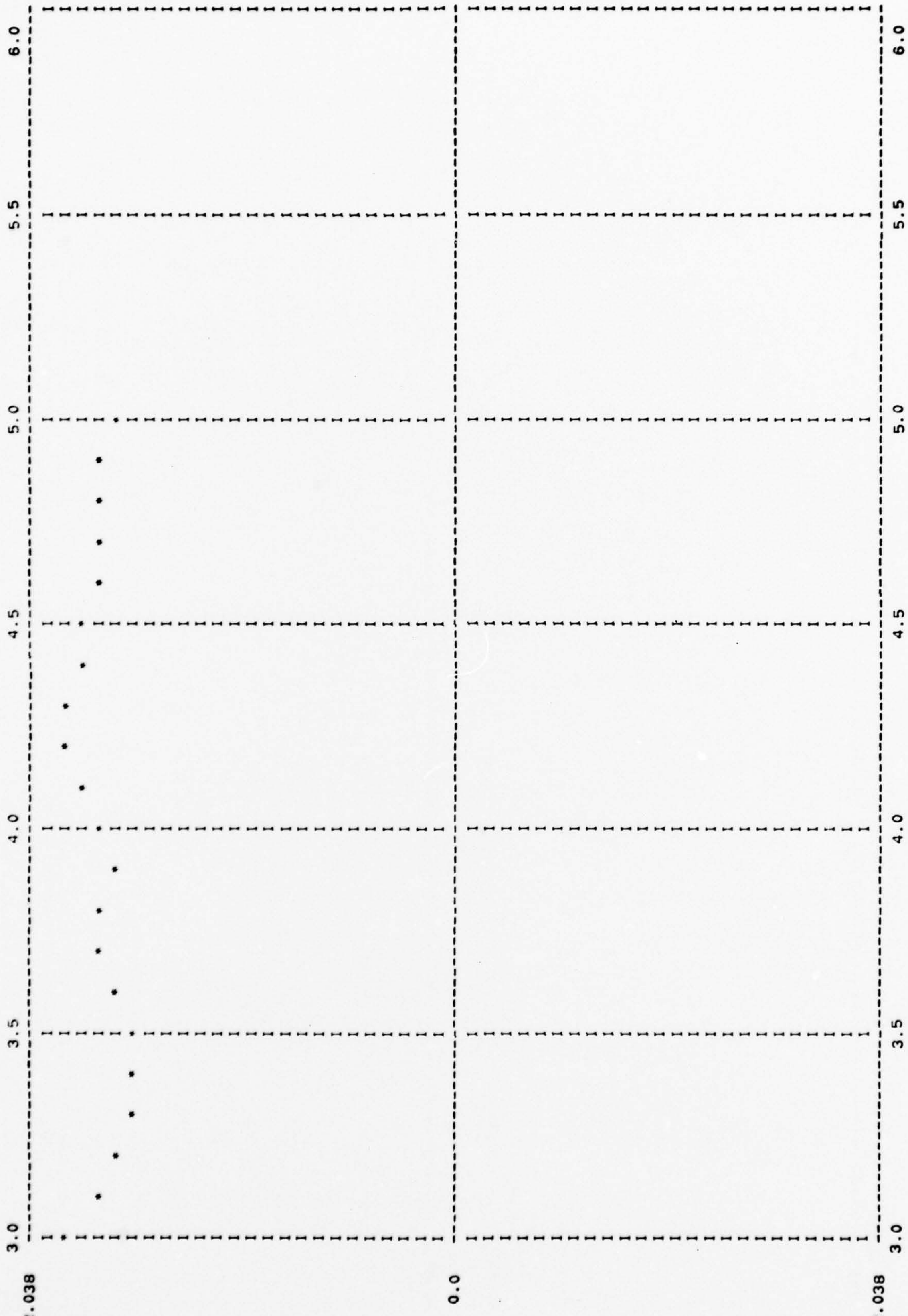


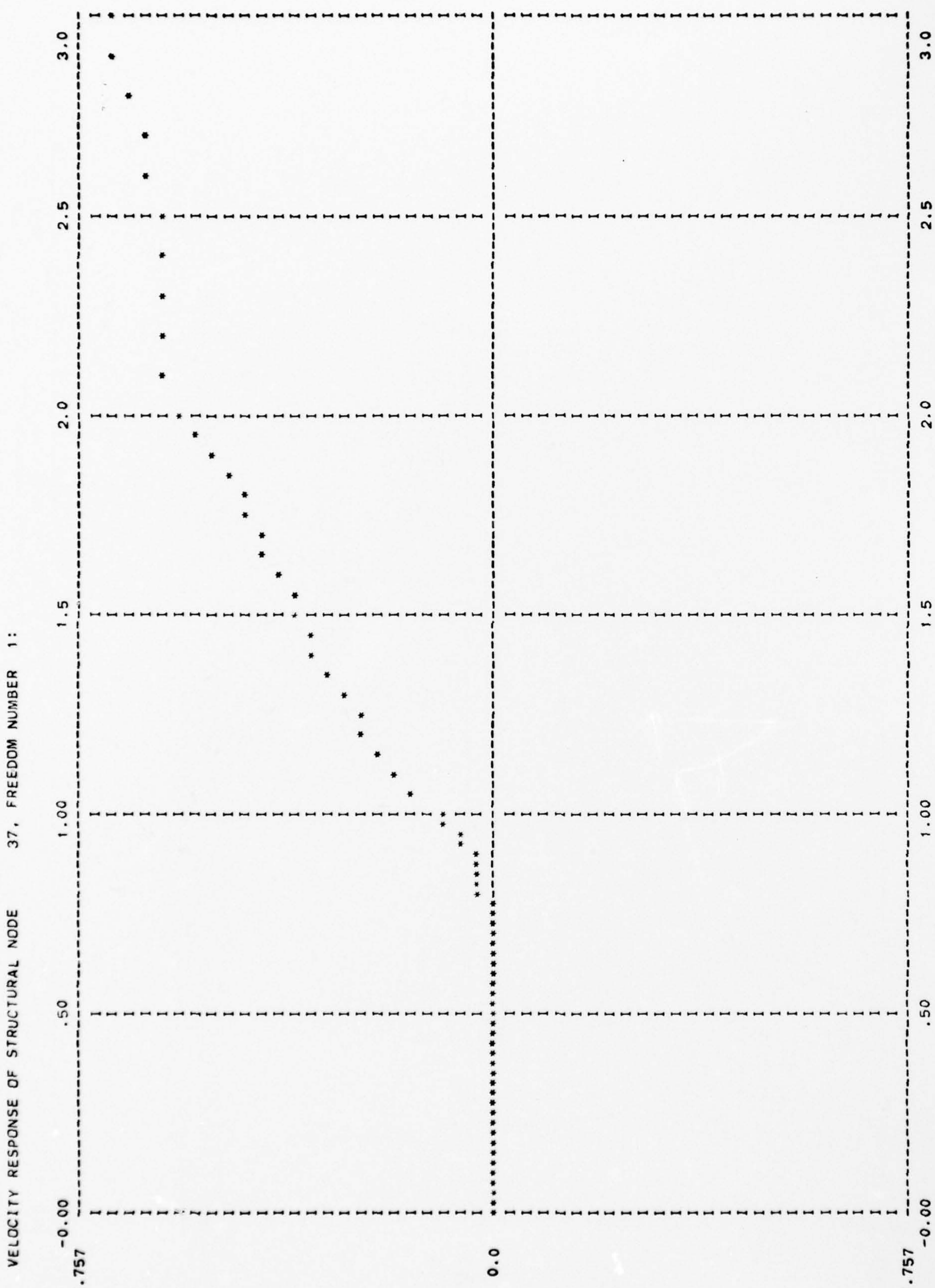


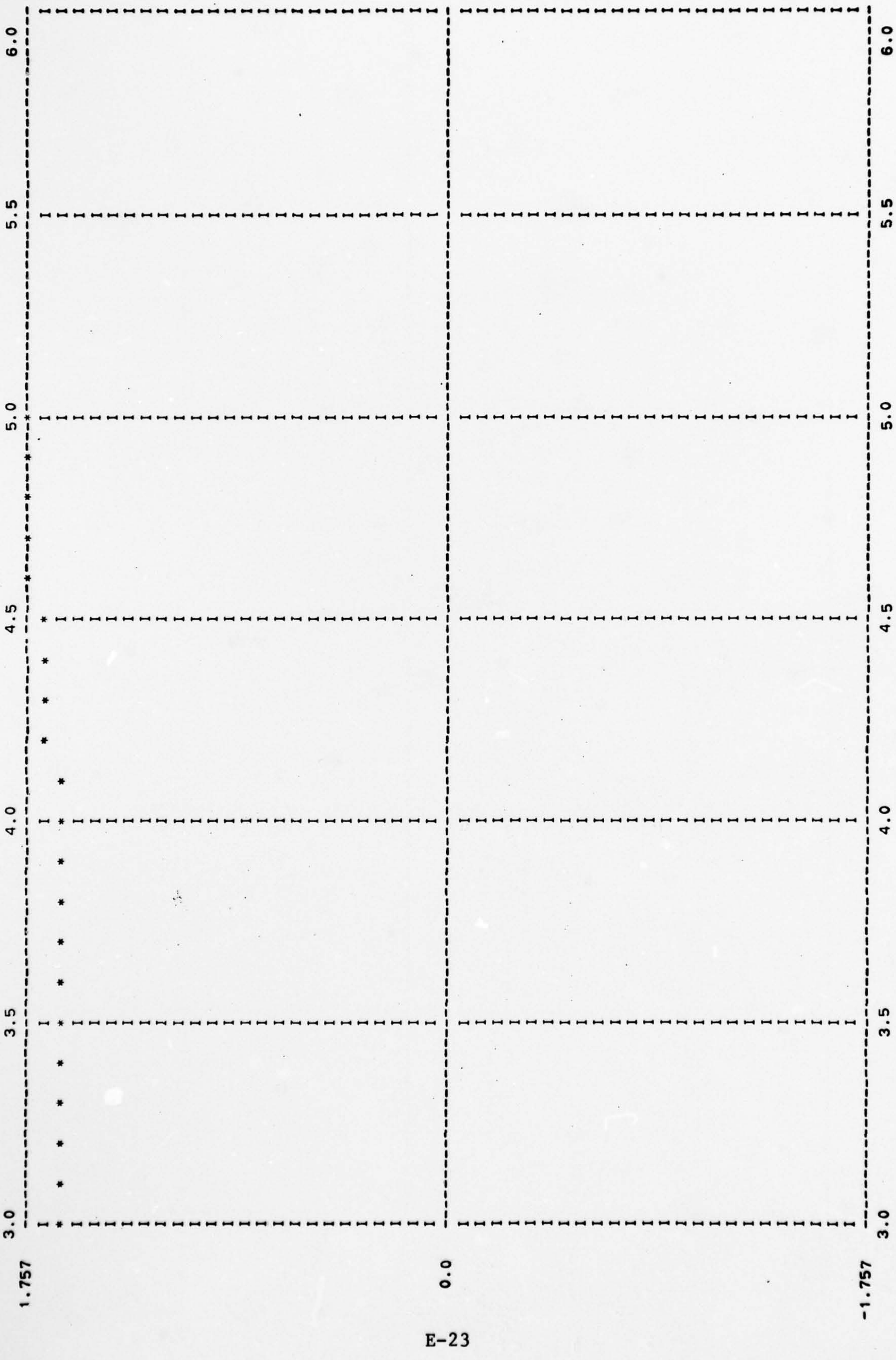
3.0
3.5
4.0
4.5
5.0
5.5
6.0
.6894
0.0
-.6894

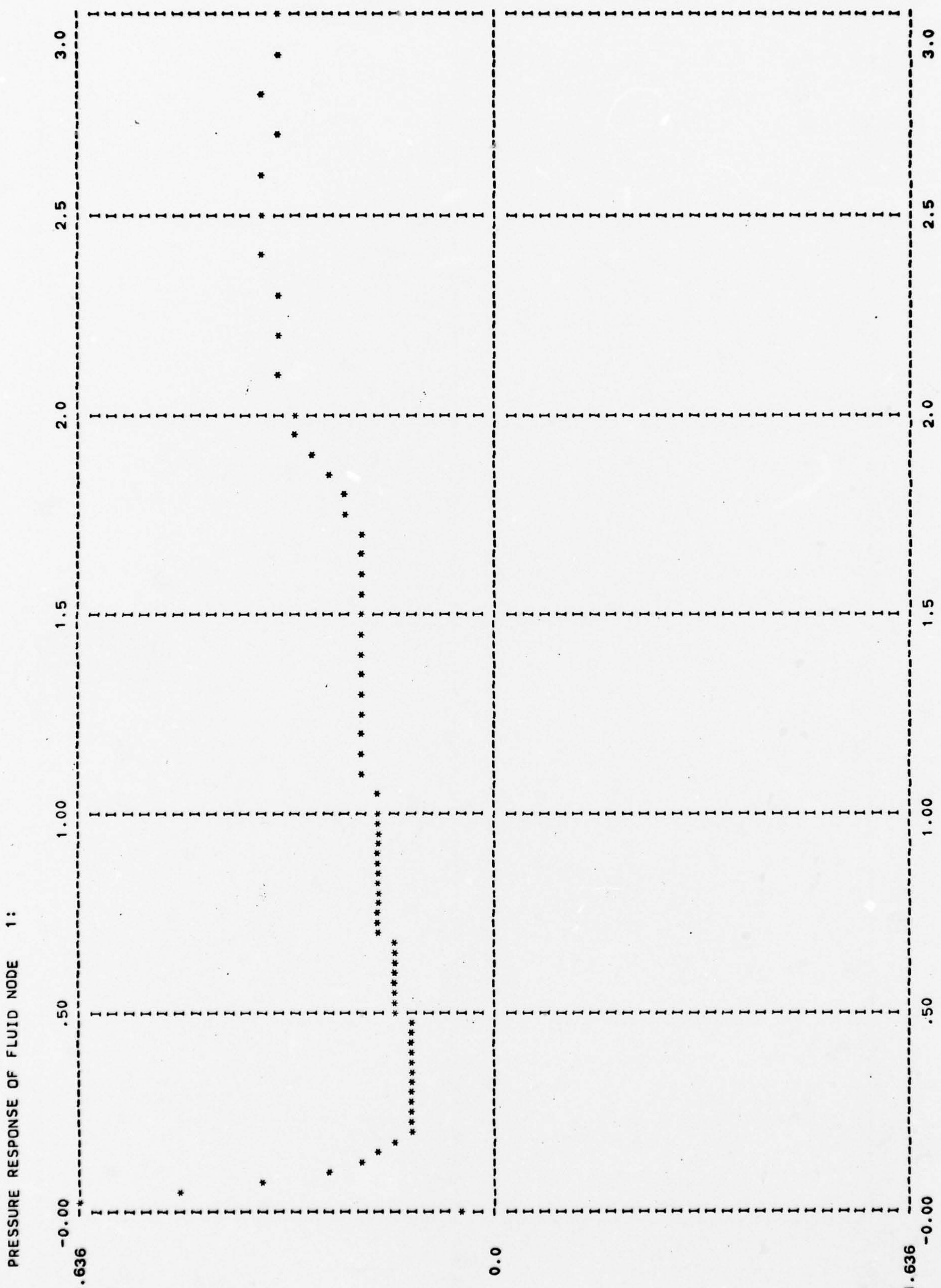
VELOCITY RESPONSE OF STRUCTURAL NODE 19, FREEDOM NUMBER 2:

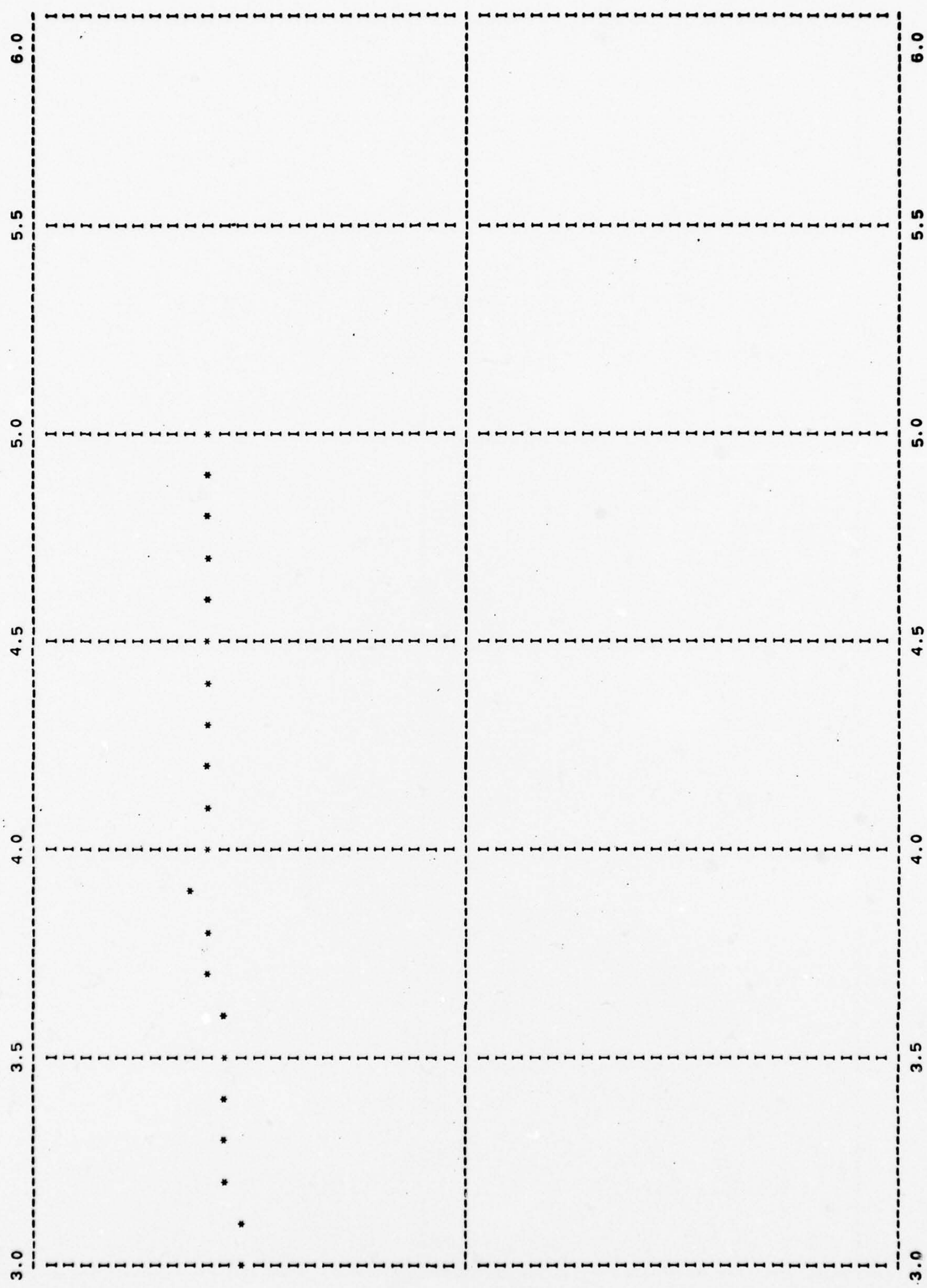



3.0
3.5
4.0
4.5
5.0
5.5
6.0
2.038
0.0
-2.038

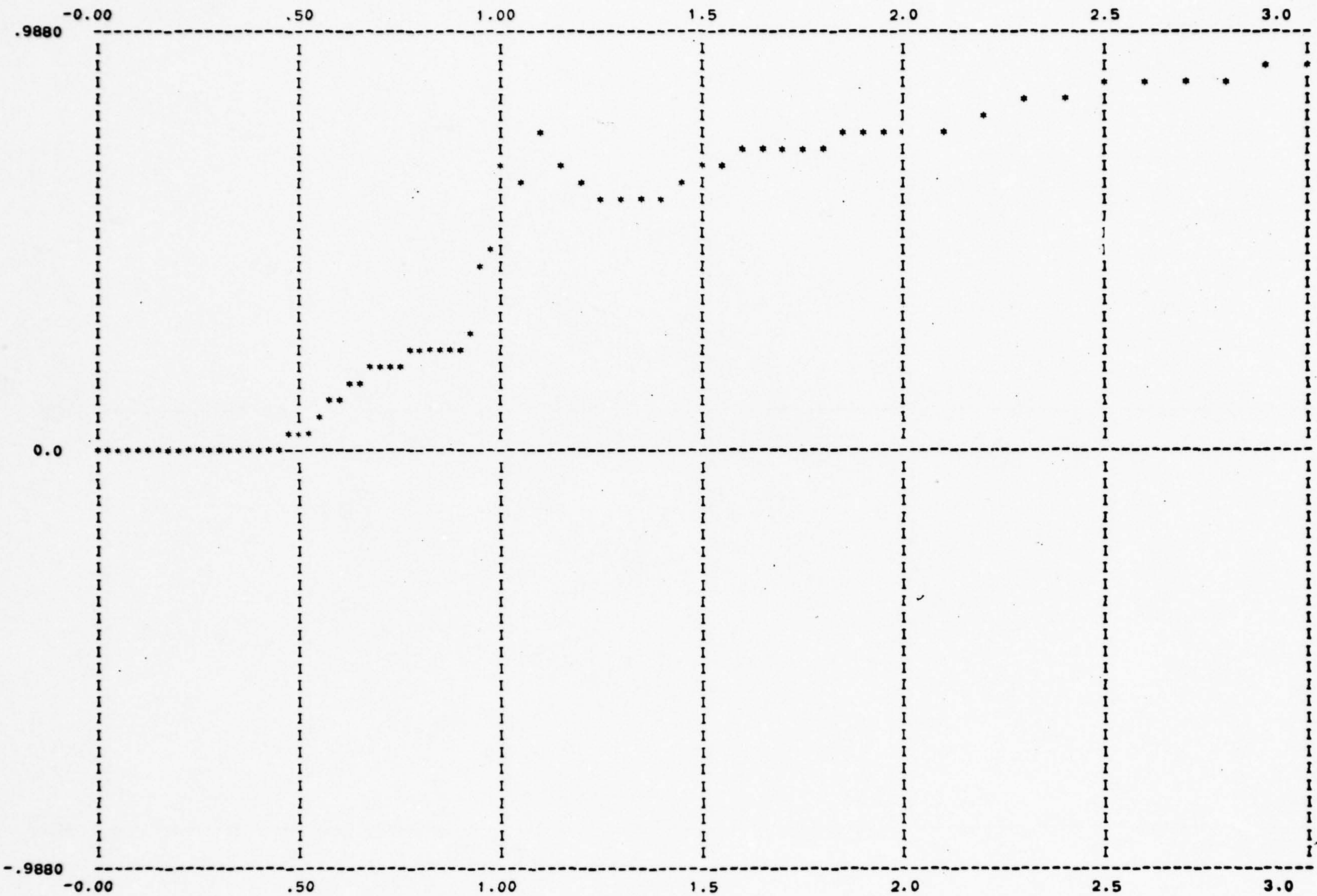

VELOCITY RESPONSE OF STRUCTURAL NODE 37, FREEDOM NUMBER 1:
-0.00
.50
1.00
1.5
2.0
2.5
3.0
1.757
0.0
-1.757

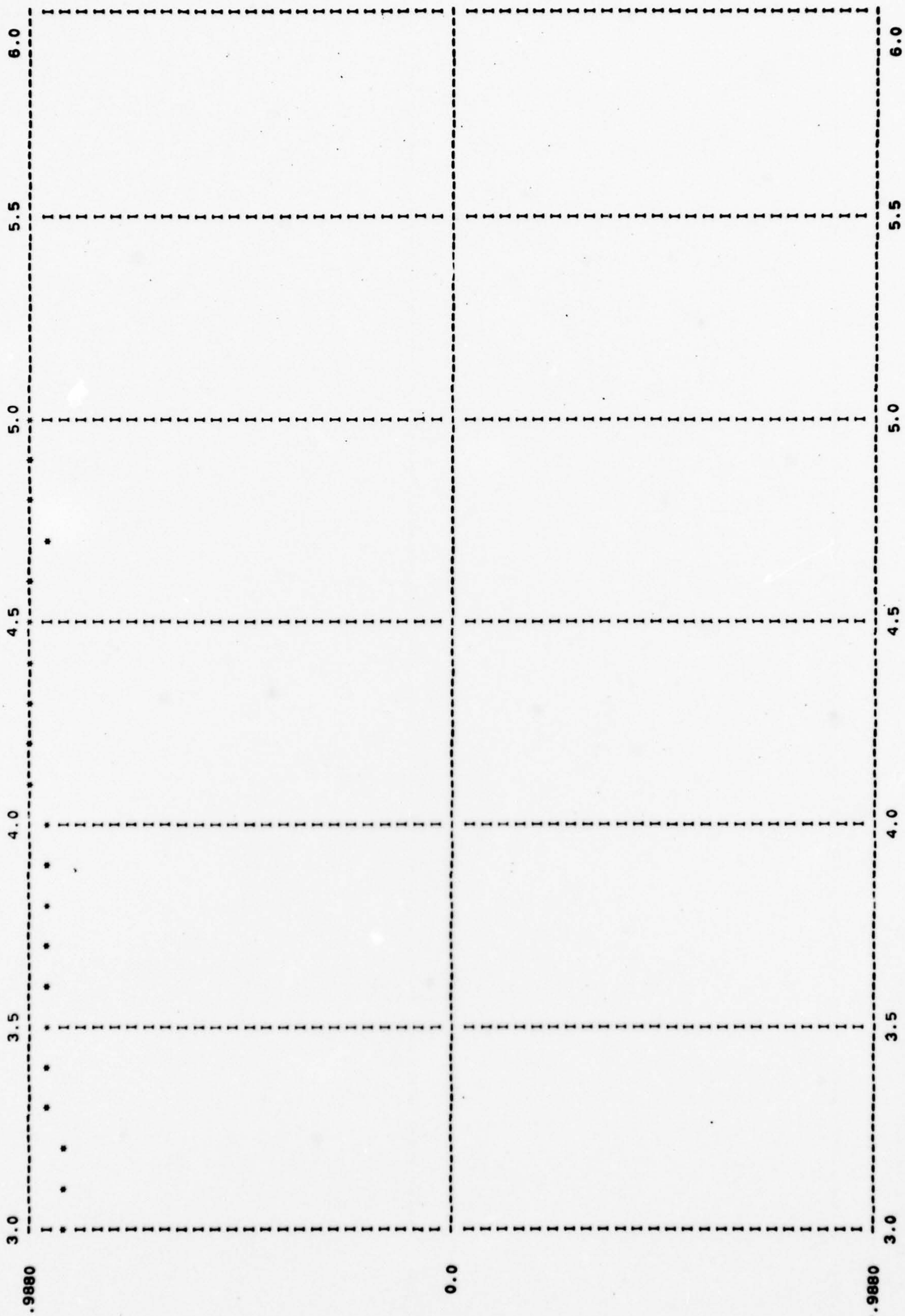

3.0
3.5
4.0
4.5
5.0
5.5
6.0
1.757
0.0
-1.757


PRESSURE RESPONSE OF FLUID NODE 1:
1.636
0.0
-1.636
-0.00
.50
1.00
1.5
2.0
2.5
3.0

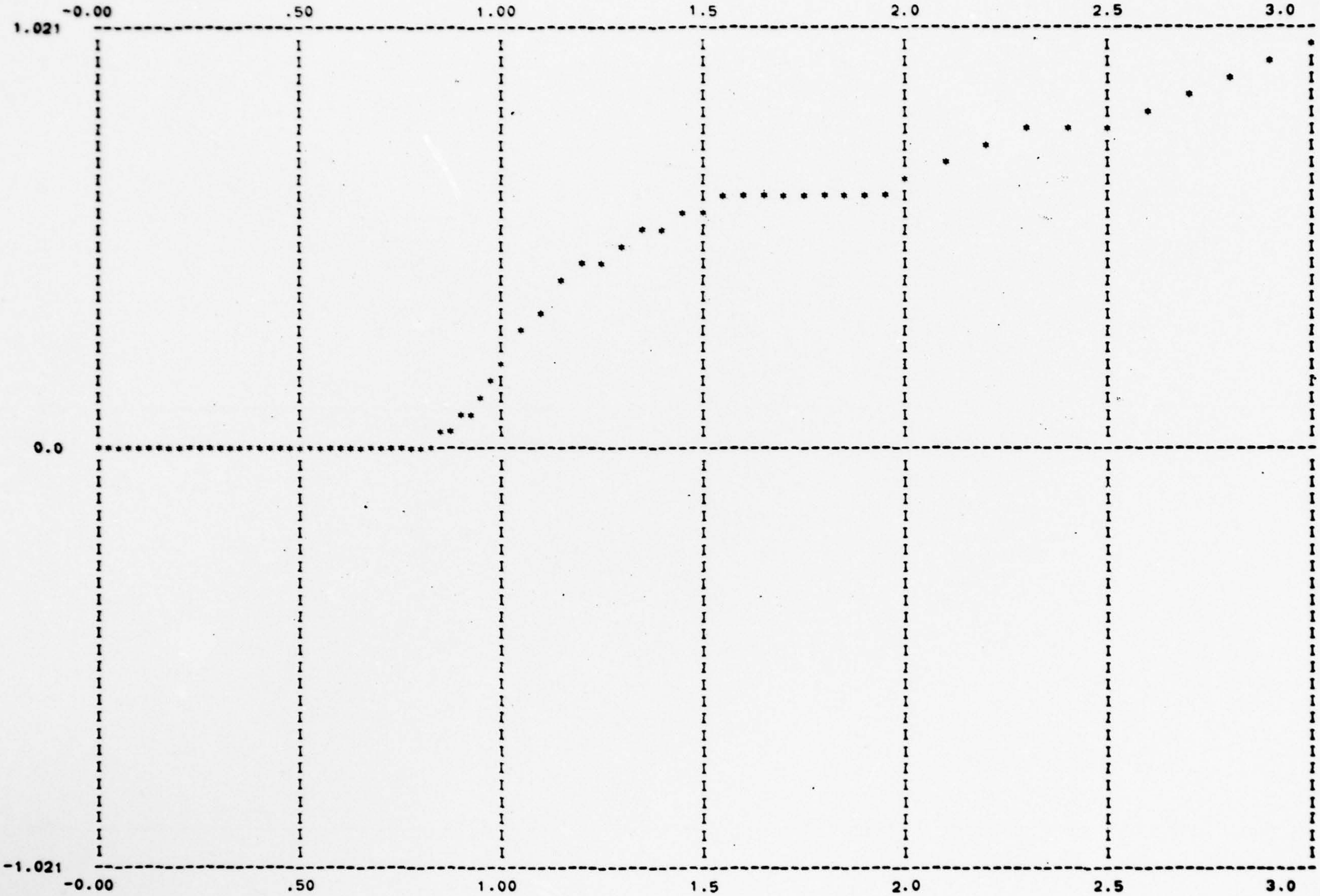

6.0
5.5
5.0
4.5
4.0
3.5
3.0
1.636
0.0
-1.636

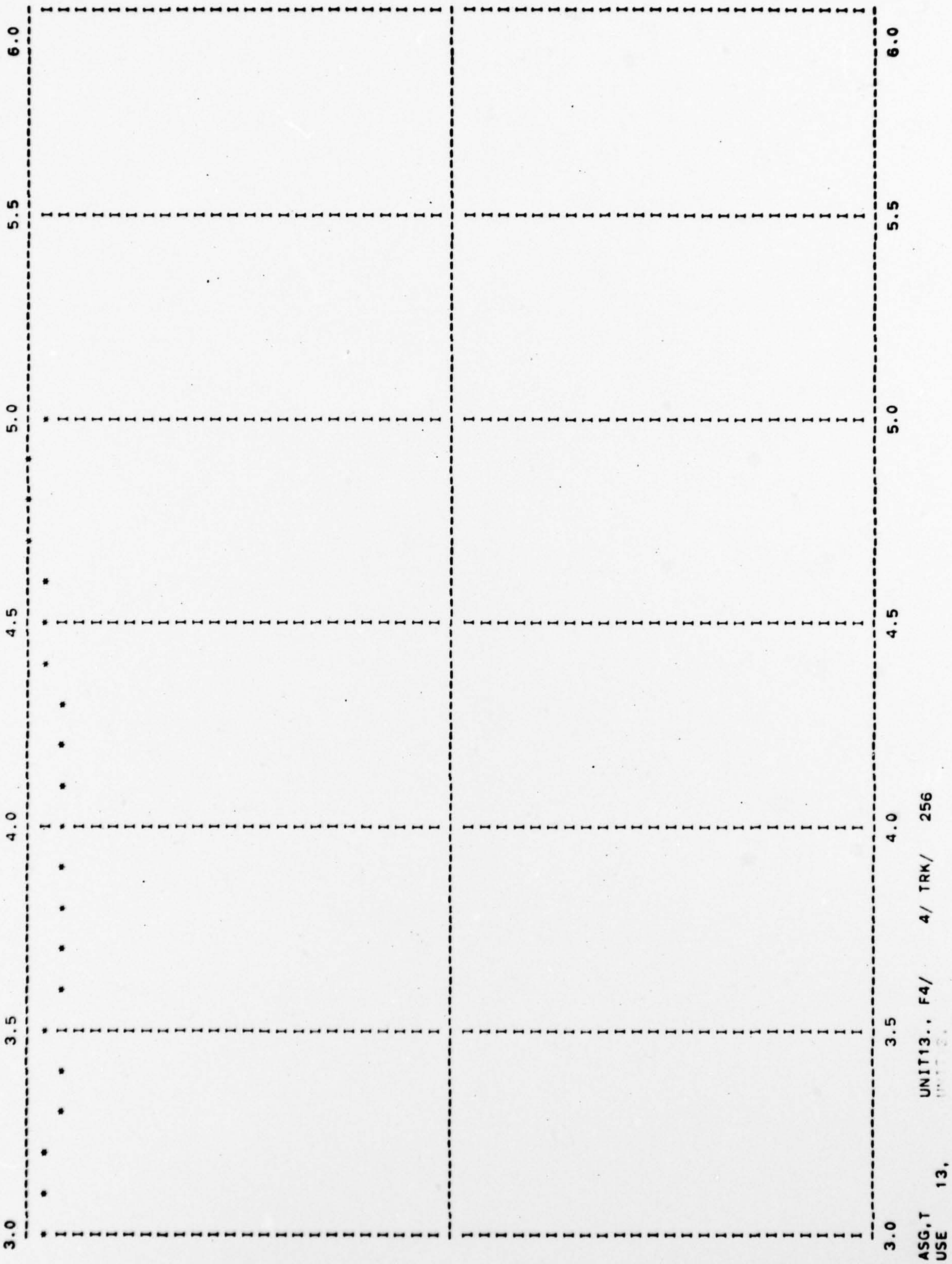
PRESSURE RESPONSE OF FLUID NODE 10:




3.0
3.5
4.0
4.5
5.0
5.5
6.0
.9880
0.0
-.9880

PRESSURE RESPONSE OF FLUID NODE 19:





3.0
3.5
4.0
4.5
5.0
5.5
6.0
1.021
0.0
-1.021
+++ @ ASG,T UNIT13., F4/ 4/ TRK/ 256
+++ @ USE 13,

+++ ● FREE UNIT13.

PSEUDO-VELOCITY SHOCK SPECTRA:

	1	2	3	4	5	6	7	8	9	10
	.00000	.25000-01	.50000-01	.75000-01	.10000+00	.12500+00	.15000+00	.17500+00	.20000+00	.22500+00
1/1	.00000	.13014+01	.18344+01	.19197+01	.19774+01	.20305+01	.21886+01	.22251+01	.22209+01	.22064+01
19/1	.00000	.42646-01	.84839-01	.12613+00	.16609+00	.20429+00	.26137+00	.32711+00	.39992+00	.49659+00
19/2	.00000	.10901+01	.16846+01	.16952+01	.17332+01	.16892+01	.16142+01	.16533+01	.16951+01	.17248+01
37/1	.00000	.84302+00	.14346+01	.16052+01	.15292+01	.14698+01	.14013+01	.13251+01	.12529+01	.11983+01

	11	12	13	14	15	16	17	18	19	20
	.25000+00	.27500+00	.30000+00	.32500+00	.35000+00	.37500+00	.40000+00	.42500+00	.45000+00	.47500+00
1/1	.22076+01	.21887+01	.21424+01	.20849+01	.20077+01	.19200+01	.19095+01	.19027+01	.18967+01	.18902+01
19/1	.57905+00	.65309+00	.72302+00	.79459+00	.86051+00	.91182+00	.95711+00	.99446+00	.10390+01	.10748+01
19/2	.17546+01	.17780+01	.17904+01	.17898+01	.17753+01	.17586+01	.18029+01	.18885+01	.19297+01	.19885+01
37/1	.11490+01	.10963+01	.10394+01	.98378+00	.92907+00	.87375+00	.82580+00	.78668+00	.75383+00	.72507+00

	21	22	23	24	25	26	27	28	29	30
	.50000+00	.52500+00	.55000+00	.57500+00	.60000+00	.62500+00	.65000+00	.67500+00	.70000+00	.72500+00
1/1	.18835+01	.18772+01	.18709+01	.18645+01	.18571+01	.18496+01	.18440+01	.19723+01	.20882+01	.21073+01
19/1	.11012+01	.11305+01	.11575+01	.11675+01	.11599+01	.11747+01	.11593+01	.11619+01	.11530+01	.11495+01
19/2	.21126+01	.22619+01	.24620+01	.26596+01	.27382+01	.27053+01	.26852+01	.25425+01	.23028+01	.20715+01
37/1	.69944+00	.67562+00	.65309+00	.63425+00	.61466+00	.59839+00	.58112+00	.56750+00	.55211+00	.53961+00

	31	32	33	34	35	36	37	38	39	40
	.75000+00	.77500+00	.80000+00	.82500+00	.85000+00	.87500+00	.90000+00	.92500+00	.95000+00	.97500+00
1/1	.21711+01	.21366+01	.21064+01	.20922+01	.20138+01	.20158+01	.19031+01	.18830+01	.18247+01	.17736+01
19/1	.11434+01	.11451+01	.11518+01	.11564+01	.11506+01	.11504+01	.11510+01	.11429+01	.11264+01	.11259+01
19/2	.18421+01	.16585+01	.14813+01	.13504+01	.12829+01	.11949+01	.11163+01	.10808+01	.10630+01	.10429+01
37/1	.52770+00	.51454+00	.50361+00	.49422+00	.48392+00	.47276+00	.46455+00	.45731+00	.44942+00	.44088+00

	41	42	43	44	45	46	47	48	49	50
	.10000+01	.10250+01	.10500+01	.10750+01	.11000+01	.11250+01	.11500+01	.11750+01	.12000+01	.12250+01
1/1	.17451+01	.17379+01	.17249+01	.17158+01	.17072+01	.17023+01	.16951+01	.16858+01	.16742+01	.16798+01
19/1	.11194+01	.11063+01	.10869+01	.10728+01	.10651+01	.10757+01	.11138+01	.11078+01	.10812+01	.11177+01
19/2	.10273+01	.10099+01	.99269+00	.97822+00	.96218+00	.94684+00	.93399+00	.91986+00	.90508+00	.89430+00
37/1	.43170+00	.42636+00	.44755+00	.48110+00	.49497+00	.53597+00	.53319+00	.53282+00	.54147+00	.50232+00

	51	52	53	54	55	56	57	58	59	60
	.12500+01	.12750+01	.13000+01	.13250+01	.13500+01	.13750+01	.14000+01	.14250+01	.14500+01	.14750+01
1/1	.17505+01	.18412+01	.18527+01	.18375+01	.18510+01	.18279+01	.17660+01	.17392+01	.17000+01	.16934+01
19/1	.10651+01	.10064+01	.10030+01	.97805+00	.95344+00	.92307+00	.88025+00	.84340+00	.85533+00	.83648+00
19/2	.88246+00	.86960+00	.85768+00	.84835+00	.83819+00	.82722+00	.81548+00	.80688+00	.79877+00	.79001+00
37/1	.50696+00	.46752+00	.43867+00	.40775+00	.37769+00	.36234+00	.35386+00	.34400+00	.34035+00	.33630+00

	61	62	63	64	65	66	67	68	69	70
	.15000+01	.15250+01	.15500+01	.15750+01	.16000+01	.16250+01	.16500+01	.16750+01	.17000+01	.17250+01
1/1	.16390+01	.16210+01	.15990+01	.15673+01	.15628+01	.15572+01	.15507+01	.15431+01	.15345+01	.15249+01
19/1	.79135+00	.77641+00	.76106+00	.74546+00	.72977+00	.71412+00	.69861+00	.68334+00	.66839+00	.65382+00
19/2	.78064+00	.87869+00	.10789+01	.13343+01	.14083+01	.16471+01	.16841+01	.16272+01	.16961+01	.14589+01
37/1	.33188+00	.32709+00	.32194+00	.31647+00	.31068+00	.30461+00	.29827+00	.29502+00	.29182+00	.28839+00

	71	72	73	74	75	76	77	78	79	80
	.17500+01	.17750+01	.18000+01	.18250+01	.18500+01	.18750+01	.19000+01	.19250+01	.19500+01	.19750+01
1/1	.15786+01	.16681+01	.16702+01	.16511+01	.16675+01	.16171+01	.15754+01	.15579+01	.14862+01	.14629+01
19/1	.63966+00	.63128+00	.62454+00	.61810+00	.61200+00	.60625+00	.60086+00	.59583+00	.59115+00	.58680+00
19/2	.13985+01	.13197+01	.12954+01	.11722+01	.10146+01	.97377+00	.89731+00	.79299+00	.67025+00	.63994+00
37/1	.28474+00	.28089+00	.27688+00	.27271+00	.26842+00	.26403+00	.25956+00	.25503+00	.25046+00	.24588+00

	81	82	83	84	85	86	87	88	89	90
	.20000+01	.20250+01	.20500+01	.20750+01	.21000+01	.21250+01	.21500+01	.21750+01	.22000+01	.22250+01
1/1	.14544+01	.14452+01	.14352+01	.14246+01	.14217+01	.14191+01	.14160+01	.14124+01	.14083+01	.14037+01
19/1	.58276+00	.57900+00	.57547+00	.57215+00	.56899+00	.56594+00	.56296+00	.56000+00	.55701+00	.55393+00
19/2	.62441+00	.61714+00	.61198+00	.60661+00	.60106+00	.59532+00	.58940+00	.58332+00	.57708+00	.57070+00
37/1	.24130+00	.23674+00	.23222+00	.22775+00	.22333+00	.21898+00	.21471+00	.21538+00	.20954+00	.21449+00

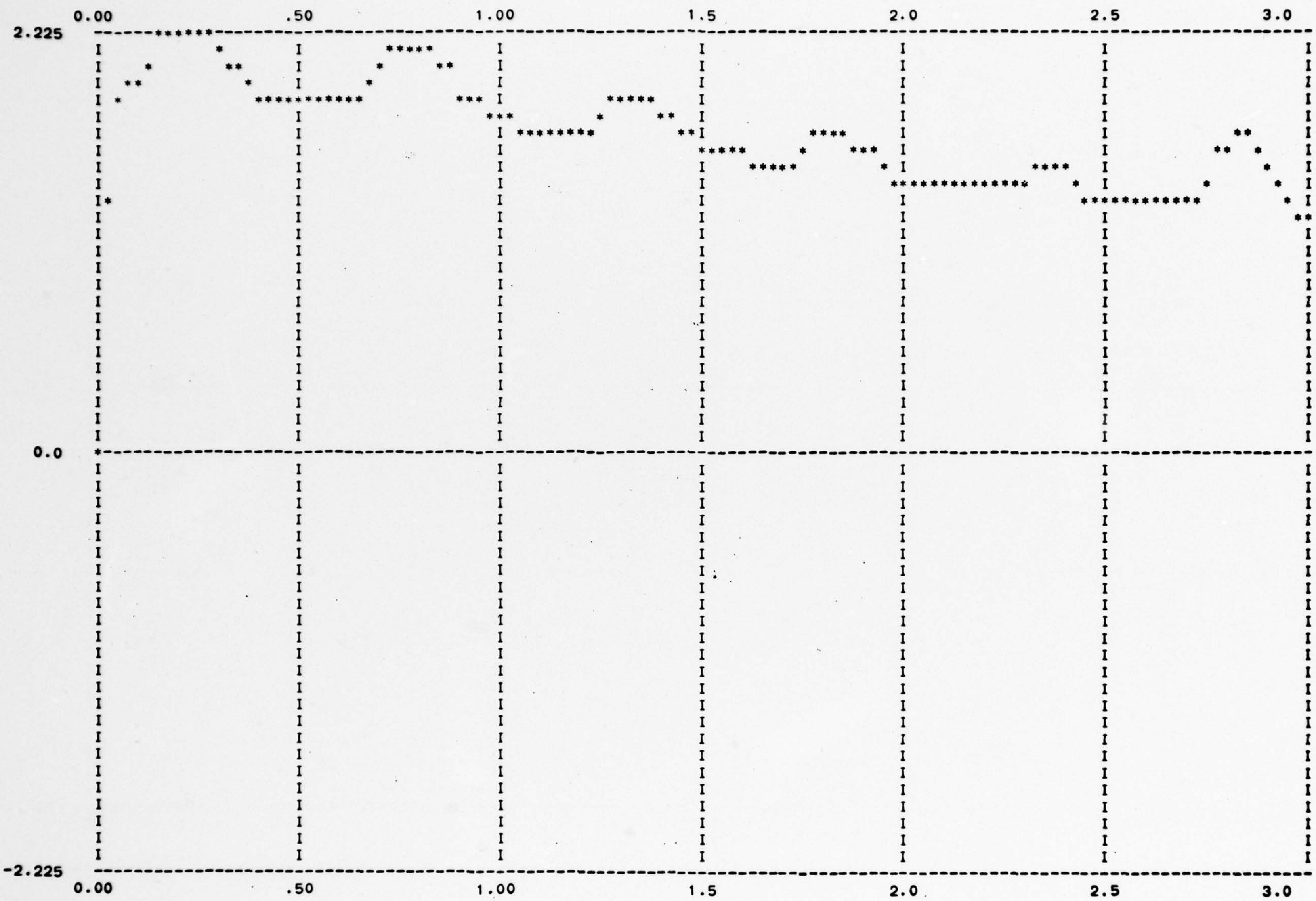
	91	92	93	94	95	96	97	98	99	100
	.22500+01	.22750+01	.23000+01	.23250+01	.23500+01	.23750+01	.24000+01	.24250+01	.24500+01	.24750+01
1/1	.13986+01	.13976+01	.14629+01	.15070+01	.15447+01	.15356+01	.15199+01	.14579+01	.13403+01	.13309+01
19/1	.55073+00	.54735+00	.54374+00	.53985+00	.53565+00	.53108+00	.52610+00	.52068+00	.51986+00	.52220+00
19/2	.56417+00	.55750+00	.55072+00	.54382+00	.53680+00	.52977+00	.52537+00	.52086+00	.60781+00	.67320+00
37/1	.21652+00	.22477+00	.25016+00	.26635+00	.27196+00	.26633+00	.26580+00	.31912+00	.30518+00	.29343+00

	101	102	103	104	105	106	107	108	109	110
	.25000+01	.25250+01	.25500+01	.25750+01	.26000+01	.26250+01	.26500+01	.26750+01	.27000+01	.27250+01
1/1	.13217+01	.13316+01	.13180+01	.13157+01	.13146+01	.13100+01	.13067+01	.13031+01	.12991+01	.12964+01
19/1	.52435+00	.52628+00	.52794+00	.52930+00	.53032+00	.53095+00	.53118+00	.53096+00	.53026+00	.52906+00
19/2	.62558+00	.55560+00	.62221+00	.58126+00	.59594+00	.62188+00	.63133+00	.62350+00	.59845+00	.61271+00
37/1	.34239+00	.33017+00	.31349+00	.30253+00	.29094+00	.29785+00	.30171+00	.29524+00	.28251+00	.26966+00

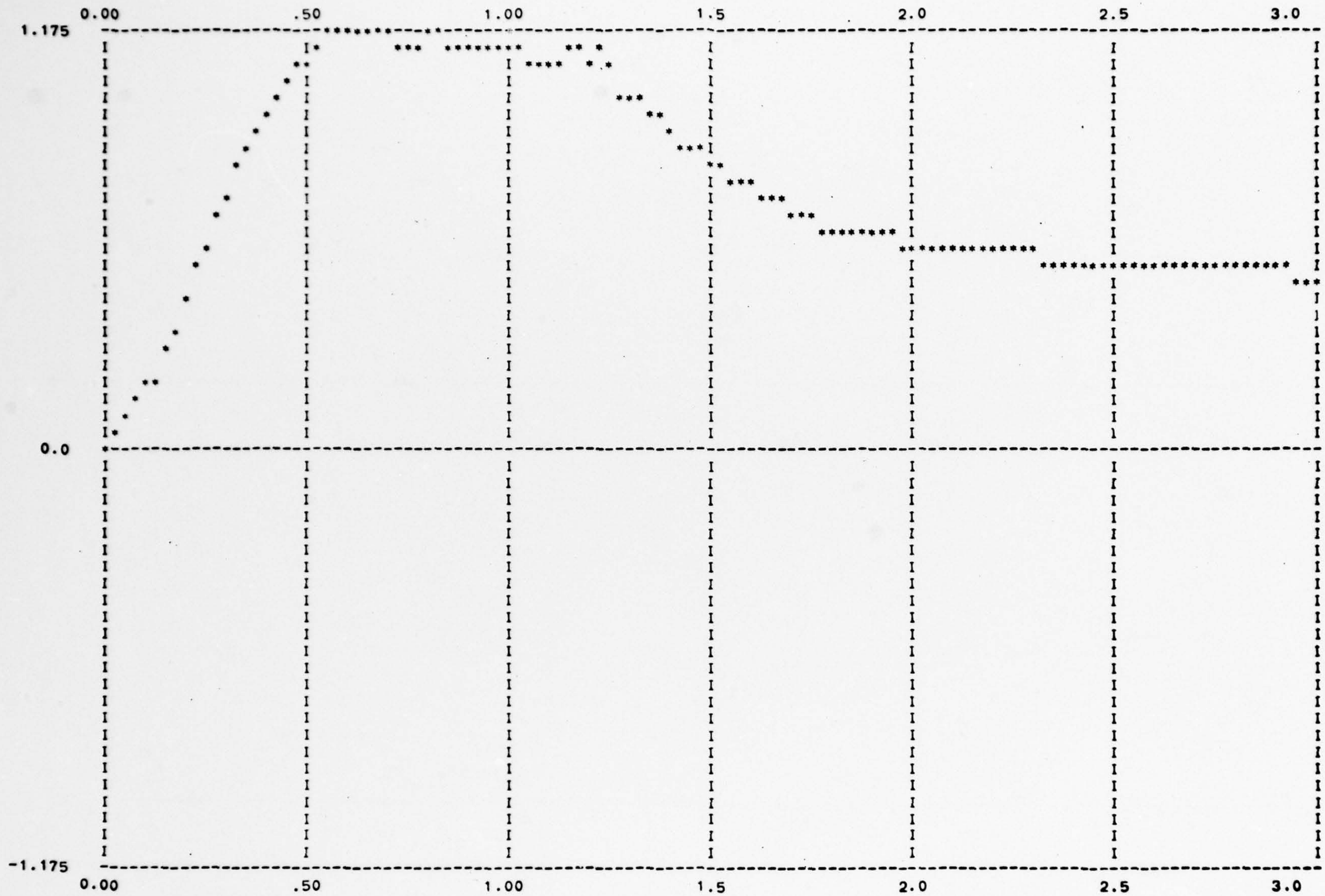
	111	112	113	114	115	116	117	118	119	120
	.27500+01	.27750+01	.28000+01	.28250+01	.28500+01	.28750+01	.29000+01	.29250+01	.29500+01	.29750+01
1/1	.14662+01	.15600+01	.16309+01	.16700+01	.16998+01	.16102+01	.15540+01	.14413+01	.13010+01	.12356+01
19/1	.52734+00	.52508+00	.52225+00	.51884+00	.51486+00	.51028+00	.50512+00	.49938+00	.49307+00	.48620+00
19/2	.62470+00	.67364+00	.78839+00	.90180+00	.88474+00	.94333+00	.93318+00	.96958+00	.94031+00	.94437+00
37/1	.25886+00	.26088+00	.25964+00	.27704+00	.27359+00	.25928+00	.24275+00	.25174+00	.23984+00	.24993+00

	121
	.30000+01
1/1	.12281+01
19/1	.47879+00
19/2	.97503+00
37/1	.25167+00

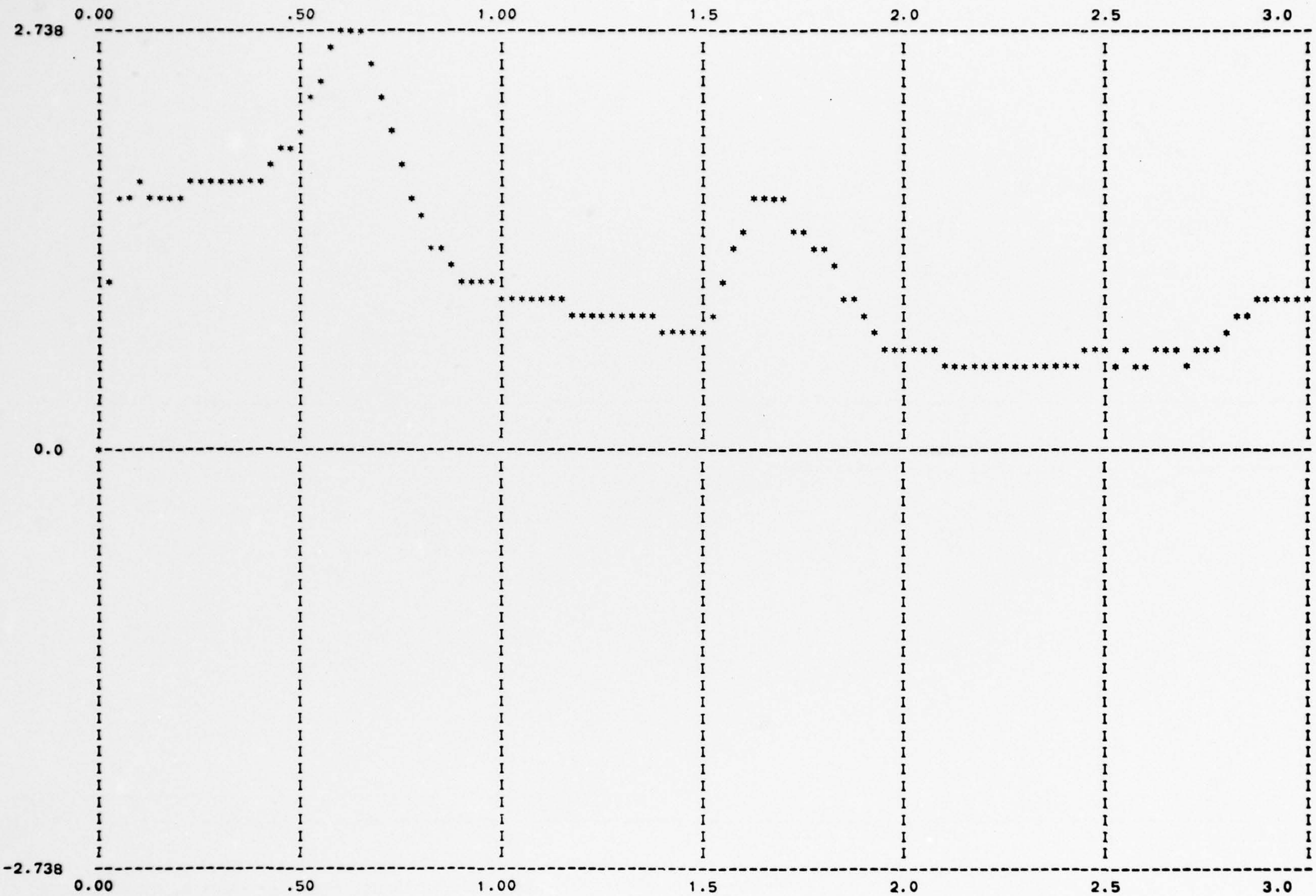
PSEUDO-VELOCITY SHOCK SPECTRUM FOR STRUCTURAL NODE 1, FREEDOM NUMBER 1:



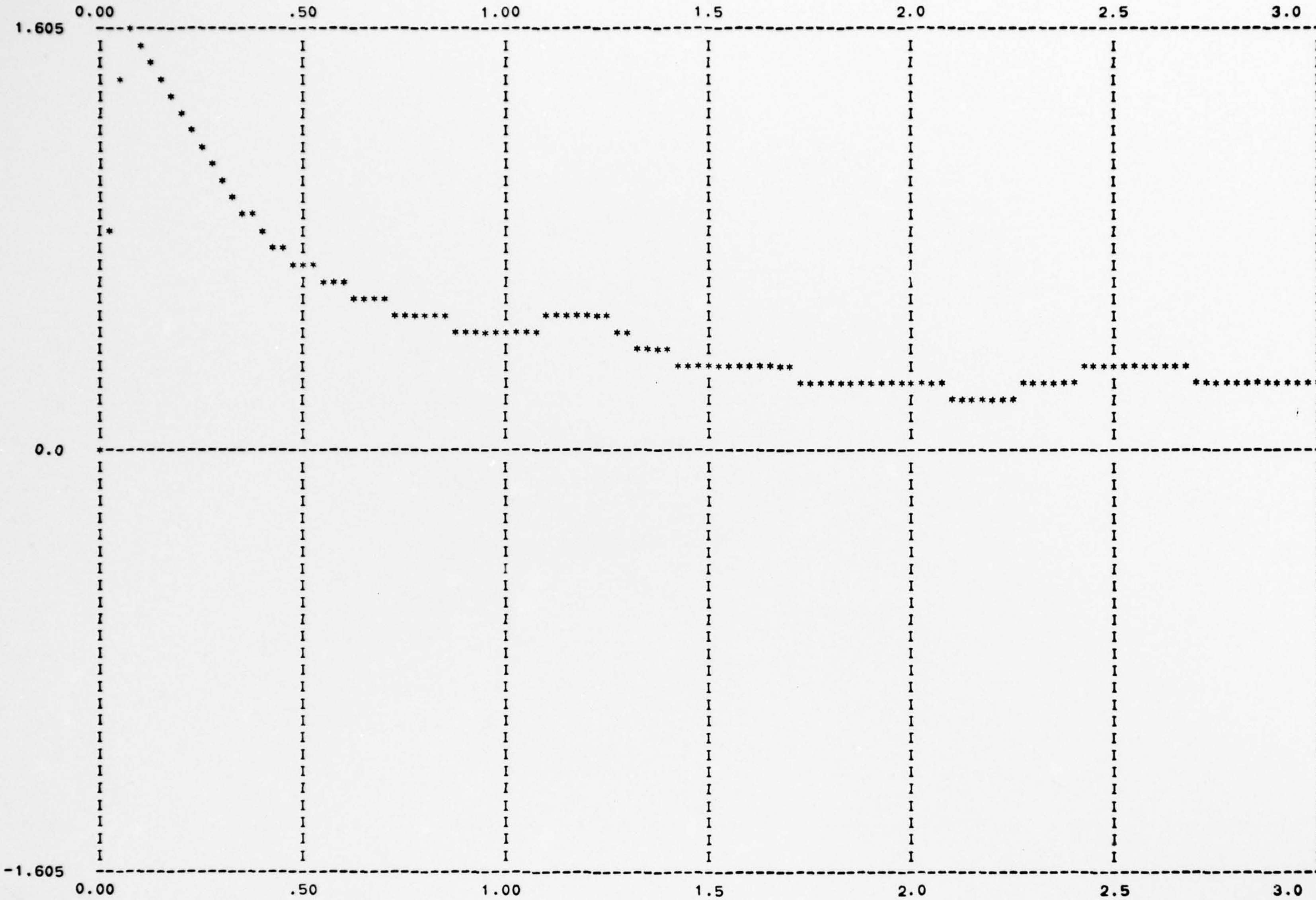
PSEUDO-VELOCITY SHOCK SPECTRUM FOR STRUCTURAL NODE 19, FREEDOM NUMBER 1:



PSEUDO-VELOCITY SHOCK SPECTRUM FOR STRUCTURAL NODE 19, FREEDOM NUMBER 2:



PSEUDO-VELOCITY SHOCK SPECTRUM FOR STRUCTURAL NODE 37, FREEDOM NUMBER 1:



+++ @ FREE CYL*RESPON.

APPENDIX F

USER INSTRUCTIONS FOR INTERFACING WITH USA

To use the Underwater Shock Analysis (USA) Code in its linear stand-alone mode, the user must first construct a permanent data file that contains the structural mass and stiffness matrices and some assorted bookkeeping information. The purpose of this appendix is to describe the structure of the file and to specify how it is to be created. At this time utility routines that carry out this task have been written for SPAR and NASTRAN. An abbreviated form of this file is also required when USA is coupled with a nonlinear structural analyzer and such an interface also exists for STAGS.

USA contains the data management utility module DMGASP that carries out all data transfer activities between core and peripheral storage. This is done by unformatted and unbuffered data transmissions and it is imperative that DMGASP be used to create the structural interface file. Otherwise the user must supply or have access to a similar means of direct transfer. Section 3 of [10] contains a comprehensive discussion of the half-dozen or so DMGASP commands that are required to activate, position, write upon, read from, and free a peripheral storage device. Subsidiary commands also exist for error handling and listing of selected information pertaining to auxiliary storage.

The current configuration of USA uses a diagonal mass matrix associated with a lumped mass representation of the structure, assumes that there is no velocity dependent structural damping, and further, only, single precision matrices may be processed. In addition, if the stiffness matrix has been reordered or reduced in any way for input to USA the mass matrix must also be reordered or condensed so that its degrees of freedom (DOF) are the same and appear in the same order as in the stiffenss matrix. Finally, the stiffness matrix must be placed in a multi-block* skyline format as discussed in [13]. This description consists of a Matrix Master Record (MMR) followed by a series of Matrix Value Records (MVR) which contain the numerical values of the matrix. These are the only constructs the user need be concerned with; all others required are already embedded in USA. During construction of the MMR a logical device index (LDI) must be set in the record which USA will access later. For UNIVAC operation, this should be set equal to twenty (20), while for CDC operation this should be set as two (2).

The file structure required is shown in Table F-1 where NDOF stands for the number of structural DOF which USA must process. NMMR is the number of words in the matrix master record, and NWBL is the number of words in each matrix value record (which is expected to be the same for each record). NWBL should also be an integer multiple of 448 for most efficient use of storage.

* For small problems a single block is permissible.

Table F-1

Record	Number of Words	Data
1	1	NDOF
2	NDOF	Diagonal Mass Matrix
3	1	NDOF
4	NDOF	Grid Point/DOF Vector
5	1	NMMR
6	NMMR	Matrix Master Record for Stiffness Matrix
7	NWBL	First Matrix Value Record for Stiffness Matrix
.	NWBL	Second Matrix Value Record for Stiffness Matrix
.	.	
.	NWBL	Last Matrix Value Record for Stiffness Matrix

The Grid Point/DOF vector consists of an integer value for each global DOF from 1 through NDOF that is constructed as ten times the external node number plus the local DOF number that apply to that particular structural equation.

For example, if the 87th DOF to appear in the mass and stiffness matrices corresponds to the second degree of freedom at a node identified externally as 4637 then the 87th entry in the Grid Point/DOF vector would be 46372. Local translational degrees of freedom should be numbered 1-3, rotational degrees of freedom should be numbered from 4-6 and any others should be numbered with 7-9. If more than 9 degrees of freedom are carried at any node it is a simple matter to change the factor of ten to one hundred in a few places in USA to accommodate this.

It should be noted that records 1-4 are accessed by the USA pre-processor AUGMAT before the time integration phase of the analysis commences. This portion of the file is required for both USA in the linear stand-alone mode, and for USA when it is interfaced with a nonlinear structural analyzer. In this latter case, the fifth and succeeding records do not exist.

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