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STRUCTURAL MATERIALS & DEVELOPMENT

ADVANCED COMPOSITES TECHNOLOGY

ANISOTROPIC CURVED PANEL ANALYSIS

D. J. Wilkins

Advanced Composites Division
Air Force Materials Laboratory
Wright-Patterson Air Force Base, Ohio

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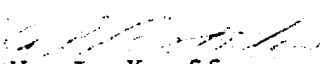
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15 May 1973

ANISOTROPIC CURVED PANEL ANALYSIS

Prepared by

Dr. D. J. Wilkins

Prepared for

Advanced Composites Division
Air Force Materials Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

GENERAL DYNAMICS
Convair Aerospace Division
Fort Worth Operation

A B S T R A C T

An analysis of laminated-composite cylindrically curved shells has been formulated and incorporated into digital computer procedure SS8. Many discrete effects were considered, including ring and stringer stiffening, by implementing a Rayleigh-Ritz energy analysis. The procedure solves static deflection, buckling, and natural frequency problems.

The results of an extensive experimental program for graphite-epoxy and boron-epoxy shells are included.

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L I S T O F S Y M B O L S

$[A], [B], [D]$	Constitutive matrix terms
A	Area
A_{rk}	Ring cross-sectional area, in^2 .
$A_{s\ell}$	Stringer cross-sectional area, in^2 .
a	Mode shape constants
a, b, h	Panel dimensions in (x;y;z) directions
C_{mj}	Mode shape constants
d	Strain energy partitions defined in Equations (14) - (22)
E_1	Fiber direction elastic modulus
E_2	Transverse direction elastic modulus
E_{rk}	Ring modulus of elasticity, psi.
$E_{s\ell}$	Stringer modulus of elasticity, psi.
f	Natural frequency, Hz.
G_{12}	In-plane shear modulus
$(GJ)_{rk}$	Ring torsional stiffness, lb-in^2 .
$(GJ)_{s\ell}$	Stringer torsional stiffness, lb-in^2 .
i_x, i_y	Initial modal term in (x;y) direction
I_{xxrk}	Moment of inertia of the ring area about the mid-surface x-axis at the line of attachment, in^4 .
I_{xzrk}	Product of inertia of the ring area about the mid-surface x-z axis at the line of attachment, in^4 .
I_{zzrk}	Moment of inertia of the ring area about the z-axis at the line of attachment, in^4 .

L I S T O F S Y M B O L S (Continued)

$I_{yys\ell}$	Moment of inertia of the stringer area about the mid-surface y-axis at the line of attachment, in^4 .
$I_{zzs\ell}$	Moment of inertia of the stringer area about the z-axis at the line of attachment, in^4 .
$I_{yzs\ell}$	Product of inertia of the stringer area about the mid-surface y-z axis at the line of attachment, in^4 .
K_L	Spring constant, lb/in/in
K_P	Spring constant lb/in
K_x, K_y, K_{xy}	Curvatures
K_{xy}	Proportionality constant (Tables VI and VII)
$K_{x1}, K_{x2},$ K_{y1}, K_{y2}	Rotational spring constants, in-lb/rad/in
M_L	Line moment, in-lb/in
M_P	Point moment, in-lb
M_x, M_y, M_{xy}	Moment resultants
m	axial mode number
$\bar{m}$	Lumped mass, $\text{lb-sec}^2/\text{in}$
N_x, N_y, N_{xy}	Stress resultants
n	circumferential mode number
n_x, n_y	Number of terms in (x;y) direction
P	Coefficients defined in Eqs. (30) - (32), lb/in. ; load in ring or stringer, lb .
P	Pitch (Figure 17)
P_c	Point load, lb .

L I S T O F S Y M B O L S (Continued)

Q	Potential energy of lateral loads
q	Coefficients defined in Eq. (42)
$\bar{q}$	Distributed lateral pressure
R	Radius
S	Linear part of U_p
T	Kinetic Energy
U	Potential energy of membrane loads
U_p	Total potential energy of membrane loads
u, v, w	Displacements in (x;y;z) direction
V	Potential energy
X, Y	Mode function in (x;y) direction
x, y, z	Coordinates in axial, circumferential, and radial directions, respectively.
x_k	Ring location
$\bar{x}_{rk}$	Location of ring centroid in the x-direction with respect to its line of attachment to the shell, in.
y_l	Stringer location
$\bar{y}_{sl}$	Location of stringer centroid in the y-direction with respect to its line of attachment to the shell, in.
$\bar{z}_{rk}$	Location of ring centroid in the z-direction with respect to the middle surface of the shell at the line of attachment, in.
$\bar{z}_{sl}$	Location of stringer centroid in the z-direction with respect to the middle surface of the shell at the line of attachment, in.

L I S T O F S Y M B O L S (Continued)

α	Observation angle (Figure 17)
α_x, α_y	Constants defined by Equation (97)
β_x, β_y	Constants defined by Equation (97)
γ	Knockdown factor
δ	Distance defined in Figure 17
$\epsilon_x^0, \epsilon_y^0, \epsilon_{xy}^0$	Midsurface strain
λ	Buckling eigenvalue
ν_{12}	Major Poisson's ratio
ρ	Density
ρ_{jm}	Mode shape functions
ρ_{rk}	Average density of ring material, lb-sec ² /in ⁴ .
ρ_{sl}	Average density of stringer material, lb-sec ² /in ⁴ .
τ	Time; shear stress
ϕ	Integrals defined by Equation (105)
ψ	Integrals defined by Equation (102)
Ω	Integrals defined by Equation (104)
ω	Circular frequency

SECTION I

INTRODUCTION

Modern aircraft are constructed with many curved panels. In the past, the use of isotropic materials permitted a relatively small number of tests to be used in the generation of simplified analytical methods and design curves. The advent of high-performance laminated composites has required the development of improved analysis tools since material properties of composites have defied simplification and their various coupling effects are often unconservative.

Ashton [1] has shown that the Rayleigh-Ritz method, when properly formulated and coupled with an efficient method of calculating the necessary integrals, can be a very versatile and efficient tool for structural analysis.

Consequently, an analysis tool for cylindrically curved anisotropic panels was proposed. The resulting program includes the following capabilities:

A. Types of Analysis

1. Static deflection and strength under complicated variations of edge and lateral loads with complicated support conditions
2. Elastic stability under complicated edge loads
3. Natural frequencies and mode shapes.

B. Geometry

1. Flat panel
2. Cylindrically curved panel
3. Full cylinder (specially orthotropic only).

C. Construction

1. Sheet with discrete rings and stringers
2. Sandwich with discrete rings and stringers (neglecting core shear).

D. Material - Linearly Elastic

1. Panel - layered anisotropic
2. Stiffeners - orthotropic.

E. Boundary Conditions

1. All combinations of clamped and simply supported;
some combinations with free edges
2. Elastic moment restraint on opposite edges.

The analytical approach and the documentation of most of the required derivations is given in Section II. Other detailed derivations and assumptions are explained under the appropriate subroutine titles in the computer program documentation.

SECTION II

ANALYTICAL FORMULATION

2.1 METHOD OF ANALYSIS

The Rayleigh-Ritz energy method has been chosen for the analysis because of its versatility and speed when compared to finite-element or finite-difference techniques. Many effects may be considered by simply adding their contributions to the total energy of the system, without increasing the size of the resulting set of equations.

The basic energy principle involved is the theorem of stationary potential energy. In the present case it may be written as

$$V + U + Q - T = \text{constant} \quad (1)$$

where

V = strain energy

U = potential energy of membrane loads

Q = potential energy of lateral loads

T = kinetic energy

For a static deflection problem, Equation (1) takes the form

$$V + U + Q = \text{constant} \quad (2)$$

For an elastic stability problem, Equation (1) becomes

$$V + \lambda U = \text{constant} \quad (3)$$

where λ is the buckling eigenvalue.

For a free-vibration problem, including membrane loads, Equation (1) is reduced to

$$V + U - T = \text{constant} \quad (4)$$

These energies are formulated in the following sections. The Rayleigh-Ritz method is then applied to form a set of simultaneous equations for the static deflection problem, or a standard eigenvalue problem for the buckling and vibration cases. This resulting problem is solved with a digital computer program, as described in Appendix I.

All of the following assumptions will be implicit in the analysis:

1. The shell is thin and has constant thickness
2. The displacements are small when compared to the thickness
3. Transverse shear effects are negligible.

2.2 RAYLEIGH-RITZ METHOD

As noted above, each of the problems of concern is governed by Equation (1), where the variations can be replaced with the problem of finding the minimum of Equation (1) by assuming the displacements in the form of a finite series:

$$\begin{aligned}
 u &= \sum_{m=m_i}^{m_f} \sum_{n=n_i}^{n_f} a_{1mn} X_{1m}(x) Y_{1n}(y) \sin \omega z \\
 v &= \sum_{m=m_i}^{m_f} \sum_{n=n_i}^{n_f} a_{2mn} X_{2m}(x) Y_{2n}(y) \sin \omega z \\
 w &= \sum_{m=m_i}^{m_f} \sum_{n=n_i}^{n_f} a_{3mn} X_{3m}(x) Y_{3n}(y) \sin \omega z
 \end{aligned} \tag{5}$$

where

$$m_i = i_x \quad ; \quad m_f = i_x + n_x - 1$$

$$n_i = i_y \quad ; \quad n_f = i_y + n_y - 1$$

the a_{1mn} are undetermined constants, and the functions X_{1m} , Y_{1n} are chosen to satisfy the geometric boundary conditions on u , v , and w . Introducing the assumed series into Equation (1) reduces the problem to finding the minimum of Equation (1) with respect to the undetermined constants, a_{1mn} . Thus, Equation (1) is now a function of only the undetermined constants, a_{1mn} , and is equivalent to the following conditions:

$$\frac{\partial}{\partial a_{imn}} (V+U+Q-T) = 0 \quad (6)$$

where $i = 1, 2, 3$; $m = m_1, \dots, m_f$; $n = n_1, \dots, n_f$; such that Equation (6) denotes a set of $3 n_x n_y$ simultaneous algebraic equations, for which solution techniques are readily available.

The assumed series (5) always involve additional constraints on the energy criteria beyond the physical constraints on the problem, so that the solution obtained by the Rayleigh-Ritz method is always in the direction of a stiffer structure. However, if the assumed series is complete and satisfies the geometric boundary conditions, then the consecutive solutions obtained by including additional terms in the assumed series must approach the correct solution.

2.3 SHELL THEORY

Before proceeding with the analysis, a set of equations defining the midsurface strains and curvatures in terms of the deflections u , v , and w are required. These strain-displacement relations constitute the shell theory being used. Several theories are commonly used, namely Love's, Donnell's, Novozhilov's, etc. In this work, Vlasov [2] shell theory will be used. In the present notation, it requires that

$$\begin{aligned} \epsilon_x^0 &= u_{,x} \\ \epsilon_y^0 &= v_{,y} + w/R \\ \epsilon_{xy}^0 &= u_{,y} + v_{,x} \\ K_x &= -w_{,xx} \\ K_y &= -w_{,yy} - R^{-2}w \\ K_{xy} &= -2w_{,xy} - R^{-1}u_{,y} + R^{-1}v_{,x} \end{aligned} \quad (7)$$

where the commas denote partial differentiation with respect to the variables following them; the coordinate system and sign conventions are shown in Figures 1 and 2.

With the definitions of Equation (7), the total strain at any point at a distance z from the middle surface is written as

$$\begin{aligned}\epsilon_x &= \epsilon_x^0 + z K_x \\ \epsilon_y &= \epsilon_y^0 + z K_y \\ \epsilon_{xy} &= \epsilon_{xy}^0 + z K_{xy}\end{aligned}\tag{8}$$

2.4 SHELL STRAIN ENERGY

The derivation of the shell strain energy is necessary for all three of the analyses to be performed. The derivation depends on the coordinate system and sign conventions shown in Figures 1 and 2.

For a laminated anisotropic material, the constitutive relations [3] are

$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \\ M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} & B_{11} & B_{12} & B_{16} \\ A_{12} & A_{22} & A_{26} & B_{12} & B_{22} & B_{26} \\ A_{16} & A_{26} & A_{66} & B_{16} & B_{26} & B_{66} \\ B_{11} & B_{12} & B_{16} & D_{11} & D_{12} & D_{16} \\ B_{12} & B_{22} & B_{26} & D_{12} & D_{22} & D_{26} \\ B_{16} & B_{26} & B_{66} & D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{bmatrix} \epsilon_x^0 \\ \epsilon_y^0 \\ \epsilon_{xy}^0 \\ K_x \\ K_y \\ K_{xy} \end{bmatrix}\tag{9}$$

which includes bending-stretching coupling, as well as coupling between normal stress, shearing and twisting deformations.

The strain energy of the shell may be concisely stated as

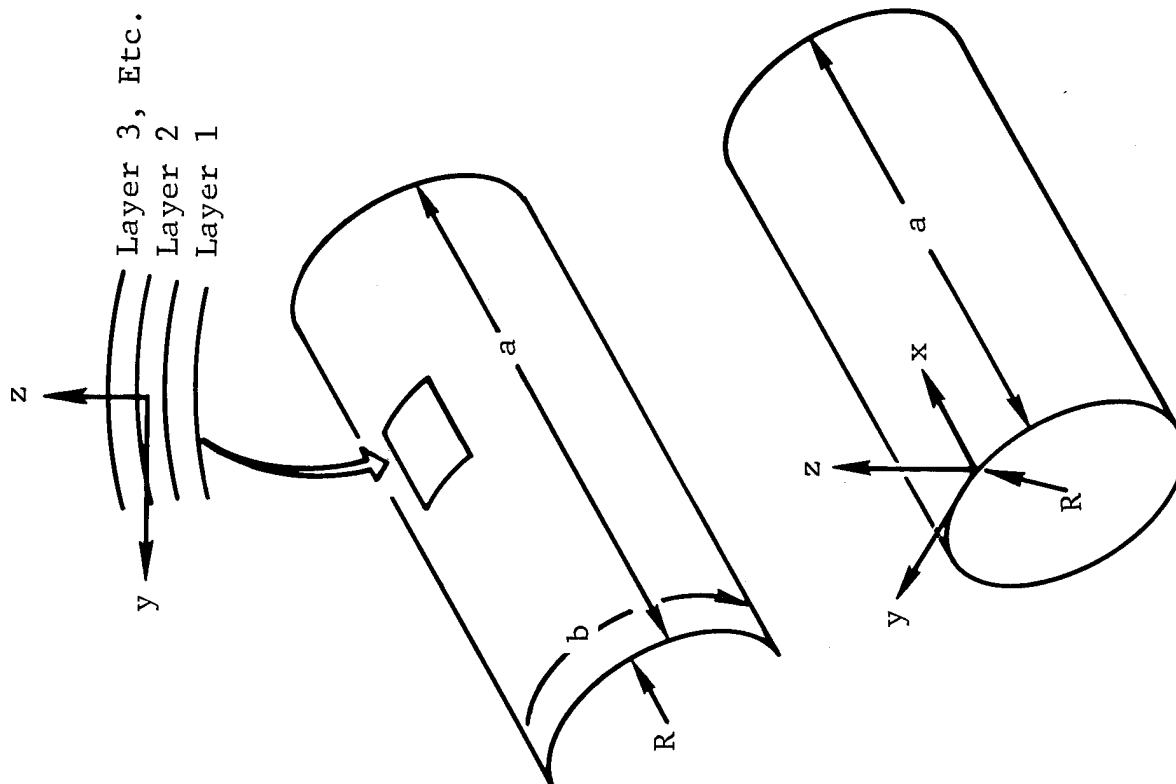


Figure 1 Shell Geometry

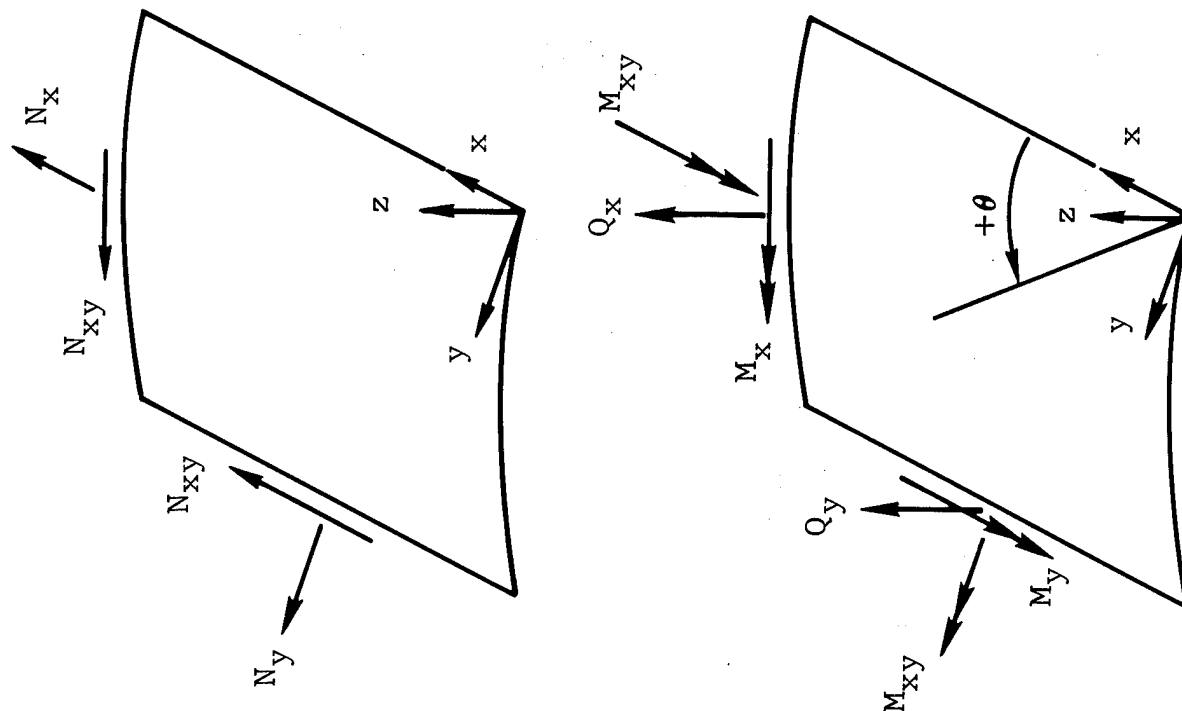


Figure 2 Sign Convention for Positive Loads

$$V_S = \frac{1}{2} \iint_A \begin{Bmatrix} N \\ M \end{Bmatrix}^T \begin{Bmatrix} \epsilon^0 \\ K \end{Bmatrix} dA \quad (10)$$

which, after substituting from Equation (9), takes the form

$$V_S = \frac{1}{2} \iint_{\text{Area}} \{ \epsilon^0 \}^T [A] \{ \epsilon^0 \} + 2 \{ \epsilon^0 \}^T [B] \{ K \} + \{ K \}^T [D] \{ K \} dA \quad (11)$$

Using Equations (7) and (9) and performing the indicated matrix operations in Equation (11) results in the following:

$$\begin{aligned} V_S = & \frac{1}{2} \iint_A A_{11} [u_{,x}^2] + 2A_{12} [u_{,x} u_{,y} + R^{-1} u_{,x} w] \\ & + 2A_{16} [u_{,x} u_{,y} + u_{,x} v_{,x}] + A_{22} [v_{,y} + R^{-1} w]^2 \\ & + 2A_{26} [u_{,y} v_{,y} + v_{,x} v_{,y} + R^{-1} u_{,y} w + R^{-1} v_{,x} w] + A_{66} [u_{,y} + v_{,x}]^2 \\ & - 2B_{11} [u_{,x} w_{,xx}] - 2B_{12} [v_{,y} w_{,xx} + R^{-1} w w_{,xx} + u_{,x} w_{,yy} - R^{-2} u_{,x} w] \\ & + 2B_{16} [R^{-1} u_{,x} v_{,x} - u_{,y} w_{,xx} - v_{,x} w_{,xx} - 2u_{,x} w_{,xy} - R^{-1} u_{,x} u_{,y}] \\ & - 2B_{22} [v_{,y} w_{,yy} + R^{-1} w w_{,yy} + R^{-2} v_{,y} w + R^{-3} w^2] \\ & + 2B_{26} [R^{-1} v_{,x} v_{,y} - u_{,y} w_{,yy} - v_{,x} w_{,yy} - 2v_{,y} w_{,xy} - 2R^{-1} w w_{,xy} \\ & - R^{-1} u_{,y} v_{,y} - 2R^{-2} u_{,y} w] + 2B_{66} [R^{-1} v_{,x}^2 - 2u_{,y} w_{,xy} - 2v_{,x} w_{,xy} \\ & - R^{-1} u_{,y}^2] + D_{11} [w_{,xx}^2] + 2D_{12} [w_{,xx} w_{,yy} + R^{-2} w w_{,xx}] \\ & + 2D_{16} [2w_{,xx} w_{,xy} + R^{-1} u_{,y} w_{,xx} - R^{-1} v_{,x} w_{,xx}] \end{aligned} \quad (12)$$

$$\begin{aligned}
& + D_{22} [2\bar{R}^2 w_{,yy} + \bar{R}^4 w^2 + w_{,yy}^2] + 2D_{26} [2w_{,xy} w_{,yy} \\
& + \bar{R}^1 u_{,y} w_{,yy} - \bar{R}^1 v_{,x} w_{,yy} + 2\bar{R}^2 w w_{,xy} + \bar{R}^3 u_{,y} w - \bar{R}^3 v_{,x} w] \\
& + D_{66} [4\bar{R}^1 u_{,y} w_{,xy} - 4\bar{R}^1 v_{,x} w_{,xy} - 2\bar{R}^2 u_{,y} v_{,x} + \bar{R}^2 u_{,y}^2 \\
& + \bar{R}^2 v_{,x}^2 + 4w_{,xy}^2] \quad d(\text{Area})
\end{aligned}$$

Substitution of Equation (5) into Equation (12), non-dimensionalization of the shape functions, taking partial derivatives with respect to the undetermined constants, and defining the integral functions ψ gives

$$\frac{\partial V_3}{\partial a_{kij}} = \sum_{l=1}^3 \sum_{m=m_i}^{m_f} \sum_{n=n_i}^{n_f} d_{kl ijmn} a_{lmn} \quad \begin{cases} k=1,2,3 \\ i=m_i, \dots, m_f \\ j=n_i, \dots, n_f \end{cases} \quad (13)$$

where

$$\begin{aligned}
d_{11 ijmn} = & A_{11} \bar{a} \bar{b} [\psi_{x2i1im} \psi_{y11jin}] + (A_{16} - B_{16} \bar{R}^1) [\psi_{x4iim} \cdot \\
& \psi_{y41n1j} + \psi_{x41m1i} \psi_{y41jin}] + \bar{a} \bar{b}^1 (A_{66} - 2B_{66} \bar{R}^1 \\
& + D_{66} \bar{R}^2) [\psi_{x11iim} \psi_{y21jin}]
\end{aligned} \quad (14)$$

$$\begin{aligned}
d_{12 ijmn} = & A_{12} [\psi_{x4i12m} \psi_{y42n1j}] + \bar{a} \bar{b}^1 (A_{16} \\
& + B_{16} \bar{R}^1) [\psi_{x2i12m} \psi_{y11j2n}] + \bar{a} \bar{b}^1 (A_{26} + B_{26} \bar{R}^1) \cdot \\
& [\psi_{x11i2m} \psi_{y21j2n}] + (A_{66} + B_{66} \bar{R}^1) [\psi_{x42m1i} \psi_{y41j2n}]
\end{aligned} \quad (15)$$

$$\begin{aligned}
d_{13ijmn} = & b\bar{R}'(A_{12}-\bar{R}'B_{12})[\psi_{x41i3m}\psi_{y11j3n}] \\
& + a\bar{R}'(A_{26}-2\bar{R}'B_{26}+\bar{R}^2D_{26})[\psi_{x11i3m}\psi_{y41j3n}] \\
& - B_{11}\bar{a}^2b[\psi_{x63m1i}\psi_{y11j3n}] - B_{12}\bar{b}'[\psi_{x41i3m}\psi_{y53n1j}] \\
& - 2B_{16}\bar{a}'[\psi_{x21i3m}\psi_{y43n1j}] + \bar{a}'(D_{16}\bar{R}'-B_{16})[\psi_{x53m1i} \cdot \\
& \psi_{y41j3n}] + a\bar{b}^2(D_{26}\bar{R}'-B_{26})[\psi_{x11i3m}\psi_{y63n1j}] \\
& + 2\bar{b}'(D_{66}\bar{R}'-B_{66})[\psi_{x43m1i}\psi_{y21j3n}]
\end{aligned} \tag{16}$$

$$\begin{aligned}
d_{22ijmn} = & A_{22}a\bar{b}'[\psi_{x12i2m}\psi_{y22j2n}] + (A_{26}+\bar{R}'B_{26}) \cdot \\
& [\psi_{x42i2m}\psi_{y42n2j} + \psi_{x42m2i}\psi_{y42j2n}] + \bar{a}'b \cdot \\
& (A_{66}+2\bar{R}'B_{66}+\bar{R}^2D_{66})[\psi_{x22i2m}\psi_{y12j2n}]
\end{aligned} \tag{17}$$

$$\begin{aligned}
d_{23ijmn} = & a\bar{R}'(A_{22}-\bar{R}'B_{22})[\psi_{x12i3m}\psi_{y42j3n}] \\
& - \bar{a}'B_{12}[\psi_{x53m2i}\psi_{y42j3n}] - \bar{a}^2b(B_{16}+\bar{R}'D_{16}) \cdot \\
& [\psi_{x63m2i}\psi_{y12j3n}] + b\bar{R}'(A_{26}-\bar{R}^2D_{26}) \cdot \\
& [\psi_{x42i3m}\psi_{y12j3n}] - a\bar{b}^2B_{22}[\psi_{x12i3m}\psi_{y63n2j}] \\
& - 2\bar{b}'B_{26}[\psi_{x43m2i}\psi_{y22j3n}] - \bar{b}'(B_{26}+\bar{R}'D_{26}) \cdot \\
& [\psi_{x42i3m}\psi_{y53n2j}] - 2\bar{a}'(B_{66}+\bar{R}'D_{66})[\psi_{x22i3m}\psi_{y43n2j}]
\end{aligned} \tag{18}$$

$$\begin{aligned}
d_{33ijmn} = & ab\bar{R}^2(A_{22}-2B_{22}\bar{R}'+D_{22}\bar{R}^2)[\psi_{x13i3m}\psi_{y13j3n}] \\
& + \bar{a}'b\bar{R}'(D_{12}\bar{R}'-B_{12})[\psi_{x53i3m}\psi_{y13j3n}+\psi_{x53m3i}\psi_{y13j3n}] \\
& + ab'\bar{R}'(D_{22}\bar{R}'-B_{22})[\psi_{x13i3m}\psi_{y53j3n}+\psi_{x13i3m}\psi_{y53n3j}] \\
& + 2\bar{R}'(D_{26}\bar{R}'-B_{26})[\psi_{x43i3m}\psi_{y43j3n}+\psi_{x43m3i}\psi_{y43n3j}] \\
& + \bar{a}^3bD_{11}[\psi_{x33i3m}\psi_{y13j3n}] \\
& + \bar{a}'\bar{b}'D_{12}[\psi_{x53i3m}\psi_{y53n3j}+\psi_{x53m3i}\psi_{y53j3n}] \\
& + 2\bar{a}^2D_{16}[\psi_{x63i3m}\psi_{y43n3j}+\psi_{x63m3i}\psi_{y43j3n}] \\
& + ab^3D_{22}[\psi_{x13i3m}\psi_{y33j3n}] \\
& + 2\bar{b}^2D_{26}[\psi_{x43i3m}\psi_{y63n3j}+\psi_{x43m3i}\psi_{y63j3n}] \\
& + 4\bar{a}'\bar{b}'D_{66}[\psi_{x23i3m}\psi_{y23j3n}]
\end{aligned} \tag{19}$$

The integral functions ψ are defined and explained in Section 2.10. Note also that

$$d_{21ijmn} = d_{12mnij} \tag{20}$$

$$d_{31ijmn} = d_{13mnij} \tag{21}$$

$$d_{32ijmn} = d_{23mnij} \tag{22}$$

so that the potential energy matrix is symmetric.

2.5 SHELL KINETIC ENERGY

The kinetic energy of the vibrating shell is based on the translational inertia in the three coordinate directions. The rotatory inertia components are neglected to maintain consistency with the previous deletion of transverse shear flexibilities. The mass times velocity-squared is written on a differential basis as

$$T = \frac{1}{2} \rho \int_{-z}^z \int_0^b \int_0^a (u_{,z}^2 + v_{,z}^2 + w_{,z}^2) dx dy dz \quad (23)$$

The integral through the thickness is trivial, giving

$$T = \frac{1}{2} \rho h \int_0^b \int_0^a (u_{,z}^2 + v_{,z}^2 + w_{,z}^2) dx dy \quad (24)$$

Performing the same substitution of the assumed modes, taking partials with respect to the undetermined constants, and using the integral definitions as for the potential energy derivations, results in the following required expressions for the variations of the kinetic energy:

$$\frac{\partial T}{\partial a_{1ij}} = \rho h a b \omega^2 \sum_m \sum_n \psi_{x1i1m} \psi_{y1j1n} a_{1mn} \quad (25)$$

$$\frac{\partial T}{\partial a_{2ij}} = \rho h a b \omega^2 \sum_m \sum_n \psi_{x12i2m} \psi_{y12j2n} a_{2mn} \quad (26)$$

$$\frac{\partial T}{\partial a_{3ij}} = \rho h a b \omega^2 \sum_m \sum_n \psi_{x13i3m} \psi_{y13j3n} a_{3mn} \quad (27)$$

2.6 POTENTIAL ENERGY OF INPLANE LOADS

The total potential energy of the inplane loads on a panel may be simply formed as the product of the vector of running loads and the vector of mid-plane strains:

$$U_p = - \iint_A \{N\}^T \{\epsilon\} dA \quad (28)$$

Expanding the strains according to Equation (7) and including first-order nonlinear terms results in

$$U_p = - \iint_A \left\{ N_x [u_{,x} + \frac{1}{2} w_{,x}^2] + N_y [v_{,y} + \bar{R}' w + \frac{1}{2} w_{,y}^2] + N_{xy} [v_{,x} + u_{,y} + w_{,x} w_{,y}] \right\} dA \quad (29)$$

To allow integration of Equation (29) requires an assumed form for N_x , N_y , and N_{xy} . The form assumed here is a power series in the x and y directions, defined as

$$N_x = \sum_{k=1}^{10} \sum_{l=1}^{10} P_{xkl} \left(\frac{x}{a}\right)^{k-1} \left(\frac{y}{b}\right)^{l-1} \quad (30)$$

$$N_y = \sum_{k=1}^{10} \sum_{l=1}^{10} P_{ykl} \left(\frac{x}{a}\right)^{k-1} \left(\frac{y}{b}\right)^{l-1} \quad (31)$$

$$N_{xy} = \sum_{k=1}^{10} \sum_{l=1}^{10} P_{xykl} \left(\frac{x}{a}\right)^{k-1} \left(\frac{y}{b}\right)^{l-1} \quad (32)$$

Before integrating Equation (29), U_p is separated into its linear and nonlinear terms,

$$U_p = S + U \quad (33)$$

where the linear terms are retained in S and the nonlinear terms are retained in U . Then,

$$S = - \iint \sum_k \sum_l \left\{ P_{xkl} [u_{,x}] + P_{ykl} [v_{,y} + w/R] + P_{xykl} [v_{,x} + u_{,y}] \right\} \left(\frac{x}{a}\right)^{k-1} \left(\frac{y}{b}\right)^{l-1} dA \quad (34)$$

Using the definitions of u , v , and w from Equation (5),

$$S = - \iint \sum_k \sum_l \left\{ P_{xkl} \left[\bar{a}' \sum_m \sum_n X_{1m,x} Y_{1n} a_{1mn} \right] + P_{ykl} \left[\bar{b}' \sum_m \sum_n X_{2m} Y_{2n,y} a_{2mn} + \bar{R}' \sum_m \sum_n X_{3m} Y_{3n} a_{3mn} \right] + P_{xykl} \left[\bar{a}' \sum_m \sum_n X_{2m,x} Y_{2n} a_{2mn} + \bar{b}' \sum_m \sum_n X_{1m} Y_{1n,y} a_{1mn} \right] \right\} \left(\frac{x}{a}\right)^{k-1} \left(\frac{y}{b}\right)^{l-1} dA \quad (35)$$

Taking partials with respect to the coefficients and using the integral definitions of Section 2.10 gives

$$\frac{\partial S}{\partial a_{1ij}} = - \sum_k \sum_l \left\{ P_{xkl} [b \phi_{kx21i} \phi_{ly11j}] + P_{xykl} [a \phi_{kx11i} \phi_{ly21j}] \right\} \quad (36)$$

$$\frac{\partial S}{\partial a_{2ij}} = - \sum_k \sum_l \left\{ P_{ykl} [a \phi_{kx12i} \phi_{ly22j}] + P_{xykl} [b \phi_{kx22i} \phi_{ky12j}] \right\}$$

$$\frac{\partial S}{\partial a_{3ij}} = - \sum_k \sum_l \left\{ P_{xykl} [ab \bar{R}' \phi_{kx13i} \phi_{ly13j}] \right\}$$

Similarly for U,

$$U = - \iint \sum_k \sum_l \left\{ P_{xkl} \left[\frac{1}{2} w_{,x}^2 \right] + P_{ykl} \left[\frac{1}{2} w_{,y}^2 \right] + P_{xykl} [w_{,x} w_{,y}] \right\} \left(\frac{x}{a} \right)^{k-1} \left(\frac{y}{b} \right)^{l-1} dA \quad (37)$$

Substituting in the definitions of Equation (5), taking partial derivatives and using the integral definitions of Section 2.10 gives

$$\begin{aligned} \frac{\partial U}{\partial a_{ilj}} &= \frac{\partial U}{\partial a_{zij}} = 0 \\ \frac{\partial U}{\partial a_{zij}} &= - \sum_m \sum_n \sum_k \sum_l [a' b P_{xkl} (\Omega_{k1zim} \Omega_{l2ijn}) \\ &\quad + a b' P_{ykl} (\Omega_{k1iim} \Omega_{l22jn}) + P_{xykl} \cdot \\ &\quad (\Omega_{k1zim} \Omega_{l22jn} + \Omega_{k13mi} \Omega_{l22jn})] a_{3mn} \end{aligned} \quad (38)$$

2.7 POTENTIAL ENERGY OF LATERAL LOADS

A distributed lateral pressure is defined by power series in the x and y directions as

$$\bar{q} = \sum_{k=1}^{10} \sum_{l=1}^{10} q_{kl} \left(\frac{x}{a} \right)^{k-1} \left(\frac{y}{b} \right)^{l-1} \quad (39)$$

The potential energy of this load is

$$Q = \iint_A \bar{q} w dA \quad (40)$$

Combination of the definitions for $\bar{q}$ and w , differentiation with respect to the coefficients, and use of the integral definitions results in

$$\frac{\partial Q}{\partial a_{1i}} = \frac{\partial Q}{\partial a_{2i}} = 0$$

$$\frac{\partial Q}{\partial a_{3ij}} = \sum_k \sum_l a b g_{kl} \phi_{k \times 13i} \phi_{l y 13j} \quad (41)$$

2.8 DISCRETE ENERGY CONTRIBUTIONS

As noted above, a significant reason for employing the Rayleigh-Ritz energy method is the ease with which many desired effects may be included. These effects and their required energy formulations are described below.

2.8.1 Stiffeners

An important effect to be included for aircraft curved panels is that of discrete, eccentric stiffening elements. These are called stringers in the x-direction and rings in the y-direction.

2.8.1.1 Stringers

The energy contributions for the discrete, eccentric stringers were adapted from Reference [4]. The appropriate geometry for the stiffened shell and the stiffeners themselves is shown in Figures 3 and 4. The potential energy of the stringers due to extension, bending, and torsion, neglecting the bending-torsion coupling, is expressed

$$\Delta V = \sum_{l=1}^L \frac{E_{sl}}{2} \int_0^a \left[(A_{sl} u_{,x}^2 - 2 \bar{y}_{sl} A_{sl} u_{,x} v_{,xx} + I_{zzsl} v_{,xx}^2) + I_{yy sl} w_{,xx}^2 - 2 \bar{z}_{sl} A_{sl} u_{,x} w_{,xx} + 2 I_{yz sl} v_{,xx} w_{,xx} \right] dx + \frac{(GJ)_{sl}}{2} \int_0^a \left. w_{,xy}^2 \right|_{y=y_l} dx \quad (42)$$

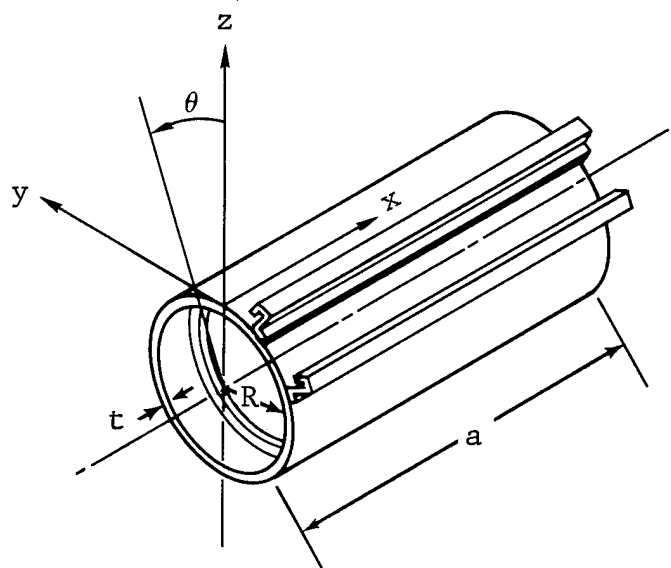
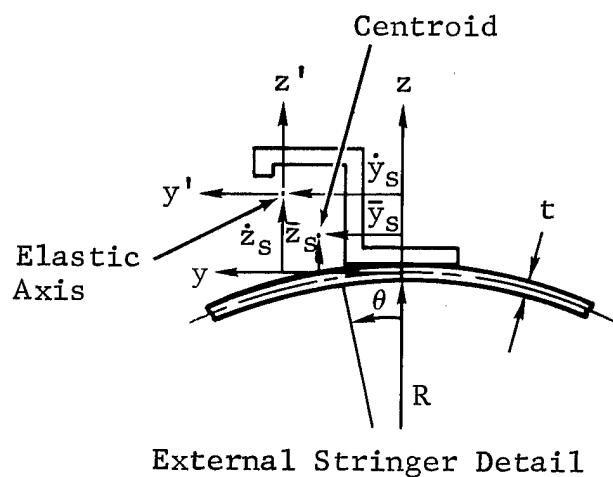
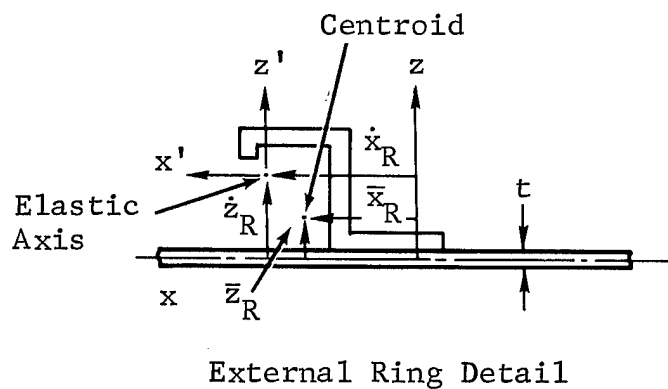


Figure 3 Geometry of Discretely Stiffened Cylinder



External Stringer Detail



External Ring Detail

Figure 4 Geometric Detail of Eccentric Stiffeners

The form of the partials after introduction of the assumed modes, nondimensionalization, and integration is

$$\frac{\partial \Delta V}{\partial a_{1ij}} = \sum_{\ell=1}^L \sum_m \sum_n E_{3\ell} A_{3\ell} \left[\bar{a}^1 \psi_{x2i1im} Y_{ij} Y_{in} a_{1mn} - \bar{a}^2 \bar{y}_{3\ell} \psi_{x62mi} Y_{ij} Y_{2n} a_{2mn} - \bar{a}^2 \bar{z}_{3\ell} \psi_{x63mi} Y_{ij} Y_{3n} a_{3mn} \right]_{y=y_\ell} \quad (43)$$

$$\frac{\partial \Delta V}{\partial a_{2ij}} = \sum_{\ell=1}^L \sum_m \sum_n E_{3\ell} \left[-\bar{a}^2 \bar{y}_{3\ell} \psi_{x62im} Y_{2j} Y_{in} a_{1mn} + \bar{a}^3 I_{333\ell} \psi_{x32i2m} Y_{2j} Y_{2n} a_{2mn} + \bar{a}^3 I_{y33\ell} \psi_{x32i3m} Y_{2j} Y_{3n} a_{3mn} \right]_{y=y_\ell} \quad (44)$$

$$\frac{\partial \Delta V}{\partial a_{3ij}} = \sum_{\ell=1}^L \sum_m \sum_n \left\{ E_{3\ell} \left[\bar{a}^3 I_{yy3\ell} \psi_{x33i3m} Y_{3j} Y_{3n} a_{3mn} - \bar{a}^2 \bar{z}_{3\ell} A_{3\ell} \psi_{x63i1m} Y_{3j} Y_{1n} a_{1mn} + \bar{a}^3 I_{y33\ell} \psi_{x33i2m} Y_{3j} Y_{2n} a_{2mn} \right] + \bar{a}^2 (GJ)_{3\ell} \left[\psi_{x23i3m} Y_{3j,1} Y_{3n,1} a_{3mn} \right] \right\}_{y=y_\ell} \quad (45)$$

The stringer kinetic energy is expressed by

$$\Delta T = \frac{1}{2} \sum_{\ell=1}^L \rho_{3\ell} \int_0^a \left[A_{3\ell} (u_{,x}^2 - 2 \bar{y}_{3\ell} u_{,x} v_{,x} + v_{,x}^2 - 2 \bar{z}_{3\ell} u_{,x} w_{,x} - 2 \bar{z}_{3\ell} v_{,x} w_{,x} + w_{,x}^2 + 2 \bar{y}_{3\ell} w_{,x} w_{,y} \right) \quad (46)$$

$$\begin{aligned}
& + I_{zzse} (v_{xz}^2 + w_{yz}^2) + 2 I_{yzse} (v_{xz} w_{xz}) \\
& + I_{yyse} (w_{xz}^2 + w_{yz}^2) \Big]_{y=y_e} dx
\end{aligned} \tag{46}$$

Cont'd.

In final form, the partials of the stringer kinetic energy are expressed as

$$\begin{aligned}
\frac{\partial \Delta T}{\partial a_{1ij}} = \sum_{e=1}^L \sum_m \sum_n \rho_{se} \omega^2 A_{se} [a \psi_{x1i1m} Y_{ij} Y_n a_{1mn} \\
- \bar{y}_{se} \psi_{x42m1i} Y_{ij} Y_{2n} a_{2mn} - \bar{z}_{se} \psi_{x43m1i} Y_{ij} Y_{3n} a_{3mn}]_{y=y_e}
\end{aligned} \tag{47}$$

$$\begin{aligned}
\frac{\partial \Delta T}{\partial a_{2ij}} = \sum_{e=1}^L \sum_m \sum_n \rho_{se} \omega^2 \{ [-A_{se} \bar{y}_{se} \psi_{x42i1m} Y_{2j} Y_n] a_{1mn} \\
+ [a A_{se} \psi_{x12i2m} + \bar{a}' I_{zzse} \psi_{x22i2m}] Y_{2j} Y_{2n} a_{2mn} \\
+ [\bar{a}' I_{yyse} \psi_{x22i3m} Y_{2j} Y_{3n} - a \bar{b}' \bar{z}_{se} A_{se} \psi_{x12i3m} Y_{2j} \cdot \\
Y_{3n, y}] a_{3mn} \} \Big]_{y=y_e}
\end{aligned} \tag{48}$$

$$\begin{aligned}
\frac{\partial \Delta T}{\partial a_{3ij}} = \sum_{e=1}^L \sum_m \sum_n \rho_{se} \omega^2 \{ [-\bar{z}_{se} A_{se} \psi_{x43i1m} Y_{3j} Y_n] \cdot \\
a_{1mn} + [-\bar{z}_{se} a \bar{b}' A_{se} \psi_{x13i2m} Y_{3j, y} + \bar{a}' I_{yzse} \cdot \\
\psi_{x23i2m} Y_{3j}] Y_{2n} a_{2mn} + [(\psi_{x13i3m}) (a A_{se} Y_{3j} \cdot \\
Y_{3n} + a \bar{b}' \bar{y}_{se} A_{se} [Y_{3j} Y_{3n, y} + Y_{3j, y} Y_{3n}] + a \bar{b}^2 Y_{3j, y} \cdot \\
Y_{3n, y} [I_{zzse} + I_{yyse}]) + \bar{a}' I_{yyse} \psi_{x23i3m} Y_{3j} Y_{3n}] a_{3mn} \} \Big]_{y=y_e}
\end{aligned} \tag{49}$$

The remaining stringer energy contribution arises from an external axial tension load, P_x , on the stringer. This energy is written

$$\Delta U = - \int_x P_x [u_{,x} - \bar{y}_{se} v_{,xx} - \bar{z}_{se} w_{,xx} + \frac{1}{2} w_{,x}^2] dx \Big|_{y=y_e}^{z=\bar{z}} \quad (50)$$

Putting the linear terms in the S vector and the nonlinear terms in the U matrix, as defined in Section 2.6, gives

$$\frac{\partial \Delta S}{\partial a_{1ij}} = - \sum_{e=1}^L P_{xe} Q_{1xzic} Y_{ij}(y_e) \quad (51)$$

$$\frac{\partial \Delta S}{\partial a_{2ij}} = + \sum_{e=1}^L P_{xe} \bar{a}' \bar{y}_e Q_{1xzic} Y_{2j}(y_e) \quad (52)$$

$$\frac{\partial \Delta S}{\partial a_{3ij}} = + \sum_{e=1}^L P_{xe} \bar{a}' \bar{z}_e Q_{1xzic} Y_{3j}(y_e) \quad (53)$$

$$\frac{\partial \Delta U}{\partial a_{1ij}} = \frac{\partial \Delta U}{\partial a_{2ij}} = 0 \quad (54)$$

$$\frac{\partial \Delta U}{\partial a_{3ij}} = - \sum_{e=1}^L \bar{a}' P_{xe} \sum_m \sum_n \psi_{x2s3icm} Y_{3j}(y_e) Y_{3n}(y_e) a_{3mn} \quad (55)$$

2.8.1.2 Rings

The energy terms for the discrete, eccentric rings are similar to those for the stringers, but are much more complicated. Reference [4] was also used for these energies; again, refer to Figures 3 and 4.

The potential energy is expressed as

$$\begin{aligned} \Delta V = & \sum_{k=1}^K \frac{E_{rk}}{2} \int_0^b [A_{rk} v_{,y}^2 + I_{xxrk} w_{,y}^2 + I_{zzrk} u_{,y}^2 + \\ & + \bar{R}^2 A_{rk} w^2 + \bar{R}^2 I_{zzrk} w_{,x}^2 - 2 \bar{z}_{rk} A_{rk} v_{,y} w_{,y} - 2 \bar{x}_{rk} A_{rk} \cdot \\ & v_{,y} u_{,y} + 2 \bar{R}^1 A_{rk} v_{,y} w + 2 \bar{R}^1 \bar{x}_{rk} A_{rk} v_{,y} w_{,x} + 2 I_{xxrk} w_{,y} \cdot \\ & u_{,y} - 2 \bar{R}^1 \bar{z}_{rk} A_{rk} w_{,y} w - 2 \bar{R}^1 I_{xxrk} w_{,y} w_{,x} - 2 \bar{R}^1 \bar{x}_{rk} A_{rk} \cdot \\ & u_{,y} w - 2 \bar{R}^1 I_{zzrk} u_{,y} w_{,x} + 2 \bar{R}^2 \bar{x}_{rk} A_{rk} w w_{,x}]_{x=x_k} dy \\ & + \frac{1}{2} (GJ)_{rk} \int_0^b [w_{,xy}^2]_{x=x_k} dy \end{aligned} \quad (56)$$

The final forms of the partials required are

$$\begin{aligned} \frac{\partial \Delta V}{\partial a_{ij}} = & \sum_{k=1}^K \sum_m \sum_n E_{rk} [\bar{b}^3 I_{zzrk} X_{ii} X_{im} \psi_{y3ijn} a_{imn} \\ & - \bar{b}^2 \bar{x}_{rk} A_{rk} X_{ii} X_{2m} \psi_{y6ijn} a_{2mn} + (\bar{b}^3 I_{xxrk} X_{ii} X_{3m} \psi_{y3ijn} \\ & - \bar{x}_{rk} A_{rk} \bar{R}^1 X_{ii} X_{3m} \psi_{y5ijn} - \bar{a}^1 \bar{b}^1 \bar{R}^1 I_{zzrk} X_{ii} X_{3m} \psi_{y5ijn}) \cdot \\ & a_{3mn}]_{x=x_k} \end{aligned} \quad (57)$$

$$\begin{aligned} \frac{\partial \Delta V}{\partial a_{cij}} = & \sum_{k=1}^K \sum_m \sum_n E_{rk} A_{rk} X_{zi} [-\bar{b}^2 \bar{x}_{rk} X_{im} \psi_{y6imej} a_{imn} \\ & + \bar{b}^1 X_{2m} \psi_{y2zjen} a_{2mn} + (-\bar{b}^2 \bar{z}_{rk} X_{3m} \psi_{y63n2j} + \bar{R}^1 X_{3m} \cdot \\ & \psi_{y42jen} + \bar{a}^1 \bar{R}^1 \bar{x}_{rk} X_{3m} \psi_{y42jen}) a_{3mn}]_{x=x_k} \end{aligned} \quad (58)$$

$$\begin{aligned}
\frac{\partial \Delta V}{\partial a_{3ij}} = & \sum_{k=1}^K \sum_m \sum_n \left\{ E_{rk} \left[(\bar{b}^3 I_{xxrk} X_{3i} X_{1m} \psi_{y33jn} \right. \right. \\
& - \bar{b} \bar{R}' \bar{x}_{rk} A_{rk} X_{3i} X_{1m} \psi_{y51n3j} - \bar{a} \bar{b} \bar{R}' I_{zzrk} X_{3i,x} X_{1m} \cdot \\
& \psi_{y51n3j}) a_{1mn} + (-\bar{b}^2 \bar{z}_{rk} A_{rk} X_{3i} X_{2m} \psi_{y63jen} \\
& + \bar{R}' A_{rk} X_{3i} X_{2m} \psi_{y42n3j} + \bar{a} \bar{R}' \bar{x}_{rk} A_{rk} X_{3i,x} X_{2m} \psi_{y42n3j}) \cdot \\
& a_{2mn} + (\bar{b}^3 I_{xxrk} X_{3i} X_{3m} \psi_{y33j3n} + \bar{b} \bar{R}'^2 A_{rk} X_{3i} X_{3m} \cdot \\
& \psi_{y13j3n} + \bar{a}^2 \bar{b} \bar{R}'^2 I_{zzrk} X_{3i,x} X_{3m,x} \psi_{y13j3n} - \bar{b} \bar{R}' \bar{z}_{rk} \cdot \\
& A_{rk} X_{3i} X_{3m} \psi_{y53j3n} - \bar{b} \bar{R}' \bar{z}_{rk} A_{rk} X_{3i} X_{3m} \psi_{y53n3j} \\
& - \bar{a} \bar{b} \bar{R}' I_{xxrk} X_{3i} X_{3m,x} \psi_{y63j3n} - \bar{a} \bar{b} \bar{R}' I_{xxrk} X_{3i,x} X_{3m} \cdot \\
& \psi_{y53n3j} + \bar{a} \bar{b} \bar{x}_{rk} \bar{R}'^2 A_{rk} X_{3i} X_{3m,x} \psi_{y13j3n} + \bar{a} \bar{b} \bar{R}'^2 \bar{x}_{rk} \cdot \\
& A_{rk} X_{3i,x} X_{3m} \psi_{y13j3n}) a_{3mn} \left. \right] + \bar{a}^2 \bar{b} (GJ)_{rk} \cdot \\
& [X_{3i,x} X_{3m,x} \psi_{y23j3n}] a_{3mn} \Big\}_{x=x_k}
\end{aligned} \quad (59)$$

The kinetic energy of the rings is expressed as

$$\begin{aligned}
\Delta T = & \frac{1}{2} \sum_{k=1}^K \rho_{rk} \int_0^b \left[A_{rk} (\dot{u}_{,z}^2 - 2 \bar{z}_{rk} \dot{u}_{,z} \dot{w}_{,xz} + \dot{w}_{,xz}^2 \right. \\
& + 2 \bar{x}_{rk} \dot{w}_{,z} \dot{w}_{,xz} + \dot{v}_{,z}^2 - 2 \bar{z}_{rk} \dot{v}_{,z} \dot{w}_{,yz} - 2 \bar{x}_{rk} \dot{v}_{,z} \dot{u}_{,yz}) \\
& + I_{xxrk} (\dot{w}_{,xz}^2 + \dot{w}_{,yz}^2) + 2 I_{xxrk} \dot{w}_{,yz} \dot{u}_{,yz} \\
& \left. + I_{zzrk} (\dot{w}_{,xz}^2 + \dot{u}_{,yz}^2) \right]_{x=x_k} dy
\end{aligned} \quad (60)$$

The final forms of the ring kinetic energy partial derivatives are

$$\frac{\partial \Delta T}{\partial a_{1ij}} = \sum_{k=1}^K \sum_m \sum_n \rho_{rk} \omega^2 \left\{ [b A_{rk} \psi_{11ijn} + b' I_{22rk} \psi_{21ijn}] \cdot \right. \\ \left. X_{1i} X_{1m} a_{1mn} - \bar{X}_{rk} A_{rk} X_{1i} X_{2m} \psi_{41j2n} a_{2mn} + [-\bar{Z}_{rk} \bar{a}' b A_{rk} \right. \\ \left. X_{3m,x} \psi_{11ijn} + b' I_{22rk} X_{3m} \psi_{21ijn}] X_{1i} a_{3mn} \right\}_{x=x_k} \quad (61)$$

$$\frac{\partial \Delta T}{\partial a_{2ij}} = \sum_{k=1}^K \sum_m \sum_n \rho_{rk} \omega^2 A_{rk} \left\{ [-\bar{X}_{rk} X_{2i} X_{1m} \psi_{412n} a_{1mn} \right. \\ \left. + b X_{2i} X_{2m} \psi_{12j2n} a_{2mn} - \bar{Z}_{rk} X_{2i} X_{3m} \psi_{43n2j} a_{3mn}] \right\}_{x=x_k} \quad (62)$$

$$\frac{\partial \Delta T}{\partial a_{3ij}} = \sum_{k=1}^K \sum_m \sum_n \rho_{rk} \omega^2 \left\{ [-\bar{a}' b \bar{Z}_{rk} A_{rk} X_{3i,x} \psi_{13ijn} \right. \\ \left. + b' I_{22rk} X_{3i} \psi_{23ijn}] X_{1m} a_{1mn} - [\bar{Z}_{rk} A_{rk} X_{3i} X_{2m} \right. \\ \left. \psi_{43j2n}] a_{2mn} + [(\psi_{13ijn})(b A_{rk} X_{3i} X_{3m} \right. \\ \left. + \bar{a}' b \bar{X}_{rk} A_{rk} [X_{3i} X_{3m,x} + X_{3i,x} X_{3m}] + \bar{a}^2 b X_{3i,x} \cdot \right. \\ \left. X_{3m,x} [I_{22rk} + I_{33rk}]) + b' I_{22rk} X_{3i} X_{3m} \psi_{23ijn}] \cdot \right. \\ \left. a_{3mn} \right\}_{x=x_k} \quad (63)$$

For a panel rather than a complete cylinder, a ring stiffener may support a circumferential load, P_y , imposed at its ends. The energy associated with P_y , which is positive in tension, is given by

$$\Delta U = -b P_y \int_y [b' (v_{,y} - z w_{,yy} - \bar{x} u_{,yy}) + (\bar{R}' w + \bar{R} \bar{x} w_{,x}) \\ + \pm b^2 w_{,y}^2] d(\frac{y}{b}) \Big|_{x=\bar{x}_k}^{x=\bar{x}_k} \quad (64)$$

After separating into linear and nonlinear terms, as for the stringers, the final partial derivatives are given as

$$\frac{\partial \Delta S}{\partial a_{1i,j}} = - \sum_{k=1}^K p_{yk} \bar{x}_k x_{1i}(x_k) \phi_{1y31,j} \quad (65)$$

$$\frac{\partial \Delta S}{\partial a_{2i,j}} = - \sum_{k=1}^K p_{yk} x_{2i}(x_k) \phi_{2y22,j} \quad (66)$$

$$\begin{aligned} \frac{\partial \Delta S}{\partial a_{3i,j}} = & - \sum_{k=1}^K p_{yk} [-\bar{z}_k x_{3i}(x_k) \phi_{y33,j} + b R^{-1} x_{3i}(x_k) \phi_{1y13,j} \\ & + b R^{-1} \bar{x}_k x_{3i,x}(x_k) \phi_{1y13,j}] \end{aligned} \quad (67)$$

$$\frac{\partial \Delta U}{\partial a_{1i,j}} = \frac{\partial \Delta U}{\partial a_{2i,j}} = 0 \quad (68)$$

$$\frac{\partial \Delta U}{\partial a_{3i,j}} = - \sum_{k=1}^K \sum_m \sum_n p_{yk} b^{-1} x_{3i}(x_k) x_{3m}(x_k) \psi_{y23j3n} a_{3mn} \quad (69)$$

2.8.2 Lumped Masses

The kinetic energy contribution of each lumped mass attached to the shell is written in terms of its translational inertia only as

$$\Delta T = \frac{1}{2} \bar{m} (u_{,r}^2 + v_{,r}^2 + w_{,r}^2) \quad (70)$$

In final partial form, after using the assumed mode definitions of u , v , and w ,

$$\frac{\partial \Delta T}{\partial a_{1i,j}} = \bar{m} \omega^2 x_{1i} Y_{1j} \sum_m \sum_n x_{1m} Y_{1n} a_{1mn} \Big|_{\text{pt.}} \quad (71)$$

$$\frac{\partial \Delta T}{\partial a_{2ij}} = \bar{m} \omega^2 X_{2i} Y_{2j} \sum_m \sum_n X_{2m} Y_{2n} a_{2mn} \Big|_{\text{pt.}} \quad (72)$$

$$\frac{\partial \Delta T}{\partial a_{3ij}} = \bar{m} \omega^2 X_{3i} Y_{3j} \sum_m \sum_n X_{3m} Y_{3n} a_{3mn} \Big|_{\text{pt.}} \quad (73)$$

2.8.3 Spring Supports

To model nonstandard boundary or internal attachment conditions, it is convenient to have the capability to introduce discrete point and line spring supports.

2.8.3.1 At a Point

Assuming that the spring acts normal to the shell surface, its energy can be defined in terms of w only as

$$\Delta V = \frac{1}{2} K_p w^2 \Big|_{\text{pt.}} \quad (74)$$

The partial derivatives are then trivially formed as

$$\frac{\partial \Delta V}{\partial a_{1ij}} = \frac{\partial \Delta V}{\partial a_{2ij}} = 0 \quad (75)$$

$$\frac{\partial \Delta V}{\partial a_{3ij}} = K_p X_{3i} Y_{3j} \sum_m \sum_n X_{3m} Y_{3n} a_{3mn} \Big|_{\text{pt.}} \quad (76)$$

2.8.3.2 Along a Line

To simplify, it is assumed that the line spring supports lie parallel to either the x - or y -axis of the shell. Then,

$$\Delta V = \begin{cases} \frac{1}{2} K_L a \int_0^1 w^2 d\left(\frac{x}{a}\right) ; & x\text{-axis} \\ \frac{1}{2} K_L b \int_0^1 w^2 d\left(\frac{y}{b}\right) ; & y\text{-axis} \end{cases} \quad (77)$$

After integration and partial differentiation,

$$\frac{\partial \Delta V}{\partial a_{1i,j}} = \frac{\partial \Delta V}{\partial a_{2i,j}} = 0 \quad (78)$$

$$\frac{\partial \Delta V}{\partial a_{3i,j}} = \begin{cases} \sum_m \sum_n K_L a \psi_{x1i3im} Y_{3j} Y_{3n} a_{3nm} \Big|_{y=y_{L,2}} & ; x\text{-axis} \\ \sum_m \sum_n K_L b X_{3i} X_{3m} \psi_{y1i3im} a_{3nm} \Big|_{x=x_{L,2}} & ; y\text{-axis} \end{cases} \quad (79)$$

2.8.4 Concentrated Loads

The potential energy of a point load applied normal to the shell surface is written simply as

$$\Delta Q = P_c w \Big|_{\text{pt.}} \quad (80)$$

The final partial form is just as simply written as

$$\frac{\partial \Delta Q}{\partial a_{1i,j}} = \frac{\partial \Delta Q}{\partial a_{2i,j}} = 0 \quad (81)$$

$$\frac{\partial \Delta Q}{\partial a_{3i,j}} = P_c X_{3i} Y_{3j} \Big|_{\text{pt.}} \quad (82)$$

2.8.5 Concentrated Moments

The energy associated with concentrated moment loading is important when input loading from attached members must be assessed. In both point and line moment cases, the vector describing the direction of the moment must be parallel to either the x or y-axis of the shell.

2.8.5.1 At a Point

The energy is formed as the product of the applied moment and the angle through which it is applied

$$\Delta Q = \begin{cases} +M_p (\bar{a}' w_{,x} + \bar{R}' u) & ; \bar{M}_p \text{ in } y\text{-dir.} \\ -M_p (\bar{b}' w_{,y} + \bar{R}' v) & ; \bar{M}_p \text{ in } x\text{-dir.} \end{cases} \quad (83)$$

Substitution of the displacement definitions and partial differentiation of the energy gives

$$\frac{\partial \Delta Q}{\partial a_{ij}} = \begin{cases} M_p \bar{R}' X_{ii} Y_{ij} \Big|_{\text{pt.}} & ; \bar{M}_p \text{ in } y\text{-dir.} \\ 0 & ; \bar{M}_p \text{ in } x\text{-dir.} \end{cases} \quad (84)$$

$$\frac{\partial \Delta Q}{\partial a_{zizj}} = \begin{cases} 0 & ; \bar{M}_p \text{ in } y\text{-dir.} \\ -M_p \bar{R}' X_{zi} Y_{zj} \Big|_{\text{pt.}} & ; \bar{M}_p \text{ in } x\text{-dir.} \end{cases} \quad (85)$$

$$\frac{\partial \Delta Q}{\partial a_{zij}} = \begin{cases} \bar{a}' M_p X_{zi,x} Y_{zj} \Big|_{\text{pt.}} & ; \bar{M}_p \text{ in } y\text{-dir.} \\ -\bar{b}' M_p X_{zi} Y_{zj,y} \Big|_{\text{pt.}} & ; \bar{M}_p \text{ in } x\text{-dir.} \end{cases} \quad (86)$$

2.8.5.2 Along a Line

The formation of the energy contribution for line moments is the same as that for point moments except that a line integral is required. The final partials are

$$\frac{\partial \Delta Q}{\partial a_{ij}} = \begin{cases} M_L \bar{b}' \bar{R}' X_{ii} \phi_{ij} \Big|_{y=y_L, y=y_R} & ; \bar{M}_L \text{ in } y\text{-dir.} \\ 0 & \end{cases} \quad (87)$$

$$\frac{\partial \Delta Q}{\partial a_{zizj}} = \begin{cases} 0 & \\ -M_L \bar{a}' \bar{R}' \phi_{ixiz} Y_{zj} \Big|_{y=y_L, y=y_R} & ; \bar{M}_L \text{ in } x\text{-dir.} \end{cases} \quad (88)$$

$$\frac{\partial \Delta Q}{\partial a_{zij}} = \begin{cases} M_L \bar{a}' b X_{zij,x} \Phi_{y,zj} \Big|_{x=x_{Lm}} ; \bar{M}_L \text{ in } y\text{-Dir.} \\ -M_L \bar{a} b' \Phi_{x,zi} Y_{zj,y} \Big|_{y=y_{Lm}} ; \bar{M}_L \text{ in } x\text{-Dir.} \end{cases} \quad (89)$$

2.9 BOUNDARY CONDITIONS

The boundary conditions to be considered are the classical conditions of clamped, simply supported, or free. All combinations of these three may be specified, that is, any edge of a panel may be specified as clamped, supported, or free. In addition, any two opposite edges may have elastic moment restraint. A distinct advantage of the Rayleigh-Ritz method is that only the geometric boundary conditions (displacement and slope) need be satisfied to insure convergence of the solution (although convergence is improved by the satisfaction of the force boundary conditions). The Rayleigh-Ritz method does require a set of assumed modal functions, each of which satisfies the geometric boundary conditions. The functions chosen for this study are a series of simple beam vibration modes. These functions form a complete orthogonal set, and are all of the same general form. The use of these functions allows the normal deflection, w , to satisfy the following conditions:

- (1) clamped edge: $w = 0$; $w, n = 0$
- (2) simply supported edge: $w = 0$; $w,_{nn} = 0$
- (3) free edge: $w,_{nn} = 0$; $w,_{nnn} = 0$
- (4) elastically restrained edge: $w = 0$; $w,_{nn} = \alpha w,_{n}$

where n denotes a normal to the particular edge.

In addition to these conditions, which apply to flat or curved plates and the ends of a cylinder, the normal deflection in the circumferential direction of a cylinder is taken to be

$$Y_{zn} = \cos \frac{2n\pi y}{b} \quad (90)$$

An assumption has been made concerning the form of u and v . In the x direction, it is assumed that the mode shape function for v is the same as that for w and that the mode shape function for u is the derivative of that for w . Mathematically,

$$\begin{aligned} X_{1m} &= X_{3m,x} \\ X_{2m} &= X_{3m} \end{aligned} \quad (91)$$

Since the roles of u and v are reversed in the y direction, it is also assumed that

$$\begin{aligned} Y_{1n} &= Y_{3n} \\ Y_{2n} &= Y_{3n,y} \end{aligned} \quad (92)$$

These assumptions on the form of u and v allow them to always satisfy their required geometric boundary conditions. The specific form of the assumed modes and the evaluation of the necessary integrals is discussed further in Section 2.10.

In connection with the free-edge boundary condition, it must be noted that no geometric boundary conditions (deflection or slope) on the w displacement are specified. In addition, the force boundary conditions for the free edge of an anisotropic curved panel are so complicated as to be impossible to satisfy with modal functions as simple as beam modes. Thus, while the use of the beam mode functions for a free edge is intuitively acceptable, some difficulties are to be expected.

Often the boundary restraint provided by real structure is between the classical simple support and clamped conditions. Particularly in vibration problems, modeling the actual edge restraint can be important.

The inclusion of elastic moment restraint follows the approach used by Ashton in References [1], [5], and [6]. Basically, a beam mode function having the appropriate frequency and mode shape for the input elastic restraint parameters is calculated (Reference [1]). In addition, the potential energy absorbed by the boundaries must be combined with the usual strain energy.

If the edge restraint moment (in the x -direction) is assumed to be of the form

$$M_x \approx \alpha_x D_u w_{,x} \quad (93)$$

Then the potential energy contribution is of the form

$$\Delta V = \frac{1}{2} \int M_x w_{,x} \quad (94)$$

$$\Delta V = \frac{1}{2} \alpha_x D_{11} \int w_{,x}^2 dx \quad (95)$$

Generalization of this form at both x-edges and both y-edges gives rise to the following approximate potential energy increment:

$$\begin{aligned} \Delta V = \frac{1}{2} D_{11} \left[\alpha_x b \int_0^1 \bar{a}^3 w_{,x}^2 d\left(\frac{y}{b}\right) \Big|_{x=0} + \beta_x b \int_0^1 \bar{a}^3 w_{,x}^2 d\left(\frac{y}{b}\right) \Big|_{x=a} \right] \\ + \frac{1}{2} D_{22} \left[\alpha_y a b^3 \int_0^1 w_{,y}^2 d\left(\frac{x}{a}\right) \Big|_{y=0} + \beta_y a b^3 \int_0^1 w_{,y}^2 d\left(\frac{x}{a}\right) \Big|_{y=b} \right] \end{aligned} \quad (96)$$

where

$$\begin{aligned} \alpha_x &= K_{x1} a / D_{11} \\ \beta_x &= K_{x2} a / D_{11} \\ \alpha_y &= K_{y1} b / D_{22} \\ \beta_y &= K_{y2} b / D_{22} \end{aligned} \quad (97)$$

and K_{x1} , K_{x2} , K_{y1} , K_{y2} are rotational spring constants (in-lb./rad/in) which characterize the support stiffness. The final form of the varied potential energy is

$$\frac{\partial \Delta V}{\partial a_{3ij}} = \frac{\partial \Delta V}{\partial a_{2ij}} = 0 \quad (98)$$

$$\begin{aligned} \frac{\partial \Delta V}{\partial a_{3ij}} = \sum_m \sum_n \left\{ \bar{a}^3 b D_{11} \psi_{y13j3m} \left[\alpha_x X_{3i,x} X_{3m,x} \Big|_{x=0} + \beta_x X_{3i,x} X_{3m,x} \Big|_{x=a} \right] + a b^3 D_{22} \psi_{x13i3m} \right. \\ \left. \left[\alpha_y Y_{3j,y} Y_{3n,y} \Big|_{y=0} + \beta_y Y_{3j,y} Y_{3n,y} \Big|_{y=b} \right] \right\} a_{3mn} \end{aligned} \quad (99)$$

2.10 EVALUATION OF INTEGRALS

As shown in Reference [1], the beam mode shapes can be written as a sum of four terms as follows:

$$Z_m(z) = \sum_{j=1}^4 C_{mj} \rho_{jm} \quad (100)$$

where

$$\begin{aligned} \rho_{1m} &= \cosh(\epsilon_m z) \\ \rho_{2m} &= \cos(\epsilon_m z) \\ \rho_{3m} &= \sinh(\epsilon_m z) \\ \rho_{4m} &= \sin(\epsilon_m z) \end{aligned} \quad (101)$$

and the C_{mj} are constants for the particular mode shape m and the appropriate boundary condition. The ϵ_m is the corresponding natural frequency of the m^{th} mode. The C_{mj} constants are tabulated in Reference [1]. The successive derivatives of $Z_m(z)$ are also of this form with changes in the C_{mj} due to the repeating nature of the derivatives of the ρ_{jm} . The z -notation used here is replaced by x or y depending on the plate direction being integrated.

With this special form of the beam mode shapes all of the various integrals may be obtained in a closed form. The detailed solution method is documented in Reference [1].

Since the u and v displacement functions are assumed to be of the same form as w or its derivatives, all of the functions used can be integrated by the same solution technique.

The definition of the integral terms used throughout the analysis to denote the product of two functions is

$$\psi_{z k i j m n} \equiv \int_0^1 Z_{i j, k z} Z_{m n, p z} dz \quad (102)$$

where the k subscript defines the number of derivatives as shown in Table I.

Table I. DEFINITIONS OF ℓ AND p VERSUS k

GIVEN	DEFINES	
k	ℓ	p
1	0	0
2	1	1
3	2	2
4	1	0
5	2	0
6	2	1

For example,

$$\psi_{x4, j3n} = \int_0^1 X_{ij,x} X_{3m} dx. \quad (103)$$

The notation used to denote those integrals in which two w-functions are integrated in the presence of a power term (Section 2.6) is

$$\Omega_{kijmn} \equiv \int_0^1 z^{k-1} Z_{3m, \ell z} Z_{3n, p z} dz \quad (104)$$

where $i = 1$ means that z stands for x and $i = 2$ means that z stands for y . The relationship between j on the left side and ℓ and p on the right side is given by Table II.

Table II. DEFINITIONS OF ℓ AND p VERSUS j

GIVEN	DEFINED	
j	ℓ	p
1	0	0
2	1	1
3	1	0

The notation used to denote a single mode integrated in the presence of a power is given by

$$\phi_{i2r_{gm}} \equiv \int_0^1 z^{i-1} Z_{gm,(r-1)z} dz \quad (105)$$

The only integral evaluations involving deviations from the solution format are the rigid body modes necessary for the simple-free and free-free boundary conditions.

For the simple-free case in the x-direction

$$X_{11} = \sqrt{3} \quad (106)$$

$$X_{21} = \sqrt{3} x$$

$$X_{31} = \sqrt{3} x$$

or in the y direction,

$$Y_{11} = \sqrt{3} y \quad (107)$$

$$Y_{21} = \sqrt{3}$$

$$Y_{31} = \sqrt{3} y$$

These mode functions must be combined with the standard form mode functions in a special integral table.

For the free-free boundary condition in the x-direction,

$$X_{11} = 0 \quad X_{12} = -2\sqrt{3}$$

$$X_{21} = 1 \quad X_{22} = \sqrt{3}(1-2x) \quad (108)$$

$$X_{31} = 1 \quad X_{32} = \sqrt{3}(1-2x)$$

or in the y-direction,

$$Y_{11} = 1 \quad Y_{12} = \sqrt{3}(1-2y)$$

$$Y_{21} = 0 \quad Y_{22} = -2\sqrt{3} \quad (109)$$

$$Y_{31} = 1 \quad Y_{32} = \sqrt{3}(1-2y)$$

As in the simple-free case, these mode functions must be combined with the standard form mode function in a special integral table.

SECTION III

ANALYTICAL AND EXPERIMENTAL

CORRELATION

The results of many problem solutions using Procedure SS8 are described in this section. During the development and checkout stages, runs were made to simulate rectangular beams and flat plates. These runs served to debug minor programming errors and build confidence in the solution techniques employed. Subsequent runs were made to compare with existing theoretical and experimental results for isotropic shell segments and cylinders. To test the laminated anisotropic capabilities of the program, it was necessary to perform an experimental test program and to borrow results from on-going composites programs. These tests brought program limitations to light, some of which were overcome and some of which remain.

3.1 STATIC DEFLECTION

The static deflection of an anisotropic plate was checked against Procedure RA5, now revised to be Procedure S00. Agreement was good in all cases. No experimental results for shells could be found, so an experimental program was undertaken.

Two types of tests were performed to assess static deflection capabilities. In performing the first set, done under the Fuselage Program, deflection of fully clamped curved panels under a uniform pressure load was sought. In performing the second set, done under the Dynamic Characteristics Program, Contract F33615-70-C-1837, the determination of the influence coefficients of cantilever curved panels was sought.

3.1.1 Fuselage Program Tests

All of the advanced composite curved plate specimens were laminated graphite-epoxy and fabricated according to drawing number FW6915067. All specimens had the same geometric configuration with respect to length, width and curvature; a sketch of a typical specimen is shown in Figure 5. Average thicknesses and laminate designs of the panels were the physical variables for this program.

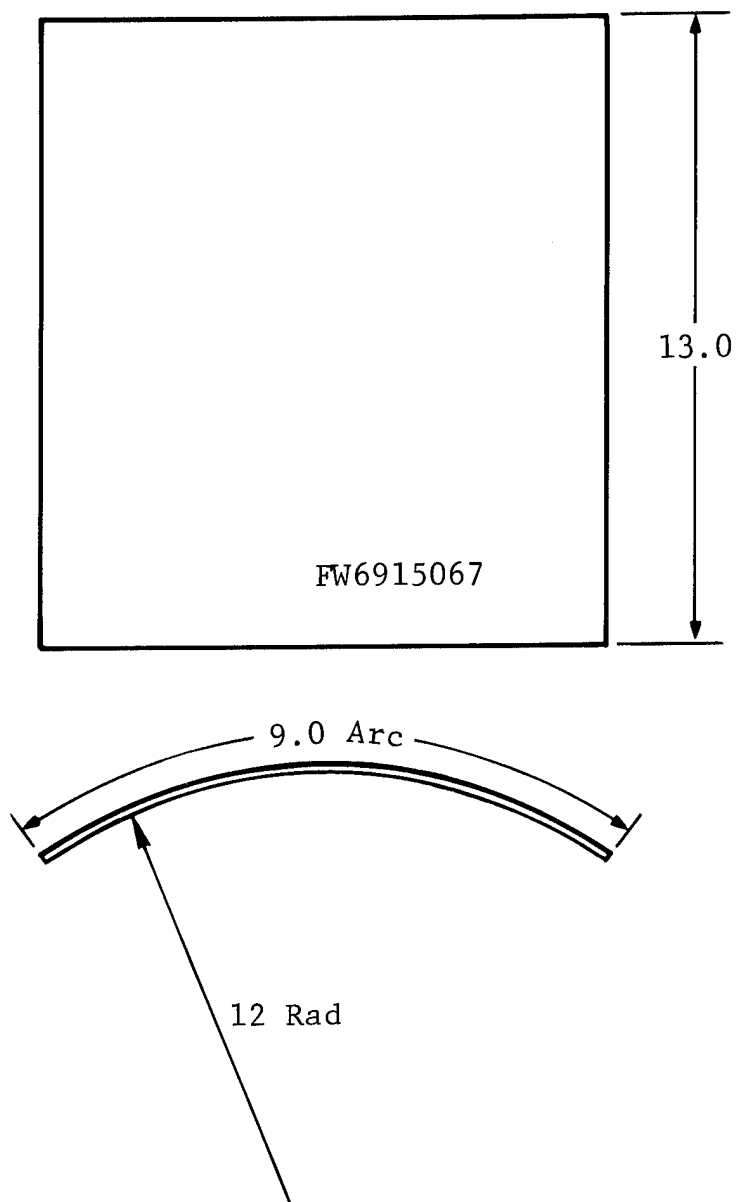


Figure 5 Fuselage Program Curved Panel Specimen Geometry

The specimens were hand-laid using Morganite II/4617 which has lamina properties of

$$E_1 = 20 \times 10^6 \text{ psi}$$

$$E_2 = 2.1 \times 10^6 \text{ psi}$$

$$G_{12} = 0.85 \times 10^6 \text{ psi}$$

$$\nu_{12} = 0.21$$

After their layup on a table, multiple-specimens were draped into a concave steel tool, bagged, and cured. The final operations were to net-trim the straight edges on a specially jugged table saw and net trim the curved edges with an end-mill.

The test fixture was not only used for the lateral pressure tests but was also used for compression buckling and vibration tests. It provided clamped-clamped boundary conditions for the curved edges and either clamped-clamped or simple-simple conditions for the straight edges. Clamping bars provided for variations in thickness of the panels. The test fixture is shown in Figures 6 through 9.

The set-up for the lateral load, or pressure, test utilized a rubber pressure bag mounted against the concave side of the panel. The back side of the bag was reacted with a stiffened pressure plate having the same contour as the panel and bolted to the fixture's side support (see Figures 10 through 13). The size of the bag, when deflated, was sufficient to cover the unsupported area of the panel without creasing or stretching, and thus provided an even load distribution over the face of the panel as air pressure was increased. During the pressure application, the load machine maintained a 100-pound edge load. After preliminary runs using a dial gage, an LVDT instrument measured the out-of-plane deflections as the pressure was increased. Measurements were recorded at increasing pressure increments. For these tests, the panel edges were fully clamped.

The test results and analytical predictions are shown in Table III in terms of center-deflection-per-psi of pressure. The load deflection plots are detailed in Reference [7]. Some analytical results with simply supported straight edges are included in Table III to indicate the sensitivity to boundary conditions. Correlation with elastically restrained edges was not attempted. It is obvious by the poor correlation that the fully clamped boundary condition was not properly modeled in the tests.

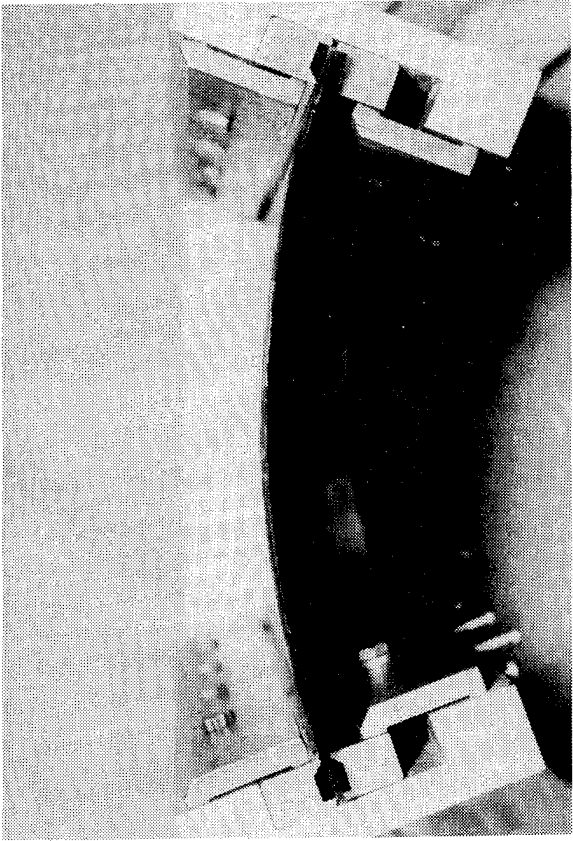


Figure 6 Top View of Test Fixture Showing Simply-Supported Sides

SMD7042

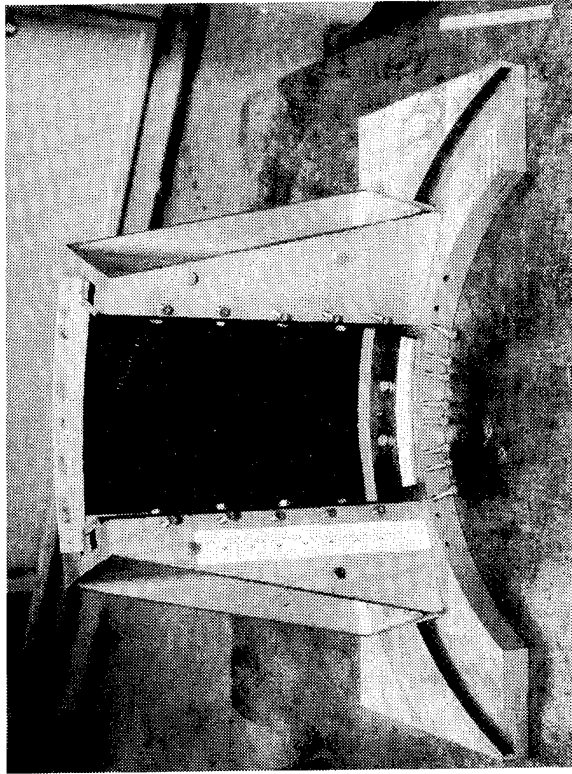


Figure 8 Front View of Test Fixture

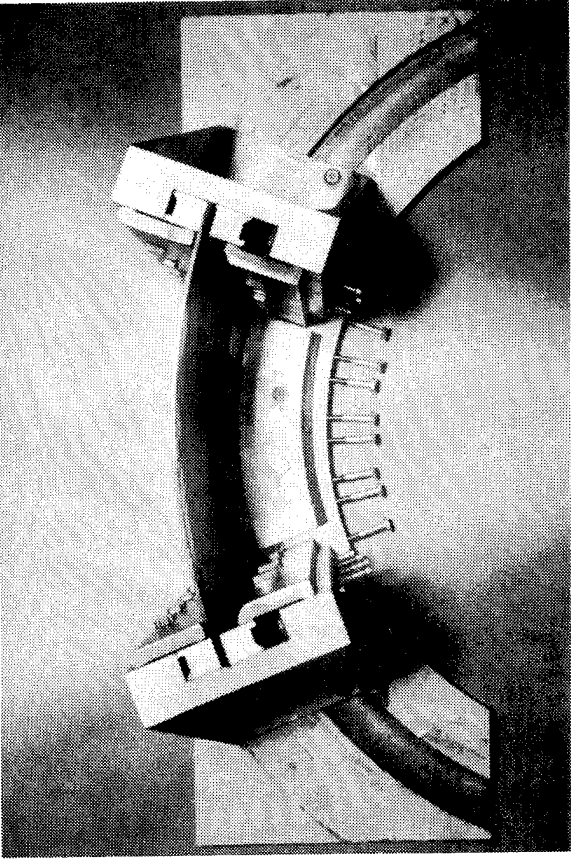


Figure 7 Top View of Test Fixture Showing Clamped Sides

SMD7043

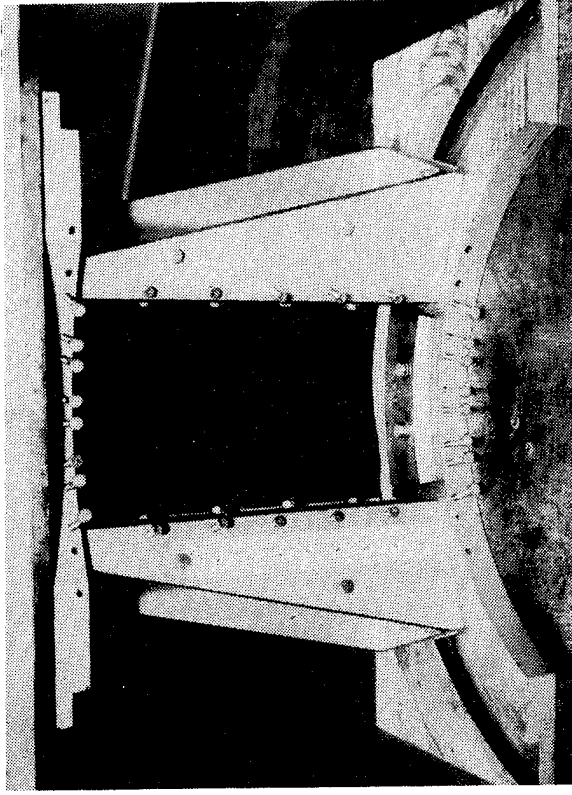


Figure 9 Front View of Test Fixture with Top Support Installed

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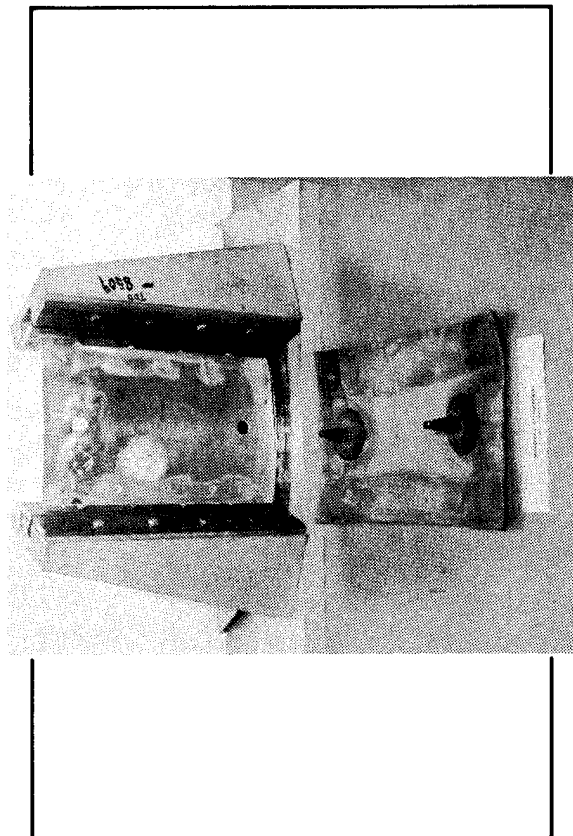


Figure 10 Backup Structure and Pressure Bag

SMD7045

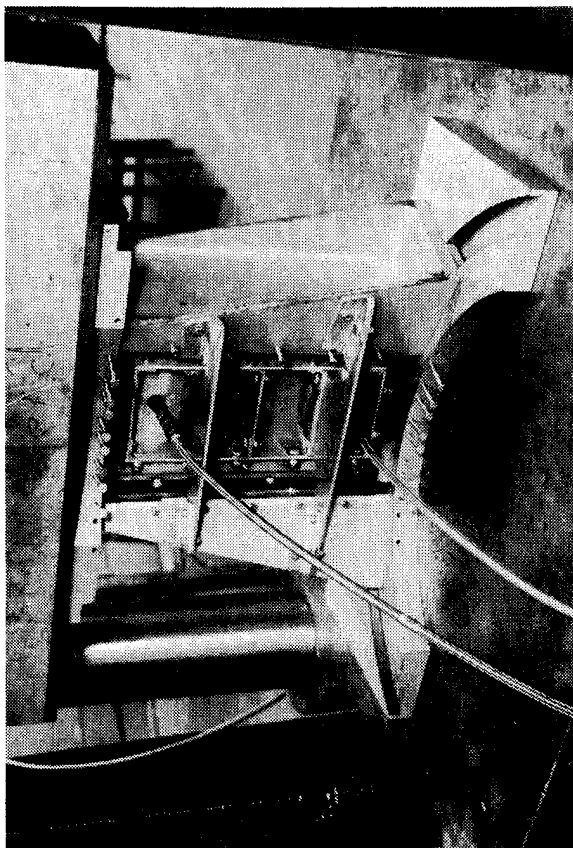


Figure 11 Assembled Pressure Fixture

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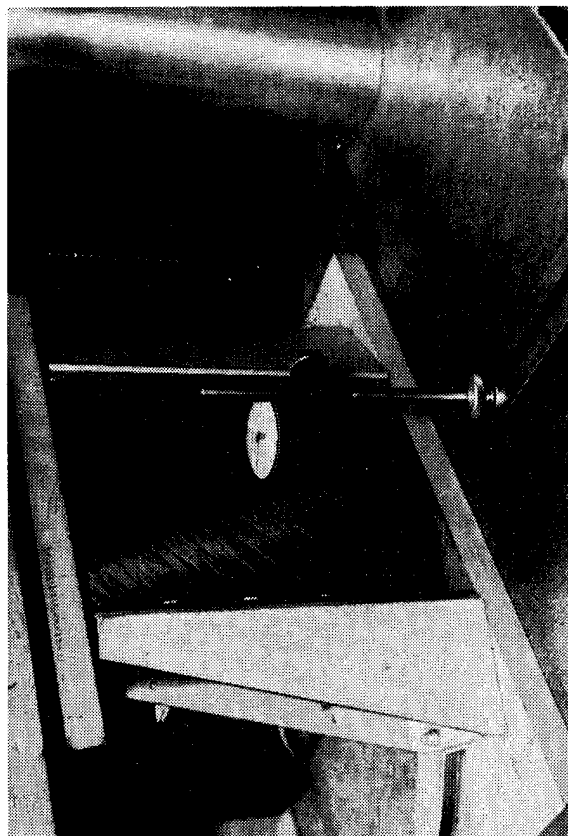


Figure 12 Deflection Measurement Setup

SMD7047

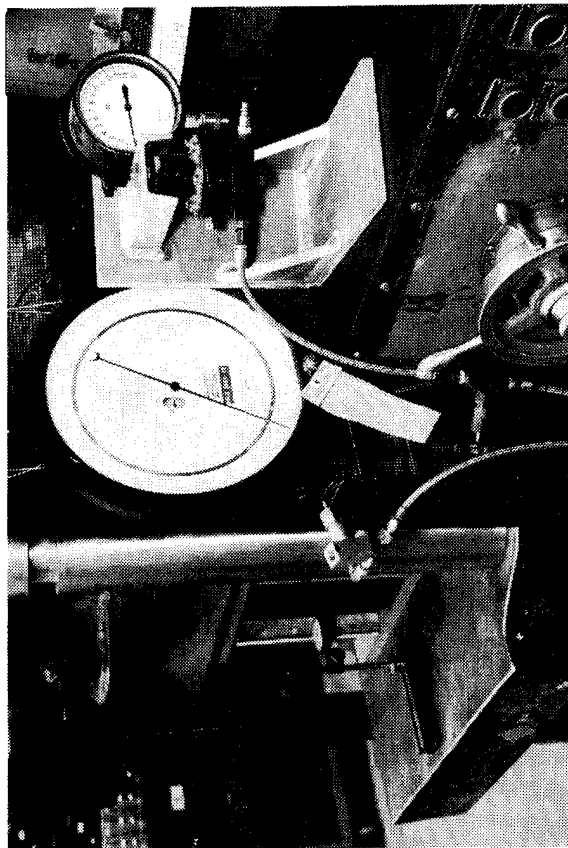


Figure 13 General View of Pressure Test Equipment

Table III PRESSURE TEST RESULTS

PANEL	LAMINATE	t	W/q mils/psi				
			EXP.	CCCC		CCSS	
				MAX.	CENTER	MAX.	CENTER
19A	[± 45] 2s	.0696	2.23	0.54	0.54		
19D	[± 45] 2s	.0719	2.25	0.52	0.52		
21A	[0, 90] s	.0289	9.20	0.83	0.83	36.2	5.6
23E	[± 45] s	.0307	5.01	1.25	0.89		
29E	[± 45] 3s	.0892	2.63	0.43	0.43		
33E	[± 45] 4s	.0591	4.8	0.67	0.67	4.3	1.6
35A	[-45] 12	.0902	2.87	0.45	0.45	2.1	1.5
39A	[+30] 8	.0580	4.70	1.35	1.29	5.2	0.44
41A	[+30] 12	.0900	3.03	0.91	0.91	2.3	1.1
45E	[0] 8	.0582	6.67	2.46	2.46	13.7	7.3
49A	[0, 90] 3s	.0880	3.88	0.28	0.28	6.7	6.7
51A	[± 30] s	.0296	7.52	2.76	1.67	19.8	-7.2
53A	[± 30] 2s	.0557	3.16	1.27	1.23	5.1	-.062
55A	[± 30] 4s	.0807	2.40	0.97	0.97	2.4	.78
59A	[0, ± 60] s	.0422	3.43	0.62	0.62	8.7	-1.02

3.1.2 Dynamic Characteristics Program Tests

Three curved cantilever panel specimens were designed to study the effect of curvature, in the presence of material anisotropy, on the response of composite structures. The specimens are designated 15, 16A, and 16B and are shown in Figures 14 through 16. All of the curved specimens have 15-inch spans and 24-ply, $[0/\pm 45_4/90]$ laminates. Specimen 15 has a 15-inch chord and a 36-inch radius, while Specimens 16A and 16B have 6-inch chords and 36- and 12-inch radii, respectively. A detailed explanation of these tests is given in Reference [13].

Some difficulty was experienced in conducting influence coefficient testing for the curved panels. A special fixture was developed with which the point loads normal to the undeflected middle surface of the specimen, i.e., in the radial direction, could be applied. Since vertical, free-floating Linear Variable Differential Transformers (LVDT's) were used for deflection measurements, the deflections were not measured radially. The LVDT's were inclined to the vertical as much as possible without compromising the accuracy of the instruments, but they could not be used in the radial direction. The maximum error in deflection caused by this setup was approximately two percent along each edge of the specimen.

Geometric nonlinearities caused by large chordwise cambering deflections were observed in these specimens, particularly in Specimen 15. This was indicated by the lack of symmetry in the off-diagonal terms of the influence coefficients as presented in Table IV. The notation DRR signifies Direct Rayleigh-Ritz, which is SS8. The notation USA denotes Unified Structural Analysis, a finite element procedure. It can be seen in the table that SS8 models the bending stiffness better than the finite element procedure, but does worse for the torsional stiffness. Generally, the correlation was rather poor, but no cause for this could be found. The problem is suspected to be that for these panels the chordwise boundary conditions are free-free, and the free-free modes are not operating properly.

3.2 STABILITY

The stability option of Procedure SS8 is the most important option available to the composites analyst and designer. The fact that composite shells exhibit complicated coupling between material and geometric stiffness effects precludes the use of simple design formulas.

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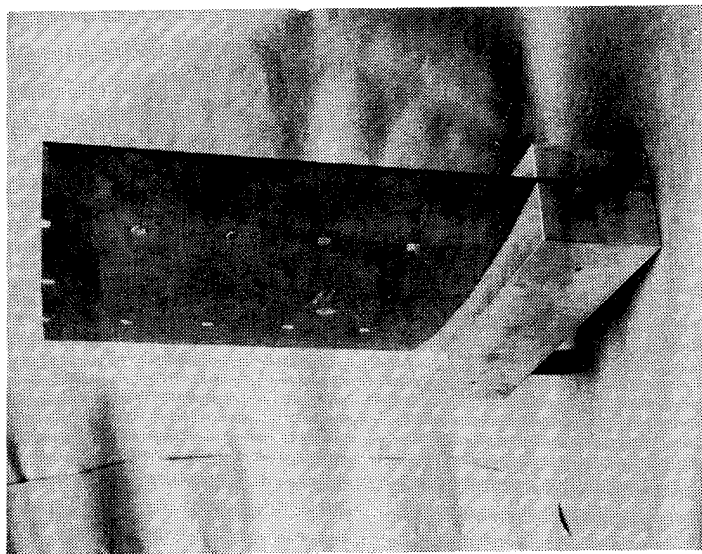


Figure 14 Curved Panel 15 -
Specimen 15

SMD7049

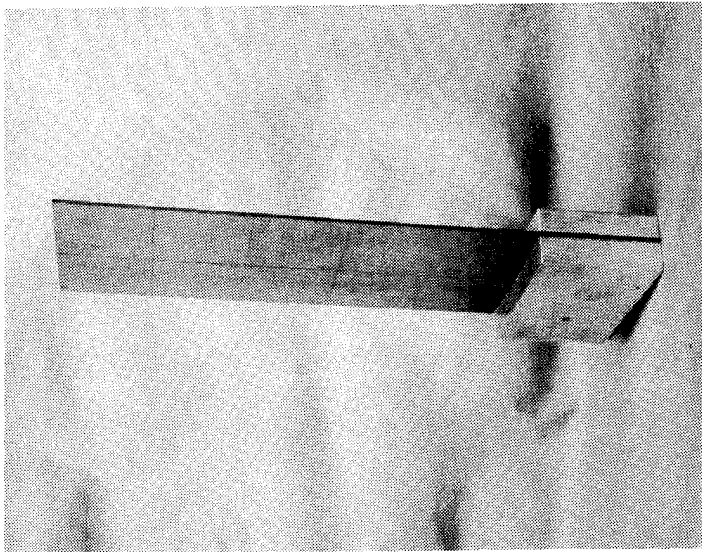


Figure 15 Curved Panel 16 -
Specimen 16A

SMD7050

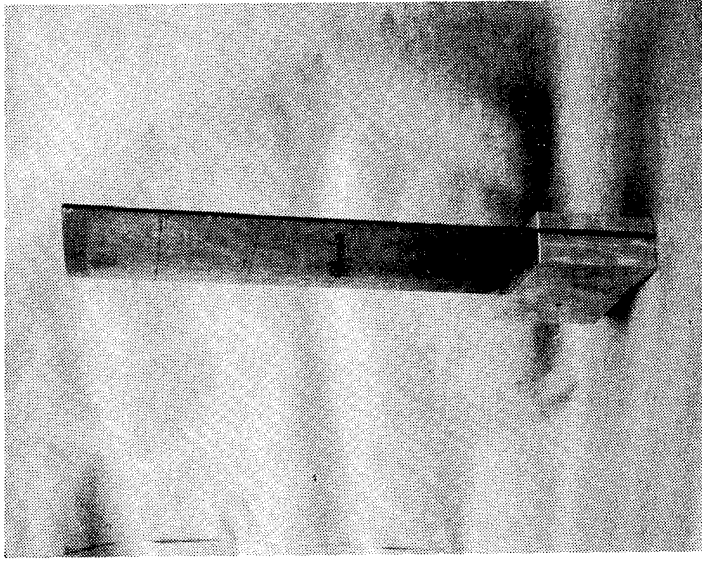


Figure 16 Curved Panel 16 -
Specimen 16B

Table IV FLEXIBILITY MATRIX ELEMENTS FOR

CURVED PANELS

SPEC. NO.	METHOD	INFLUENCE COEFFICIENTS AT THE TIP (IN./100 LB.)						AVERAGE % ERROR
		a(5,5)	a(5,10)	a(5,15)	a(10,10)	a(10,15)	a(15,15)	
15	DRR	0.90	.077	-.212	.200	.095	0.99	46.84
	EXP	1.37	.126	-.673	.242	.222	2.81	--
16*	DRR	18.60	16.14	13.84	14.81	13.32	12.77	--
	DRR	7.60	6.51	5.56	6.26	5.85	6.11	7.57
16A	USA	7.64	6.05	4.77	5.61	5.07	5.42	16.15
	EXP	8.74	7.54	6.08	6.46	6.26	6.08	--
16B	DRR	1.39	1.08	.846	1.18	1.16	1.49	28.60
	USA	1.58	0.863	.227	.934	.951	2.04	34.44
	EXP	2.03	1.30	.586	1.40	1.46	2.58	--

*Analysis of 16 as a flat plate for comparison purposes - not a test specimen.

The procedure was checked for composite plate stability with Procedure RA5 and compressive buckling of curved isotropic plates with Timoshenko [8]. Good agreement was obtained in both cases.

Compressive buckling of composite curved plates was correlated with an extensive test series especially instituted for this program. Shear buckling of curved plates was correlated with design development tests for the F-5 fuselage component.

3.2.1 Panel Compression Tests

The test panels and test fixture used in the compression tests were described previously in Section 3.1.1 and are shown in Figures 5-9.

Variations in the panels' curvature and warpage were slight and were corrected upon installation in the rigid loading fixture. Parallelism of loaded edges was determined on installation and corrected, where necessary, prior to a test run (parallelism to 0.003 in. over the edge length was assumed permissible).

Prior to assembly in the test fixture, each panel was bordered with Teflon tape, .003-inch thick, at all points that would be contacted by metal. This reduced the shear loads at the edges that resulted from high friction forces.

The structural similarity of the curved panel specimens was such that a reliable test procedure had to be developed and rigidly adhered to in order to clearly distinguish between the response of the various panels. To aid in this process, the same holding fixture, which accepted various panel thicknesses, was used in all vibration, pressure and buckling tests. A common procedure for installing the panels and aligning the set-up for test runs proved to be highly relevant in obtaining repeatable and satisfactory results. The salient features in installing the panel were to finger-tighten the bolts on the unloaded edge supports when simple support conditions were used, and wrench-tighten (to 60 in.-lb.) the bolts where clamped supports were used. In each case, the bolts were checked after two low-load excursions were applied (these loadings were used to seat the panel and remove most of the hysteresis).

Following the panel installation an axial load was applied using a 120,000-pound Baldwin Universal test machine.

In the buckling test, the information required was out-of-plane movement of the panel as the axial load was increased from 100 pounds to the critical load level. This movement was monitored by two methods: a linear differential transformer whose output was sent to a machine-mounted, x-y drum recorder and by the moire' shadow method.

The moire grid shadow method is an experimental procedure used to measure out-of-plane movements of a surface. Its principal advantage, especially for buckling tests, is that a full-field view of surface movements can be observed as the test progresses. A brief description of how the method works and the equipment used in its application on the panel studies are explained in the following paragraphs. The development of this procedure was based on the information obtained from Reference [9].

The essential pieces of equipment used in developing the moire patterns are a master grid pattern and a rigid transparent backing plate to hold the grid next to the panel. Locations of these elements on a typical test are sketched in Figure 17. In the experiments described in this report, a Kodak Carousel projector for the light source and a mounted plexiglas plate, formed to the same contour as the specimen, to hold the grid pattern in place was used. This is shown in Figures 18 and 19. With this set-up, the grid shadow was obliquely cast on the white surface of the panel. The observer, looking through the master grid, saw two grids superimposed, and as the panel points moved to, or away from, the master grid, the shadowed grid would move up or down by the amount

$$y = \delta \tan \alpha \quad (110)$$

When the panel deflected a distance equal to the pitch, ρ , of the master grid a dark band or fringe would appear. The shape and width of the fringe, as well as the number of fringes seen in an area were, therefore, a function of the change in curvature of the panel over the given area and the grid pitch. For example, a local buckle or a tight hump in the panel would display very narrow and closely spaced fringes, whereas an overall buckle would show very wide fringes which would be spaced far apart. On the other hand, if the grid pitch were halved, the sensitivity of the set-up would be doubled, or, twice as many fringes per unit deflection would be seen. The type of grid originally used in the buckling test was determined by assuming a

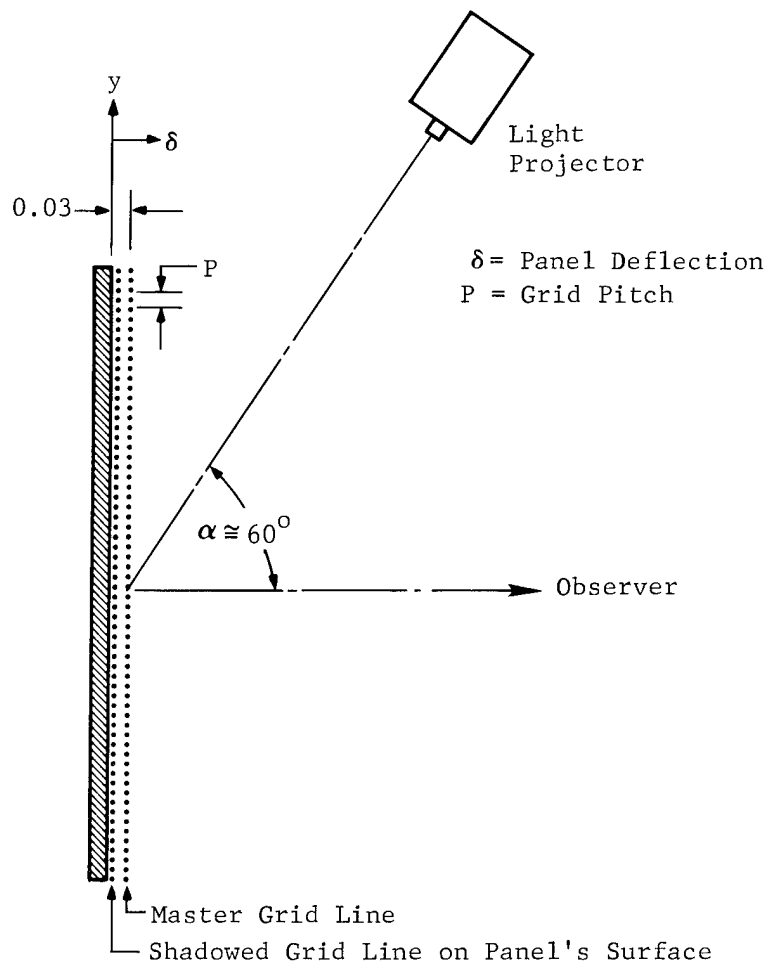


Figure 17 Test Set-Up Using the Moire Grid Shadow Method

SMD7052

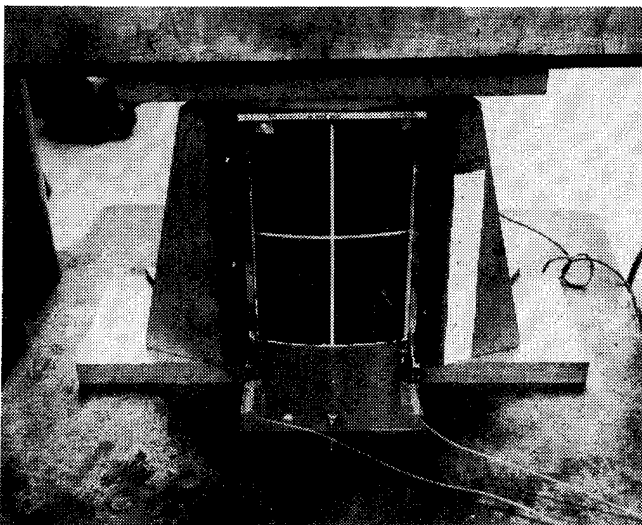


Figure 18 Rear View of Master Grid Plate and Support Structure

SMD7053

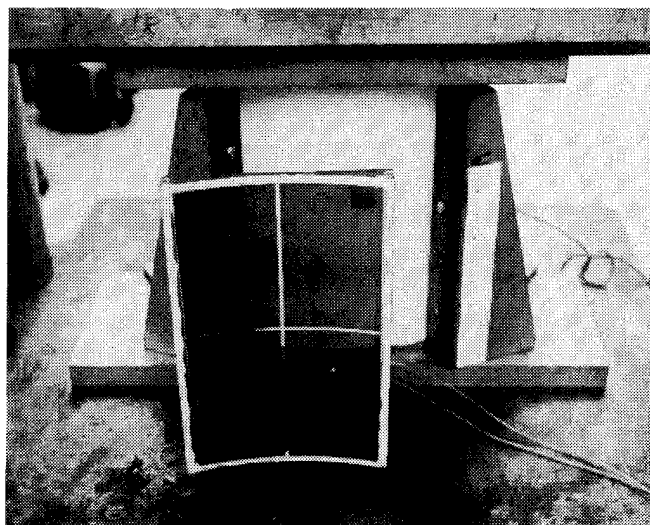


Figure 19 Master Grid as Mounted on Curved Plexiglass Surface

sensitivity of one fringe per 0.01-inch deflection would be desirable. Using the following equation

$$P = \delta \tan \alpha = 0.01 \tan 60^\circ \quad (111)$$

it was determined that 0.017 inch/grid lines, or approximately 50 lines per inch, would be acceptable. Buckling tests with this pattern showed promising results but a need for more sensitivity was required to obtain a better definition of the panel's deflection. Subsequent tests showed that grids having 100 lines/inch gave satisfactory results.

Upon installation, the differential transformer's plunger was lightly spring-loaded against the panel and displaced such that a null balance was achieved at the recorder. The location of the plunger relative to the panel was established by viewing the movements of the moire fringe pattern on the opposite face during the initial loadings. The area having the greatest fringe shift indicated the most out-of-plane activity, thus locating the plunger to obtain maximum deflections.

The moire patterns, which were developed on the white surface of the painted panel, were used to stop the loading when buckling was observed to be imminent. The characteristics of the pattern at this point were rapid fringe movement and the decreasing distance between adjacent fringes. When these conditions occurred, the load was immediately dumped and the maximum load attained was recorded.

The test setup and some representative moire photographs are shown in Figures 20 through 25. Many more photos are shown in Reference [7].

During the time the moire patterns were being observed, a simultaneous plot of the out-of-plane motion at an established point on the opposite panel face was made. This plot of deflection vs. load was provided by the test machine's integral recording system. These curves, an example of which is shown in Figure 26, were used to obtain Southwell plots (see Figure 27) which ultimately provided the critical buckling load of the panel. All Southwell plots are shown in Reference [7]. The Southwell method is a technique for obtaining the buckling load of a structure from experimental load-deflection information. The details of its implementation differ depending on the structure being

SMD7054

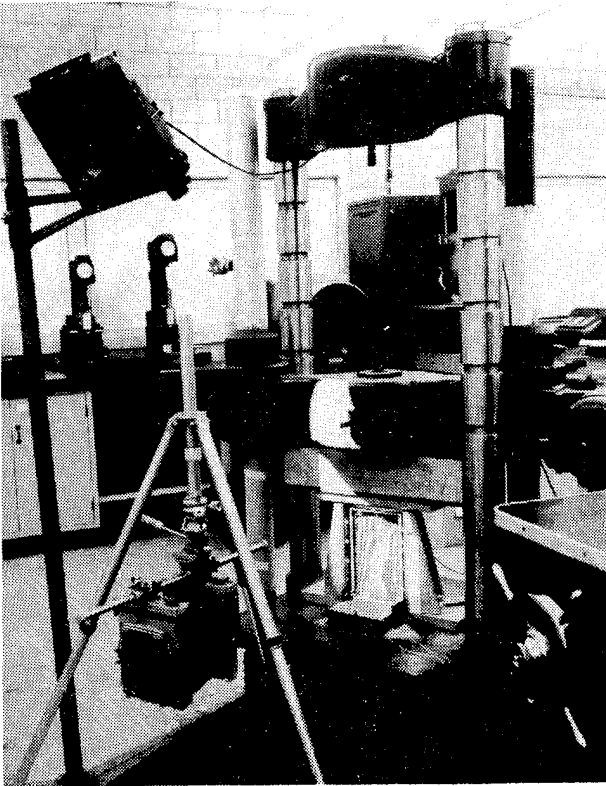


Figure 20 Test Setup for
Buckling Investigation

SMD7055

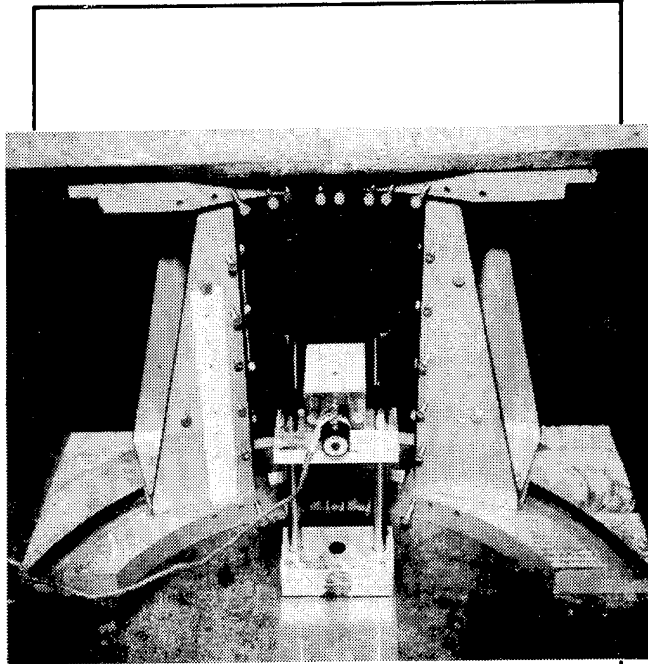


Figure 21 Rear View of
Buckling Setup

SMD7056

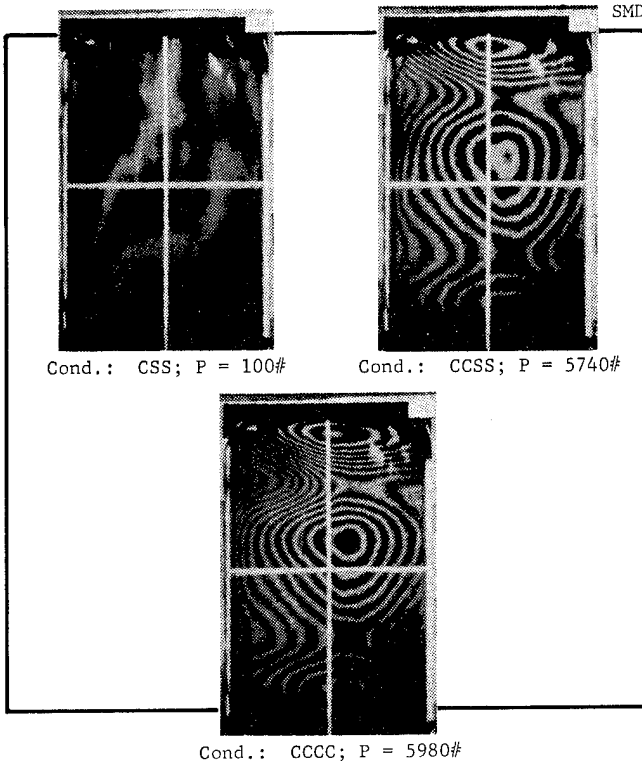


Figure 22 Moire Patterns
for -19E

SMD7057

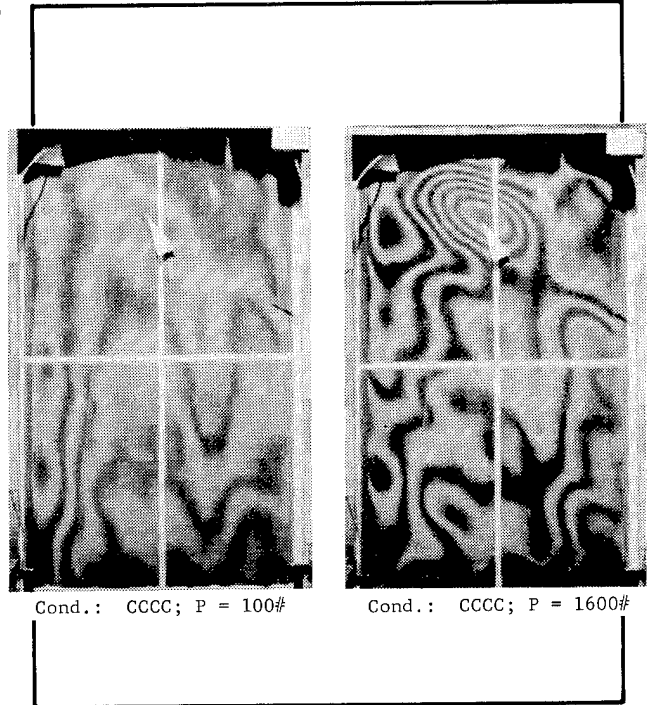


Figure 23 Moire Patterns
for -23C

SMD7058

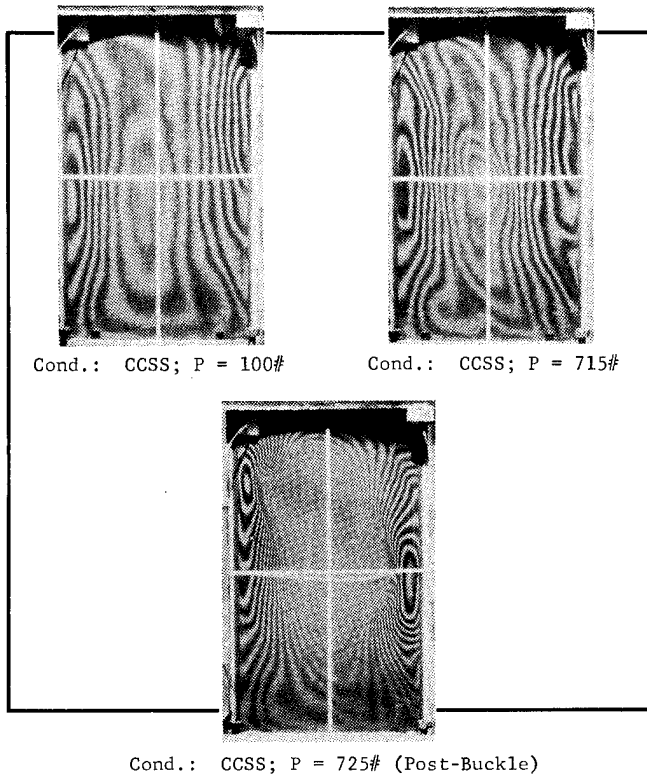


Figure 24 Moire Patterns for -37A

SMD7059

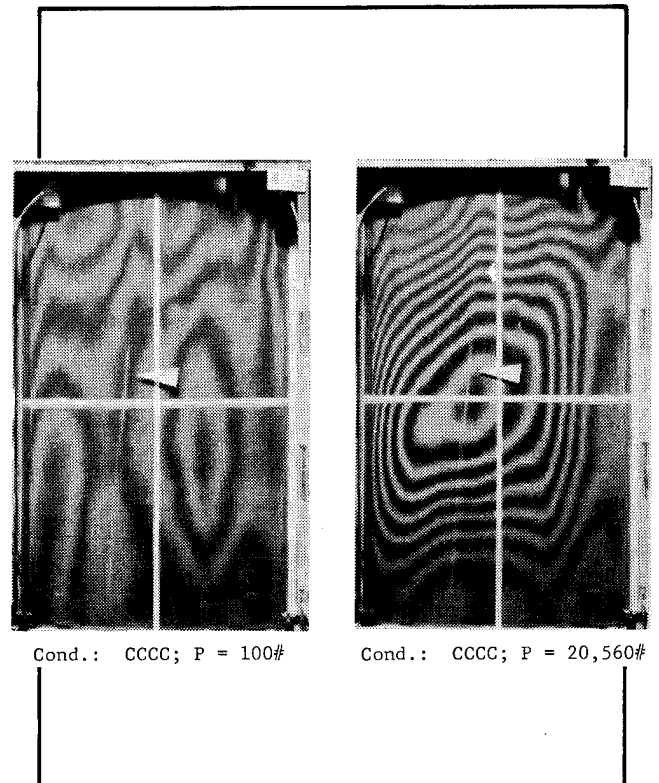


Figure 25 Moire Patterns for -47B

SMD7060

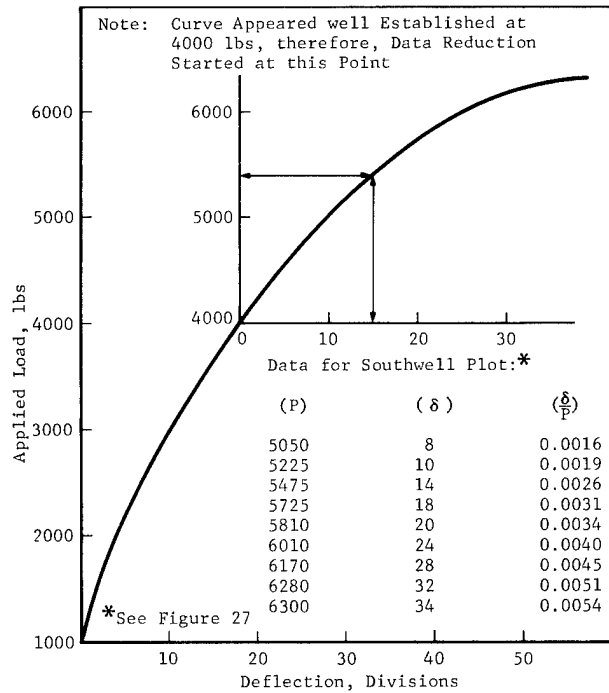


Figure 26 Typical Load-Deflection Curve

SMD7061

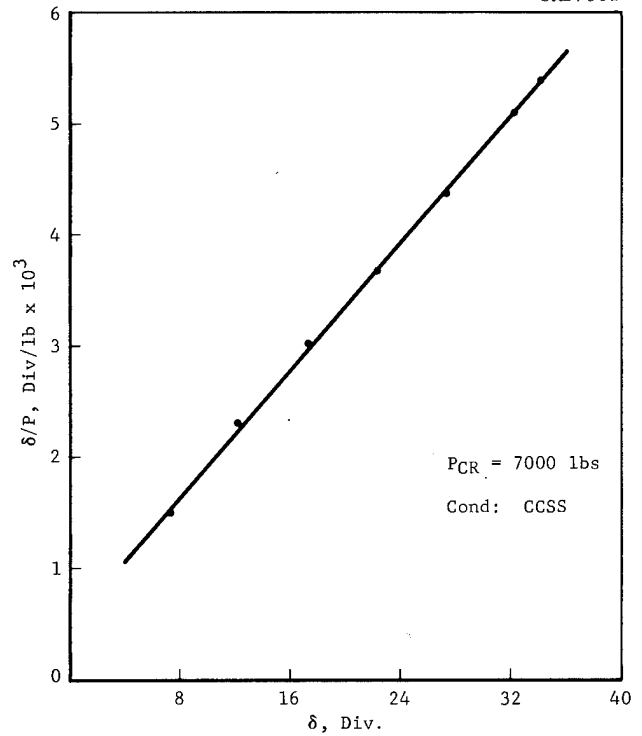


Figure 27 Southwell Curve for -33B

analyzed. It has been used for the buckling of columns, beam-columns, plates, and more recently, shells.

The theoretical basis for the use of the Southwell method for shells may be found in the works of Tenerelli and Horton [10] and Galletly and Reynolds [11]. A modification of the method of Tenerelli and Horton was used here.

Briefly, the moire grid-shadow method was used in the initial load cycle (below the buckling load) to find the point of maximum deflection on the shell. The linear variable differential transformer (LVDT) was then positioned to read deflections at that point. On subsequent load cycles, the load-deflection plot for that point was read out on the rotating drum of the test machine. A typical plot is shown in Figure 26.

The actual Southwell plots were generated by using a Hewlett-Packard 9100B calculator with a plotter. A program was written to take the load-deflection data as input and produce a plot of (deflection/applied load) versus deflection. Using the straight portion of this plot, the buckling load is calculated as the inverse of the slope of the line.

The moire procedure used in obtaining buckling loads of the various panels proved to be quite satisfactory and saved the majority of panels for future tests. There were, however, a number of panels that snapped into a post-yield buckle before loading could be stopped. When this condition occurred the panels were damaged to the extent that subsequent load cycles produced lower buckling loads. On the other hand, when the loads were dumped at initial evidence of buckling, subsequent loading cycles produced repeatable results. On a few panels, all three methods (moire, Southwell and snap-through) were used to obtain the critical buckling load. Comparing the results of these methods, using Table V, it can be seen that satisfactory correlation exists.

Curved aluminum panels were also tested to obtain base reference data for evaluating the edge restraints of the fixture. The results from these tests indicated that the clamping action on the loaded edges of the specimens was very near the classical value, however, the simple supports provided slightly more than classical restraint. This excess edge moment was 10 inch-pounds per radian per inch of length. This value was determined to be within acceptable limits and the tests proceeded without further alterations in set-up procedures.

TABLE V
BUCKLING RESULTS FOR GRAPHITE EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTI- FICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUPPORTED, CURVED EDGES CLAMPED						ALL EDGES CLAMPED			
				SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	KNOCKDOWN FACTOR		SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	
								EXP	SS8				
17A	[0/90]2s	0.0592	0.0021		6680	7323	7200	.93	.80			6740	7088
17B	[0/90]2s	0.0528	0.0036		4865		5900	.83	.73				
19A	[±45]2s	0.0696	0.0030		8660	8750	12400	.70					
19B	[±45]2s	0.0707	0.0030	9000		9050	12700	.71	.61				
19C	[±45]2s	0.0713	0.0025		8820		13000	.68	.62				
19D	[±45]2s	0.0719	0.0019		8760		13200	.66	.59				
19E	[±45]2s	0.0598	0.0026		5740		9500	.60	.44			5980	
21A	[0/90]s	0.0289	0.0015		985	1125	1530	.64	.84		1195	1175	
21B	[0/90]s	0.0282	0.0013		925		1470	.63	.83				
23A	[±45]s	0.0354	0.0025	1870	1870	1914	4000	.47					
23B	[±45]s	0.0362	0.0033	1610		1695	4180	.38	.35				
23C	[±45]s	0.0340	0.0018		1590	1624	3780	.42	.35			1625	
23D	[±45]s	0.0359	0.0025	1850			4130	.45	.47				
23E	[±45]s	0.0307	0.0013		1280	1314	2950	.43	.46				

TABLE V, Cont'd.

BUCKLING RESULTS FOR GRAPHITE-EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTI- FICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUPPORTED, CURVED EDGES CLAMPED						ALL EDGES CLAMPED		
				SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	KNOCKDOWN FACTOR		SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.
								EXP	SS8			
27	(Alum)	0.0630		17000			23500	.72	.48			
29C	[+45] 3s	0.1045	0.0027		17760	23125	27700	.64	.63			
29D	[+45] 3s	0.1066	0.0037			21889	29200	.62	.62			
29E	[+45] 3s	0.0892	0.0040		10780		19700	.55	.52			
31A	[+45] 2s	0.0343	0.0024	1550	1550	1759	2800	.55	.16			
31B	[+45] 2s	0.0356	0.0038		1505	1704	2900	.52		1480		
31C	[+45] 2s	0.0353	0.0017		1520		2900	.52				
31D	[+45] 2s	0.0347	0.0021	1500			2800	.54				
31E	[+45] 2s	0.0289	0.0015	975			2000	.49	.33			
33A	[+45] 4s	0.0692	0.0031	7050			11700	.60				
33B	[+45] 4s	0.0679	0.0024	6340	6300	7000	11300	.56	.50			
33C	[+45] 4s	0.0622	0.0030		5700	5750	9300	.61	.24			
33D	[+45] 4s	0.0709	0.0035		6620		12200	.54	.29			
33E	[+45] 4s	0.0591	0.0024	4000	4000	4021	8300	.47				

TABLE V, Cont'd.
BUCKLING RESULTS FOR GRAPHITE-EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTI- FICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUPPORTED, CURVED EDGES CLAMPED					ALL EDGES CLAMPED		
				SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	KNOCKDOWN FACTOR	SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.
35A	[+45] _{6s}	0.0902	0.0049		9180	10270	20000	.46	.36		
37A	[-30] _{2s}	0.0282	0.0071	725	715		2200	.33	.41		
39A	[-30] _{4s}	0.0580	0.0022		4730		8000	.59	.73	4985	
41A	[-30] _{6s}	0.0900	0.0018		10460	10435	17800	.59	.84		
43A	[0] _{2s}	0.0364	0.0020		1315	1575	2100	.63	.68		
43C	[0] _{2s}	0.0368	0.0032	1540			2100	.73	.64		
43D	[0] _{2s}	0.0362	0.0024	1315	1290	1418	2100	.63	.64		
43E	[0] _{2s}	0.0294	0.0020	945			1800	.53	.49		
45A	[0] _{4s}	0.0701	0.0018		5580	6468	8700	.64	.67	7300	7704
45B	[0] _{4s}	0.0699	0.0028	5735			8700	.66	.62		
45C	[0] _{4s}	0.0696	0.0014		5300	5553	8700	.56	.66		
45D	[0] _{4s}	0.0695	0.0014		5080	5610	8700	.58	.66	6600	7123
45E	[0] _{4s}	0.0582	0.0029		5105	5122	5800	.88	.64		
47A	[0] _{6s}	0.1064	0.0030		16500	18362	21600	.76	.61		

TABLE V, Cont'd.

BUCKLING RESULTS FOR GRAPHITE-EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTI- FICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUPPORTED, CURVED EDGES CLAMPED				ALL EDGES CLAMPED			
				SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	KNOCKDOWN FACTOR	EXP	SS8	SOUTHWELL LOAD LBS.
47B	[0]6s	0.1039	0.0027		18000	19598	20600	.85	.62		21538
47C	[0]6s	0.1013	0.0035		16760	17812	19600	.56	.59		
49A	[0/90]3s	0.0880	0.0026		14680	16625	16200	.91	.79		
49B	[0/90]3s	0.0781	0.0034		12460	14118	12500	.99	.79		
51A	[+30]s	0.0296	0.0019		1150		2630	.44	.55		
53A	[+30]2s	0.0557	0.0023		5405	5818	7750	.70	.70		
55A	[+30]3s	0.0807	0.0026		12900	13860	17000	.76	.68		

TABLE V, Cont'd.

BUCKLING RESULTS FOR GRAPHITE-EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTIFICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUP- PORTED CURVED EDGES CLAMPED				ALL EDGES CLAMPED				
				SNAP MOIRE' LOAD LBS. LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	KNOCKDOWN FACTOR		SNAP LOAD LBS.	MOIRE' LOAD LBS.	SOUTHWELL LOAD LBS.	
							EXP	SS8				
57A	[0/-45/90/+45] _s	0.0574	0.0018		8240	8966	10000	.82	.90			
57B	[0/-45/90/+45] _s	0.0499	0.0028		6640	6691	7500	.86	.80			
57C	[0/-45/90/+45] _s	0.0516	0.0023		6460	6897	7900	.82	.85		7100	
57D	[0/-45/90/+45] _s	0.0499	0.0028		5820	6416	7500	.78	.80			
57E	[0/-45/90/+45] _s	0.0524	0.0032		6960	7194	8250	.84	.78			
59A	[0/±60] _s	0.0422	0.0010		3355	3595	5200	.64	.92		3730	3846
59B	[0/±60] _s	0.0392	0.0018		3390	3626	4450	.76	.84	3685	3530	
59C	[0/±60] _s	0.0382	0.0026		3400	3582	4200	.81	.79			
59D	[0/±60] _s	0.0397	0.0020		3000	3170	4600	.65	.82			
59E	[0/±60] _s	0.0390	0.0028		3460	3846	4420	.78	.76			
61A	[0/±60] _{2s}	0.0870	0.0026		22950	23871	27400	.84	.76			
61B	[0/±60] _{2s}	0.0794	0.0041		18080	18571	22800	.79	.70			
61C	[0/±60] _{2s}	0.0785	0.0034		16920	18136	22300	.76	.71			

TABLE V, Concluded

BUCKLING RESULTS FOR GRAPHITE-EPOXY COMPOSITE CURVED PANELS

PANEL NUMBER	LAMINATE IDENTIFICATION	MEAN THICKNESS INCHES	THICKNESS MEAN DEVIATION INCHES	VERTICAL EDGES SIMPLY SUP- PORTED CURVED EDGES CLAMPED			ALL EDGES CLAMPED		
				SNAP LOAD LBS.	SOUTHWELL LOAD LBS.	SS8 LOAD LBS.	SNAP LOAD LBS.	MOIRE LOAD LBS.	SOUTHWELL LOAD LBS.
61D	[0/±60]₂s	0.0782	0.0029	18800	19000	22300	.84	.74	
67	Alum	0.0320		3825		8500	.45		
69A	[0₂/±45]ₛ	0.0512	0.0026	5500	5663	8150	.68	.63	
69B	[0₂/±45]ₛ	0.0521	0.0019	5410	5114	8150	.62	.70	
69C	[0₂/±45]ₛ	0.0488	0.0028	5385	5604	7400	.73	.61	
69D	[0₂/±45]ₛ	0.0504	0.0025	5310	5581	7900	.67	.63	
69E	[0₂/±45]ₛ	0.0506	0.0034	5700	5882	8000	.73	.58	
71A	[0/±45]ₛ	0.0408	0.0021	2930	3187	4870	.60	.75	
71B	[0/±45]ₛ	0.0394	0.0019	2595	2803	4540	.57	.76	
71C	[0/±45]ₛ	0.0394	0.0021	2810	2910	4540	.62	.75	
71D	[0/±45]ₛ	0.0397	0.0020	2610	2942	4600	.57	.75	
71E	[0/±45]ₛ	0.0390	0.0025	2310	3333	4440	.70	.71	

During the course of the buckling tests, a documentary film was generated showing the installation and testing of a typical graphite panel. This film, which is retained in the Composite Structures Engineering Group, provides a graphic display of the moire pattern development as the panel was loaded and the onset of buckling.

Table V includes the SS8 classical buckling load predictions for each panel as well as the knockdown factor predicted by SS8 based on the standard deviation in thickness of each panel. For the aluminum panels, the knockdown factor is found from the equation (Reference [50])

$$\gamma = 1 - 0.901(1 - e^{-\frac{1}{12} \sqrt{R/t}}) \quad (112)$$

Although the knockdown factor based on the standard deviations of the panel thickness is not always conservative, it does indicate trends fairly well and should be investigated further.

Figure 28 is a summary of all the buckling data obtained in terms of the ratio between experimental and classical buckling load versus R/t . In Figures 29 through 38, the results according to laminate orientation are separated to show that some types of laminates seem to be much more sensitive to imperfections than others and that the thin laminates are the most sensitive.

3.2.2 Panel Shear Tests

Two test specimens, one graphite-epoxy and one boron-epoxy, were used in this investigation. Each specimen consisted of an assembly of four quarter-circle panels nine inches long on a 12-inch radius, as shown in Figure 39. In both cases the basic test panels consisted of eight plies oriented at ± 45 degrees to the cylinder axis.

Loads were applied to the test apparatus to produce pure torsion. Strain gages were installed on both the inner and outer surfaces of each panel. Electrical deflection gages were installed inside the specimens to record radial deflection of the panels.

Testing was directed toward (1) the determination of the buckling stress and (2) the examination of the post-buckling strength. Determination of buckling stresses required loading the specimens to 75-90 percent of the buckling load. This

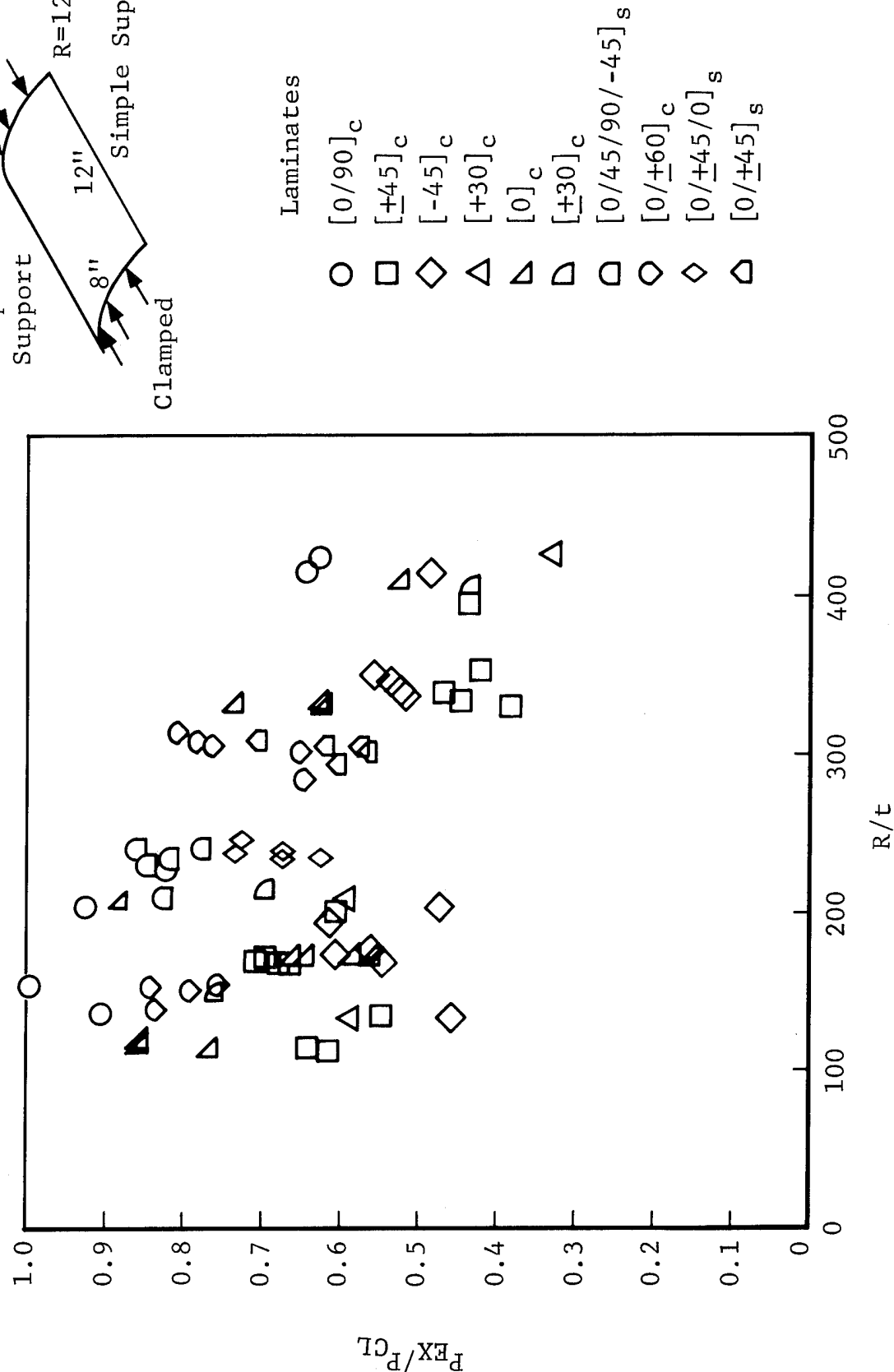
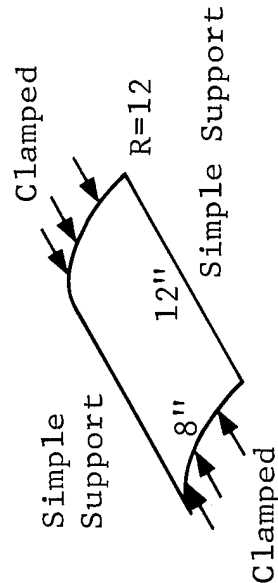


Figure 28 Curved Panel Buckling Summary

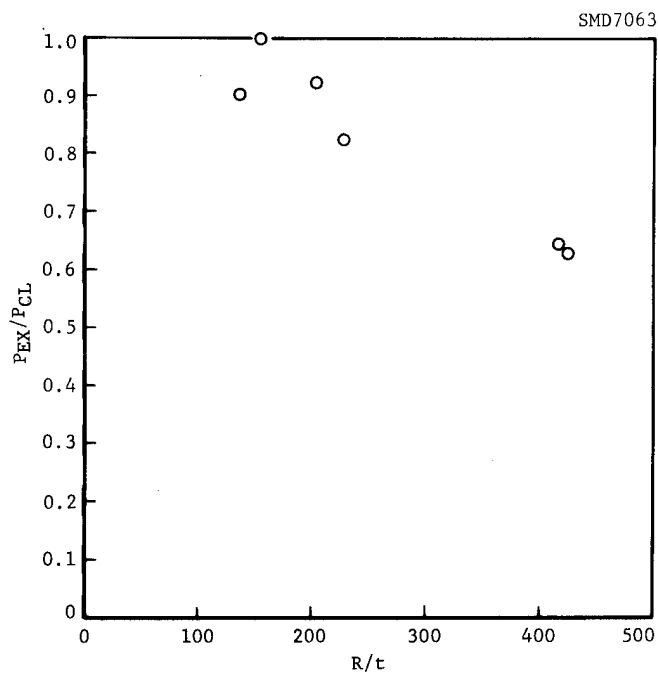


Figure 29 Curved Panel Buckling
Plot: $[0/90]_c$

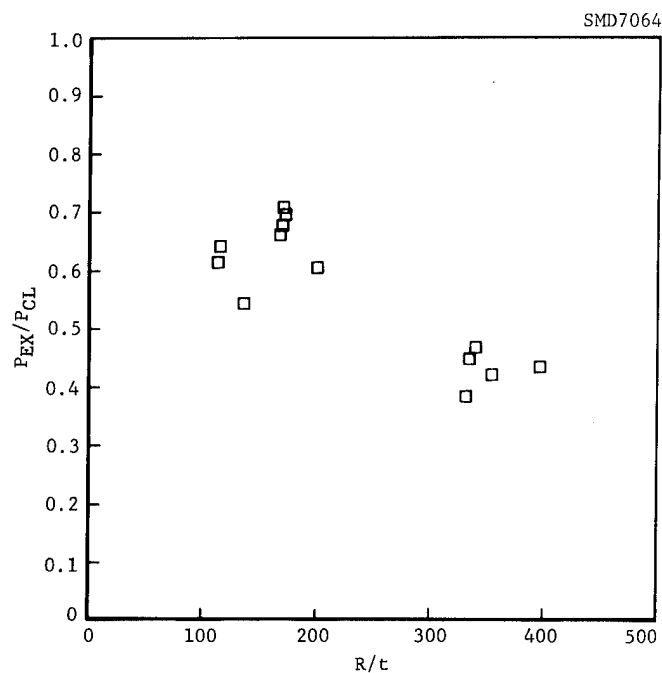


Figure 30 Curved Panel Buckling
Plot: $[+45]_c$

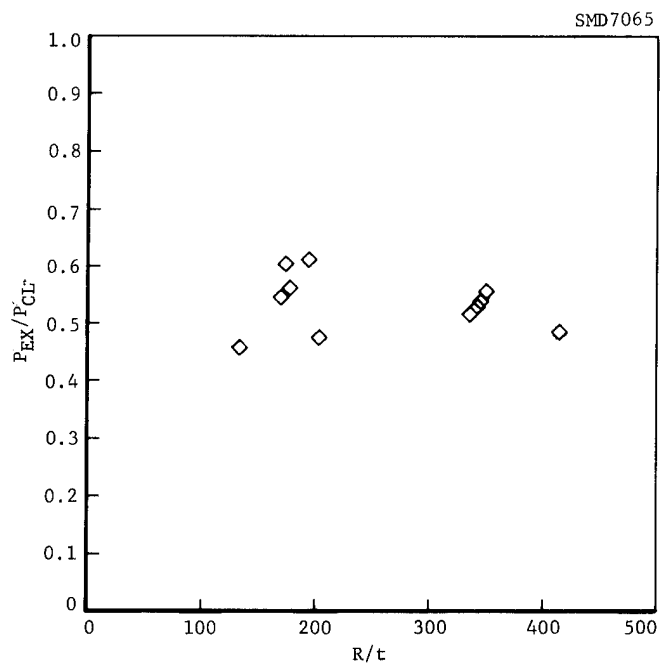


Figure 31 Curved Panel Buckling
Plot: $[-45]_c$

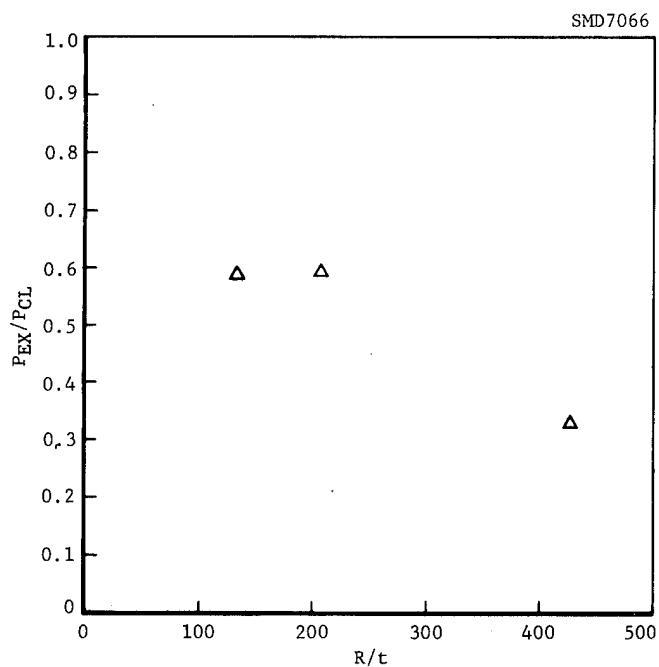


Figure 32 Curved Panel Buckling
Plot: $[+30]_c$

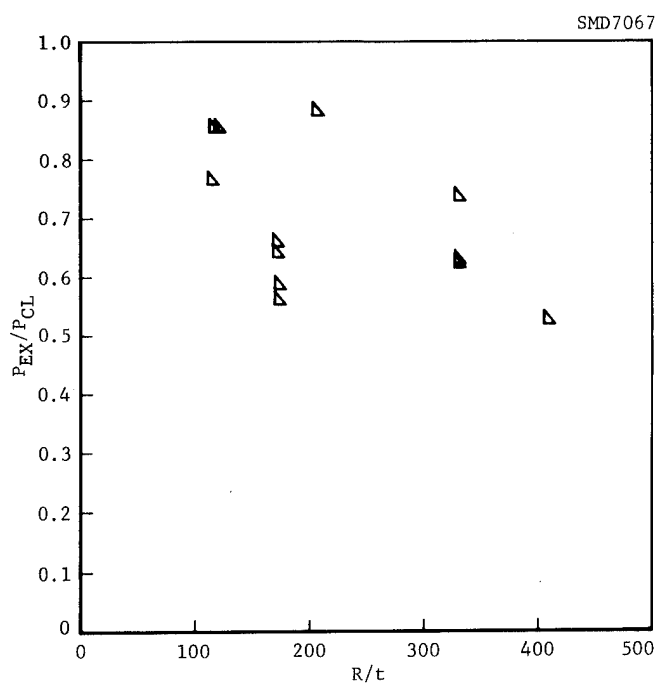


Figure 33 Curved Panel Buckling
Plot: $[0]_c$

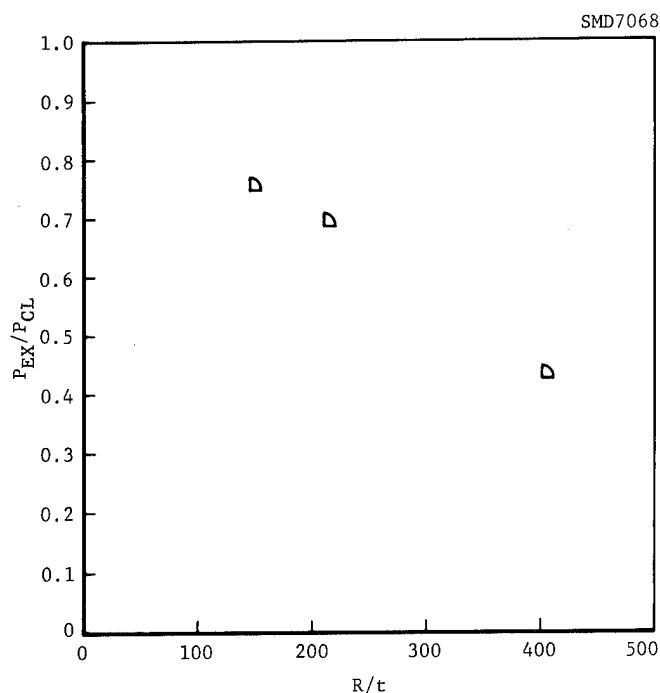


Figure 34 Curved Panel Buckling
Plot: $[\pm 30]_c$

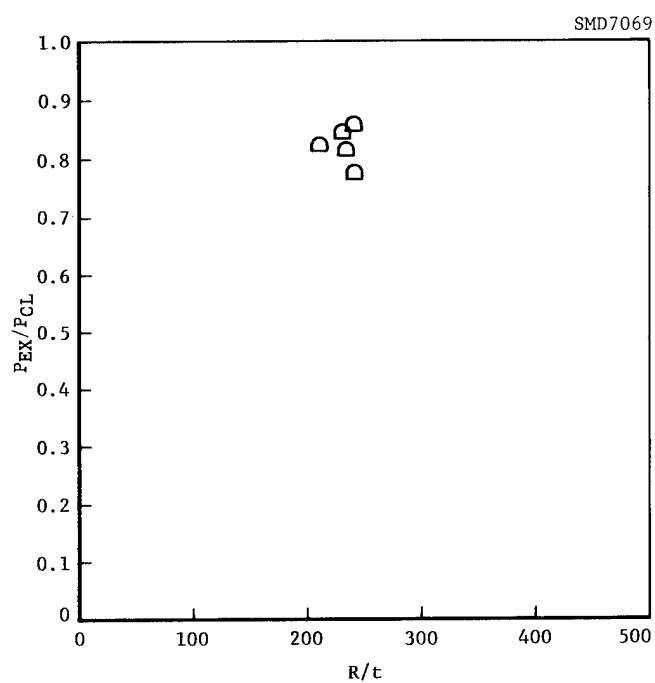


Figure 35 Curved Panel Buckling
Plot: $[0/45/90/-45]_s$

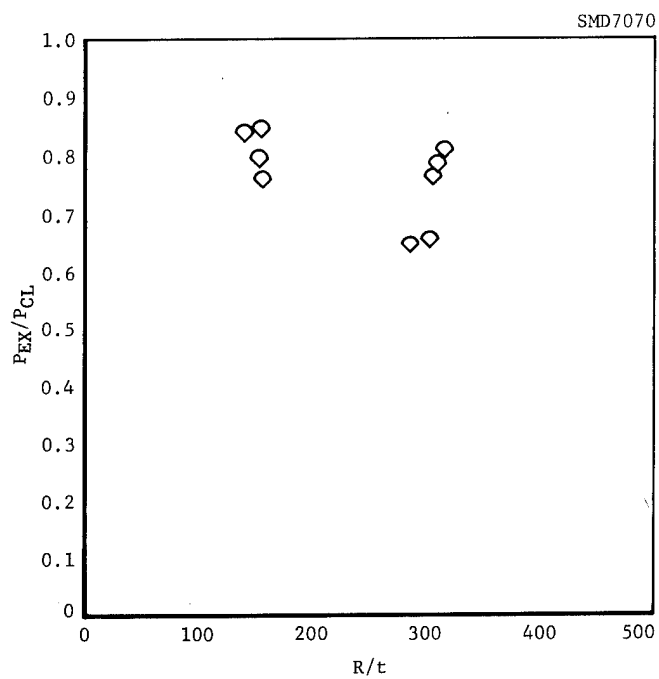


Figure 36 Curved Panel Buckling
Plot: $[0/\pm 60]_c$

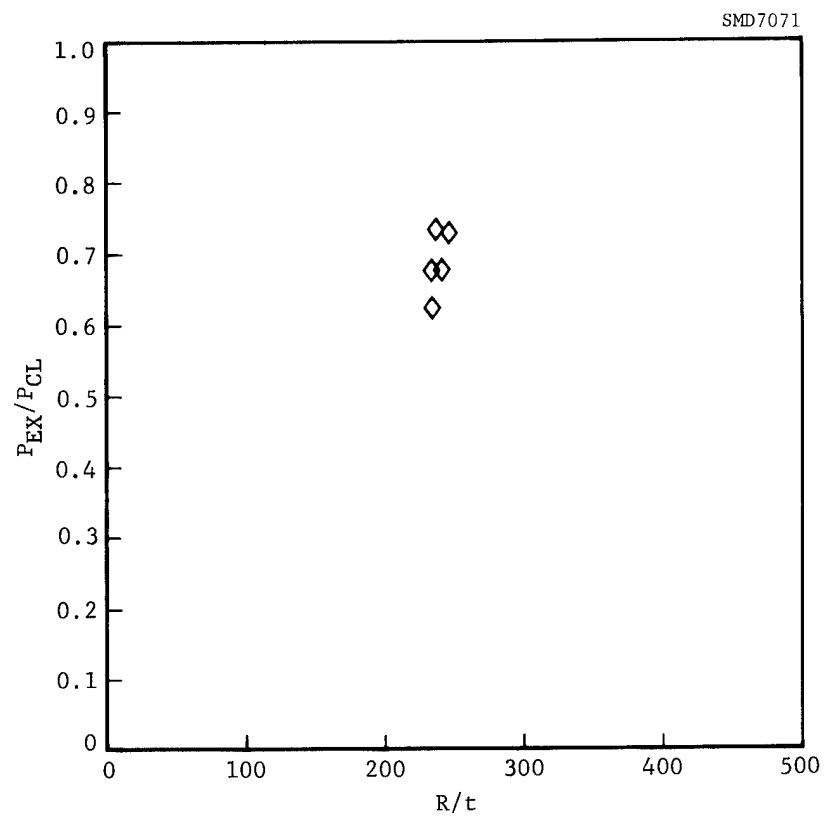


Figure 37 Curved Panel Buckling Plot: $[0/\pm 45/0]_s$

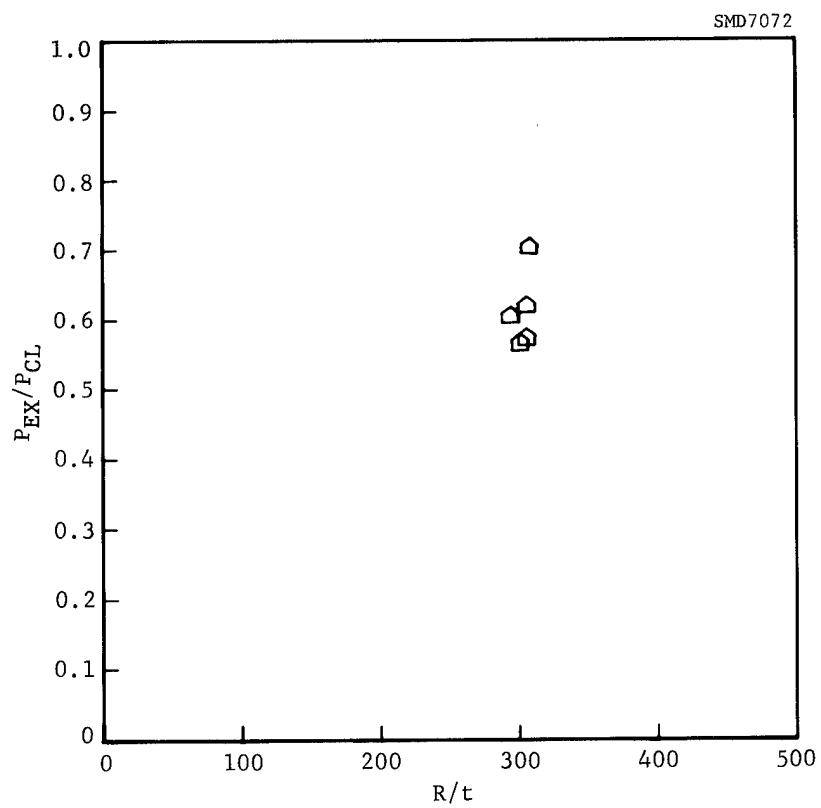


Figure 38 Curved Panel Buckling Plot: $[0/\pm 45]_s$

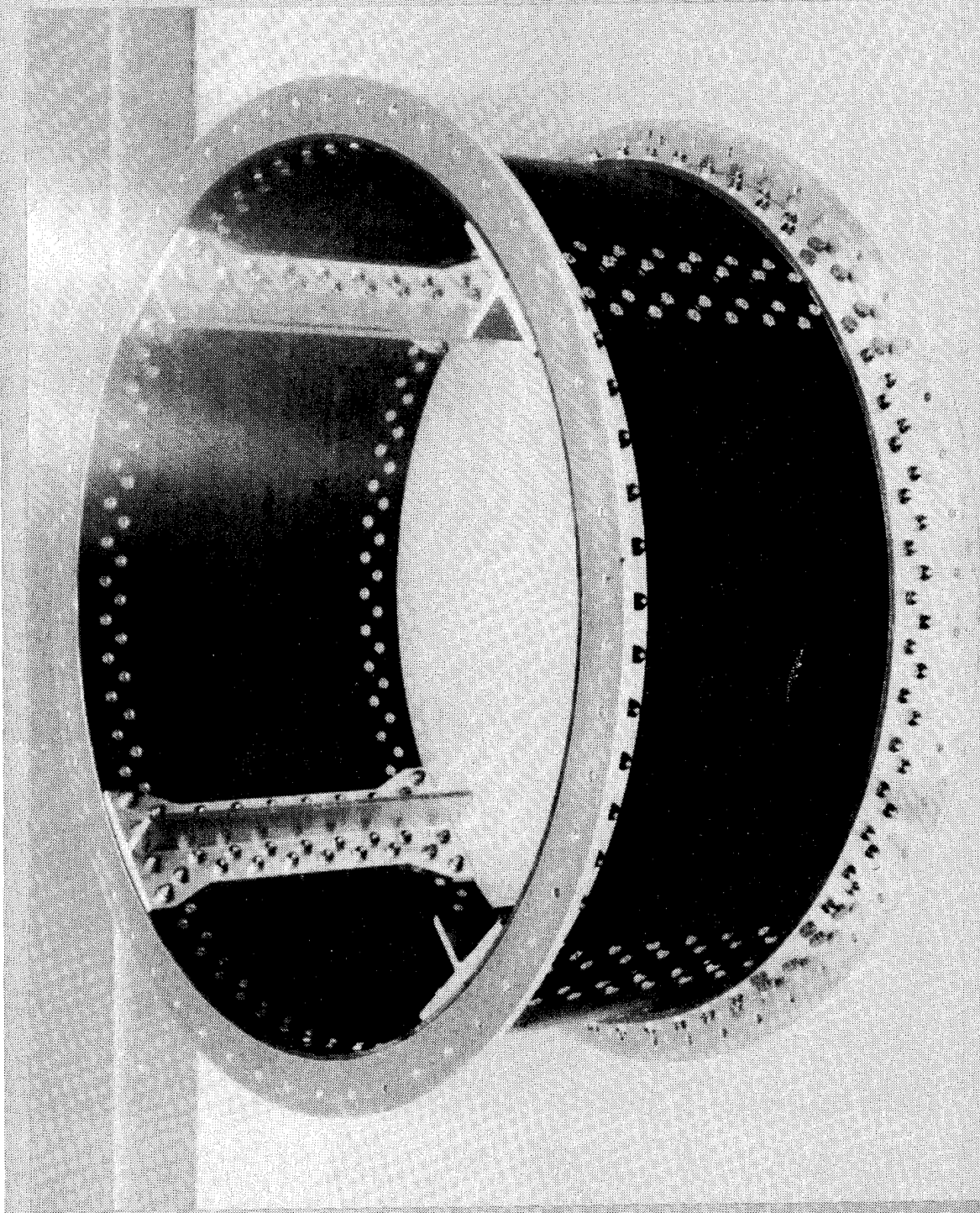


Figure 39 Curved Panel Test Assembly

procedure was usually repeated several times to check the repeatability of the data. This process was repeated for both directions of applied torque to determine the buckling stresses for different directions of applied shear. Because the composite panels consist of relatively few plies, stacking results in a basic imbalance with respect to laminate bending. This results in significantly different values of shear buckling stress of the panel for opposite directions of shear application.

Buckling stresses were experimentally determined through a "modified" Southwell Method which is a logical extension of the works of Galletly and Reynolds [11], and of Horton and Craig [12]. This method requires loading only near the actual buckling load which is desirable since actually buckling the test specimen could cause local damage and affect subsequent results. Moreover, the method allows use of the more reliable strain gages as opposed to deflection gages.

This method utilizes the stress (or load) versus surface strain curve from any point on the buckle at loads approaching buckling. This curve becomes increasingly nonlinear as the buckling load is approached, because of the increase of local bending at the buckle. The departure from linearity in terms of strain is defined as $\Delta\epsilon$. According to Galletly and Reynolds [11], the buckling stress (load) is equal to the inverse slope of the $\Delta\epsilon/P$ versus $\Delta\epsilon$ curve, (P may denote either load or stress). This technique was applied to all strain data taken during these tests with generally good results. Values of ϵ much below 100 $\mu\text{in./in.}$ generally give unreliable results because of the sensitivity limits on instrumentation. Typical results are shown below in the separate discussions of each test.

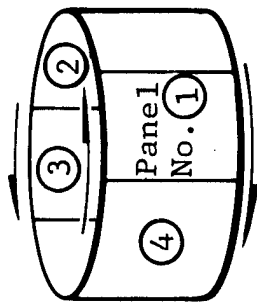
Results of the buckling tests on the graphite-epoxy panels are summarized in Table VI. Data was obtained from each of the four panels composing the test assembly. Conditions 1 and 2 refer to different directions of shear. As is seen, a significant difference in buckling loads results.

Strain gage rosettes placed back-to-back in pairs were used to obtain the data for the buckling stress determination. These gages were also used to compute K_{xy} which relates the shear stress on each panel τ to the total load P applied to the test assembly. These gages, with the exception of 1 and 2 (Table VI) are located at the center of the panel. Gages 1 and 2 were located in a corner near the edge.

Table VI GRAPHITE-EPOXY-CURVED PANEL SHEAR
BUCKLING RESULTS

8 Ply $\pm 45^\circ$ Laminate

Average
Thickness = .056 in.



		Condition 1 $\tau_{xy} > 0$			Condition 2 $\tau_{xy} < 0$			
		Southwell			Southwell			
Panel No.	Position	K_{xy} (psi/lb)	P_{CR} (lb)	τ_{CR} (psi)	K_{xy} psi/lb	P_{CR} (lb)	τ_{CR} (psi)	Deflection P_{CR} (lb) τ_{CR} (psi)
1	1	.445	-	-	.475	27,325	12,960	- -
1	2	.445	-	-	.475	-	-	- -
1	3	.445	18,431	8210	.475	26,667	12,670	26,000 12,350
1	4	.445	18,434	8210	.475	26,730	12,710	- -
2	5	.476	-	-	.475	26,774	12,720	27,000 12,800
2	6	.476	-	-	.475	26,570	12,610	- -
3	7	.476	19,020	9060	.481	-	-	26,500 12,750
3	8	.476	18,400	8770	.481	-	-	- -
4	9	.516	18,950	9780	.508	-	-	24,000 12,200
4	10	.516	18,730	9690	.508	-	-	- -
		Theory $\tau_{CR} = 9170$ psi CL-CL $\tau_{CR} = 7420$ psi SS-SS			Theory $\tau_{CR} = 13,670$ psi CL-CL $\tau_{CR} = 10,720$ psi SS-SS			

Deflection gages were placed to monitor lateral deflection at the panel center. Because of their low sensitivity these gages did not record any appreciable deflection until the panels actually buckled and very large deflections resulted. This behavior is shown in Figure 40. The points at which the deflections became large are those values listed in Table VI. These values support the Southwell data very well.

Theoretical buckling stresses were determined for the case of clamped edges and simply supported edges. The values (Table VI) for the clamped edges agree very well with the experimental results. Actual edge conditions approach the clamped case because of the stiff edgemembers and ample mechanical fasteners used.

An example of typical data used in the Southwell determination is shown in Figure 41. This data was taken for Condition 1 at Panel 4. The associated Southwell plots are seen in Figure 42.

Post-buckling behavior of the graphite-epoxy panels was characterized by large deflections with several buckles visible in each panel (see Figure 43). The behavior in terms of deflection is illustrated in Figure 2. Buckling of each panel occurred in sequence with a load drop accompanying each. With all four panels buckled, only a small amount of additional load was carried (20%) before failure. Failure occurred catastrophically at an average panel stress of approximately 16,000 psi as typically shown in Figures 44 and 45.

Results of the boron-epoxy buckling tests are summarized in Table VII. As before, loads and buckling stresses for both directions of loading were obtained with back-to-back strain gages on each of the four panels.

The data is seen to be very consistent. Analysis is seen to agree favorably as before although the results approach the case of simply-supported edges.

Typical load-strain curves and the associated Southwell plot for the boron panels are shown in Figures 46 and 47.

Visual and photographic observations of the post buckling behavior revealed that cracks appeared very soon after buckling occurred. Very little additional load was carried beyond buckling. The highest load attained was 21,500 pounds while buckling occurred at 19,000 to 20,000 pounds.

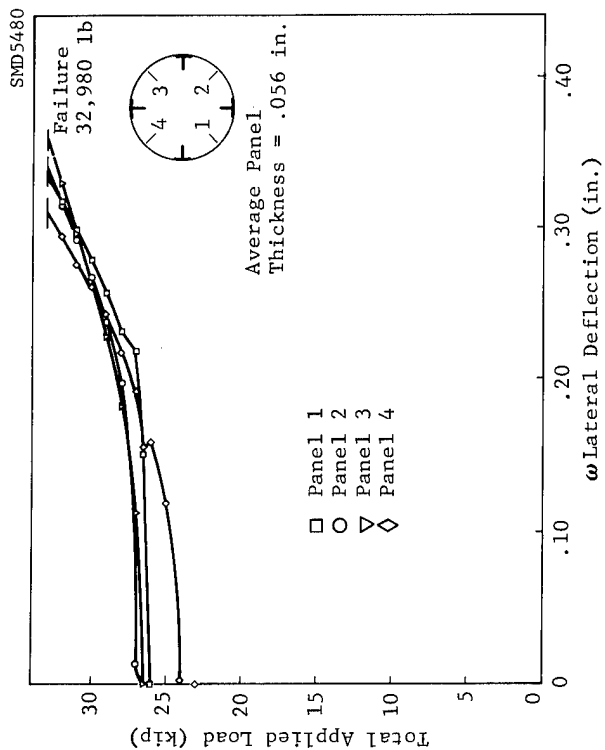


Figure 40 Load Versus Deflection for Graphite Shell

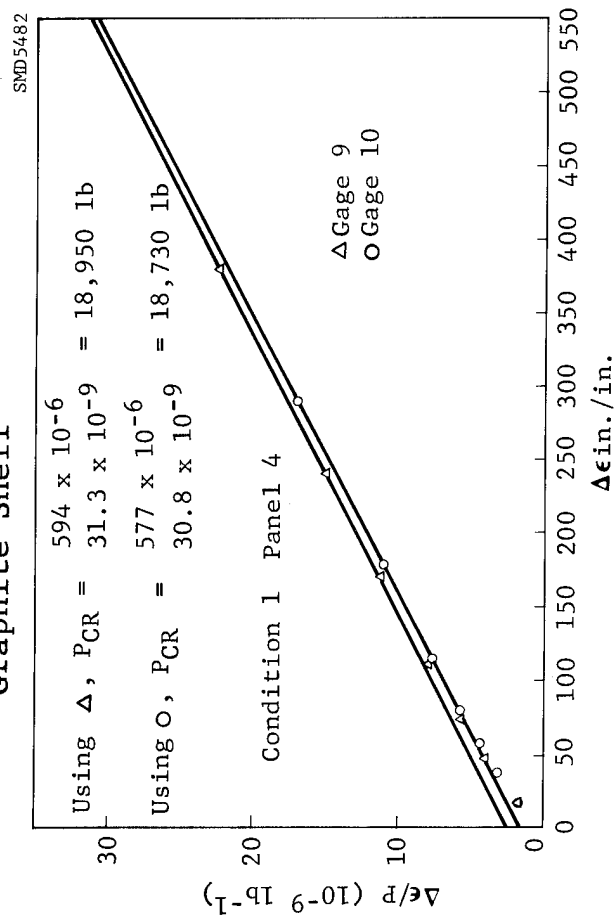


Figure 42 Southwell Plot - Graphite Curved Panel

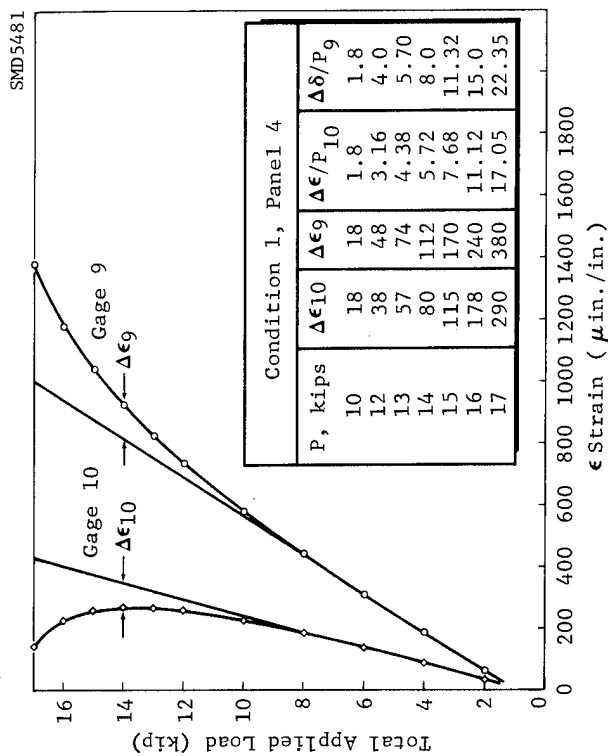


Figure 41 Load Versus Strain-Graphite Curved Panel Test

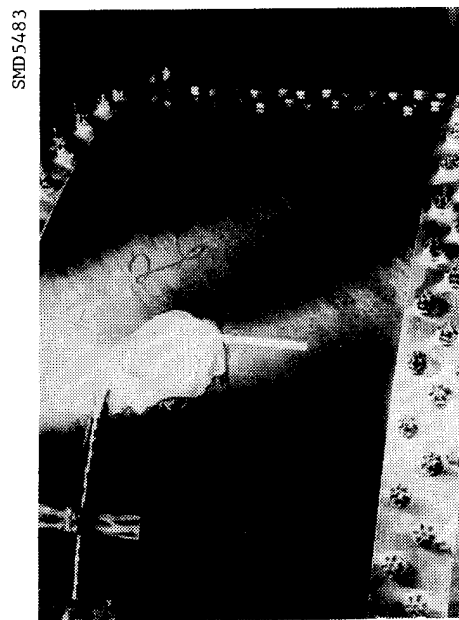


Figure 43 Graphite-Epoxy Curved Panel After Buckling

SMD 5484

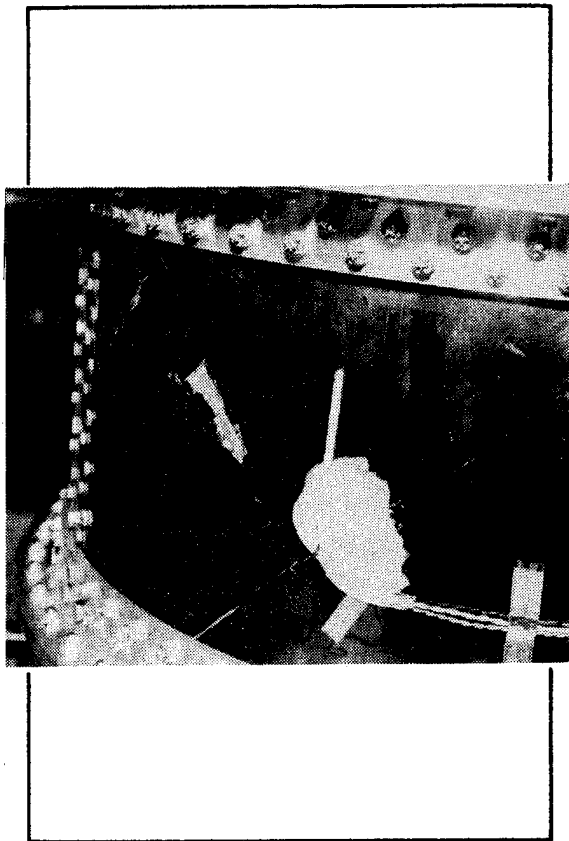


Figure 44 Failed Graphite-Epoxy Curved Panel

SMD 5485

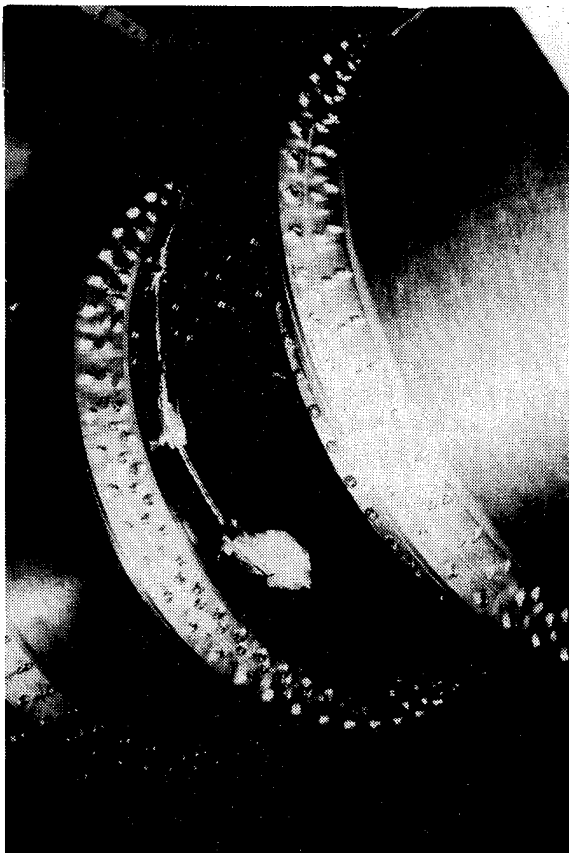


Figure 45 Failed Graphite-Epoxy Curved Panel - Overall View

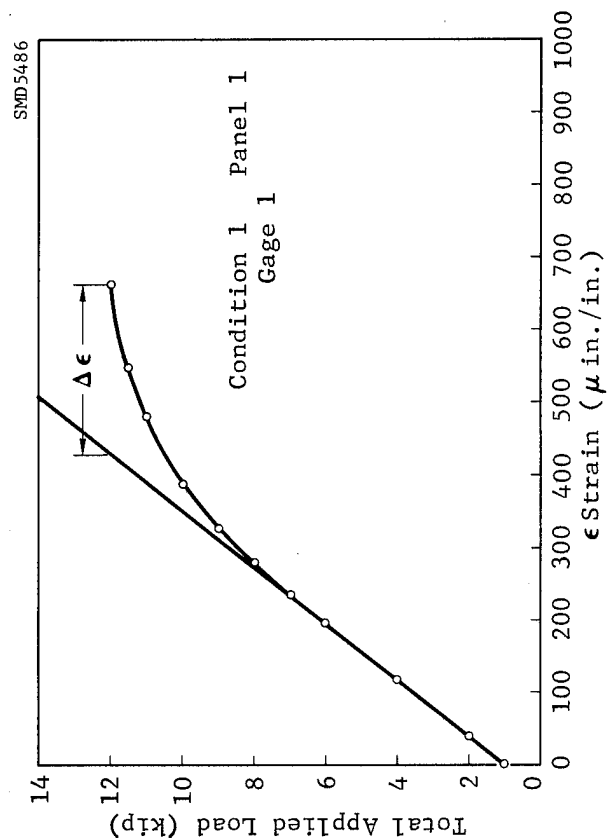


Figure 46 Load Versus Strain-Boron Curved Panel

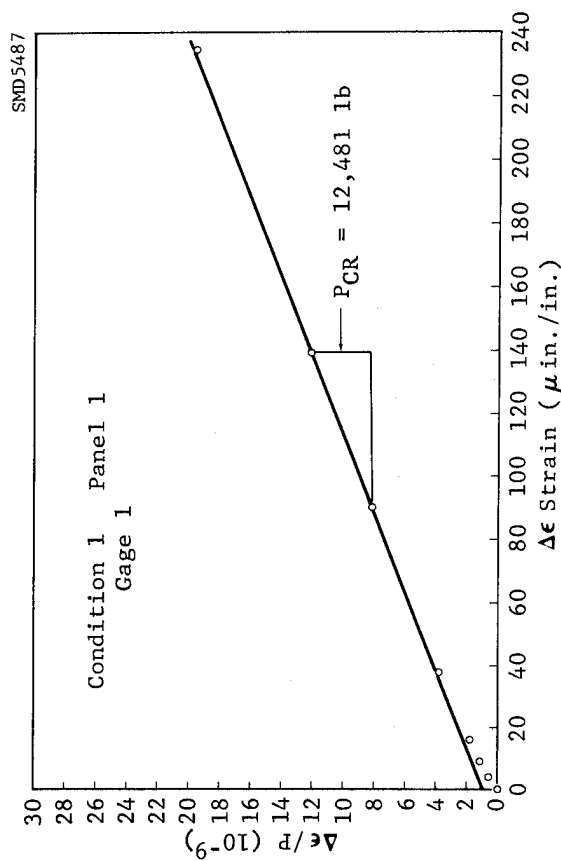
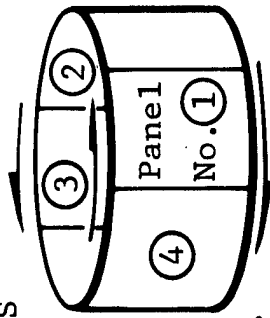


Figure 47 Southwell Plot - Boron Curved Panel

Table VII BORON-EPOXY CURVED PANEL SHEAR BUCKLING RESULTS



8 Ply $\pm 45^\circ$ Laminate Average Thickness = .042 in.

		Condition 1 $\tau_{xy} > 0$			Condition 2 $\tau_{xy} < 0$			
Panel No.	Position	Southwell			K_{xy} psi/lb	Southwell		
		K_{xy} (psi/lb)	P_{CR} (lb)	τ_{CR} (psi)		P_{CR} (lb)	τ_{CR} (psi)	Deflection
1	1	.613	12,481	7650	.608	20,154	12,220	20,250
1	2	.613	12,424	7620	.608	19,468	11,820	-
2	3	.603	13,742	8290	.595	19,862	11,810	20,250
2	4	.603	14,078	8470	.595	19,665	11,700	-
3	5	.598	13,864	8290	.592	19,595	11,600	19,800
3	6	.598	14,190	8480	.592	19,091	11,300	-
4	7	.594	-	-	.592	19,855	11,750	20,700
4	8	.594	-	-	.592	19,760	11,710	-
		Theory			Theory			
		$\tau_{CR} = 9140$ psi CL-CL SS-SS			$\tau_{CR} = 13,290$ psi CL-CL SS-SS			

3.3 VIBRATION

The vibration option was run extensively in checkout of SS8. Again, the anisotropic plate capability was checked with RA5 and showed good agreement.

The work of Sewall (Reference [14]) was used to compare natural frequency data for isotropic curved panels. As an example of the type of correlation obtained, the following results were obtained for an aluminum panel with $a = 11.0$ inches, $b = 9.0$ inches, $t = 0.028$ inch, and $R = 48.0$ inches. For one longitudinal and two circumferential modes, the following results were obtained:

	<u>f, cps</u>
SS8, simply supported edges	180.0
Sewall analysis, simply supported edges	184.0
SS8, clamped edges	468.6
Sewall analysis, clamped edges	536.5

The results indicate that SS8 gives a better frequency estimate than Sewall's analysis, since an energy solution gives an upper bound for the frequency, and SS8 shows a lower frequency in both cases. This is to be expected because Sewall neglected modal coupling effects in his one-term Rayleigh-type analysis.

For isotropic cylinders, the results of Park, et al. (Reference [15]), were used for comparison. They tested a steel cylinder built in at one end and free at the other. The dimensions were $a = 48.0$ inches, $R = 10.0$ inches, and $t = 0.03$ inches. They found the lowest natural frequency at $m = 1$, $n = 4$ of 50.4 cps. SS8 predicts a value of 51.9 cps. For $m = 1$, $n = 3$, the experimental value was 51.5 cps., while SS8 predicts 55.3 cps. For $m = 1$, $n = 5$, the experimental value was 70.9 cps., while SS8 predicts 71.5 cps.

The anisotropic capability of SS8 was tested by comparing its results with those of Bert, et al. (Reference [16]), who presented exact analytical solutions for the natural frequencies of anisotropic simply-supported cylinders. As an example, they studied a two-layer, cross-ply cylinder using material properties typical of boron-epoxy. Some examples of the excellent agreement obtained are shown below.

<u>SS8</u>	<u>Ref. (11)</u>	<u>M</u>	<u>N</u>
235 cps	235 cps	1	2
254 cps	253 cps	1	3
443 cps	443 cps	2	3

The dynamics of a cylinder with four internal stringers has been investigated and these investigations are documented in References [17], [18], and [19]. The SS8 results for this case show its discrete stiffener capability.

	<u>SS8 Anal.</u>	<u>Ref. 17 Expt.</u>	<u>Ref. 18 Anal.</u>	<u>Ref. 19 Anal.</u>
M = 1, N = 3	163 cps		158 cps	159 cps
M = 1, N = 4	99 cps	100 cps	99 cps	100 cps
M = 1, N = 5	91 cps	87 cps	91 cps	93 cps
M = 1, N = 6	106 cps	104 cps	105 cps	115 cps

Many other sources, References [20] - [47], were consulted for analytical and experimental information. Detailed correlation with these sources was not attempted since the layered composite capability could best be explored further through our test program.

3.3.1 Fuselage Program Tests

The specimens and fixture used for the Fuselage Program tests were described in Sections 3.1.1 and 3.2.1. The setup of equipment for the vibration tests is shown in Figures 48 and 49. The panel specimens were tested in the fully clamped boundary condition.

In the vibration tests the axial load was maintained at 100 pounds while the panel was tapped with a cardboard cylinder to set the panel vibrating at its resonant frequency. This frequency was monitored by the following equipment. The transducer was a one gram MB Electric Velocity Pickup (Model 115) connected to a Tektronix, Storage type Oscilloscope (Model 549). Incorporated in the system was a Krohn-Hite Variable Band Filter to obtain the frequency output within the ranges of interest. Photographs of the oscilloscope traces were made with a Hewlett-Packard Camera (Model 197A). These photographs constituted the data output of the system.

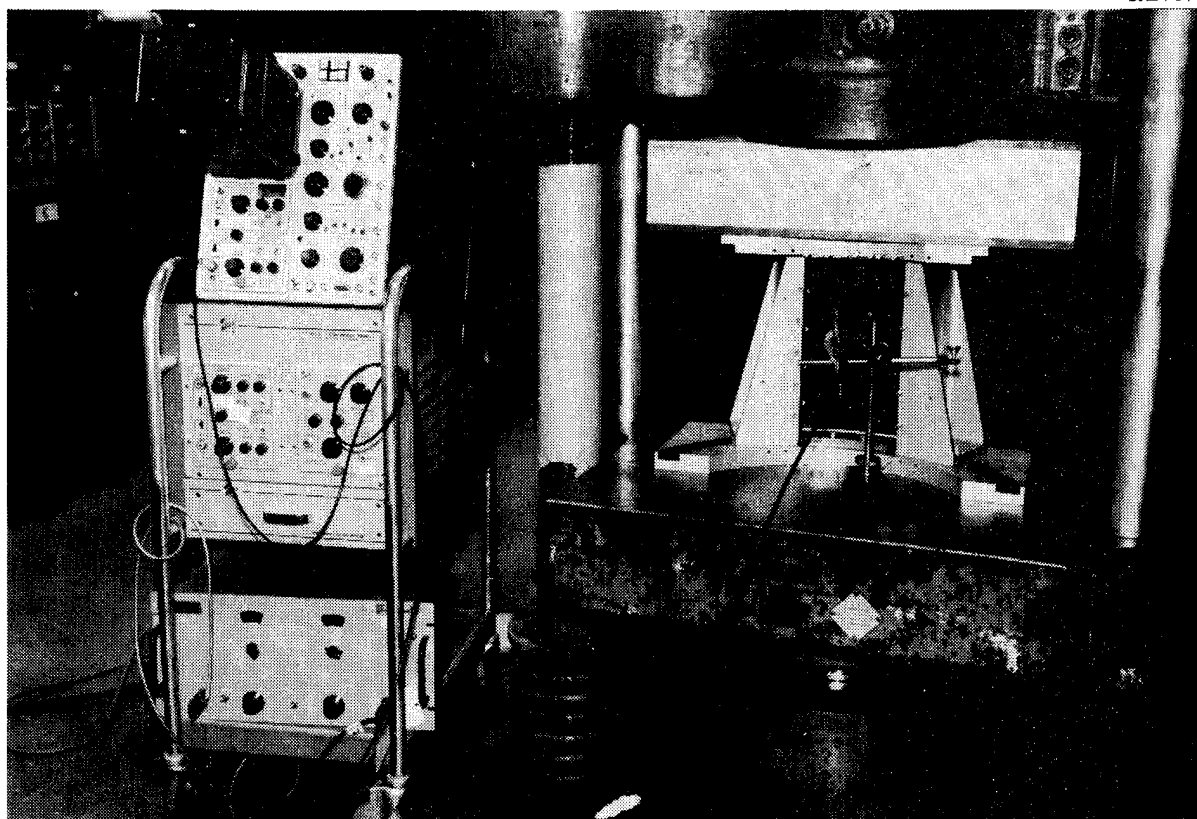


Figure 48 Test Setup and Instrumentation for Vibration Tests

SMD7074

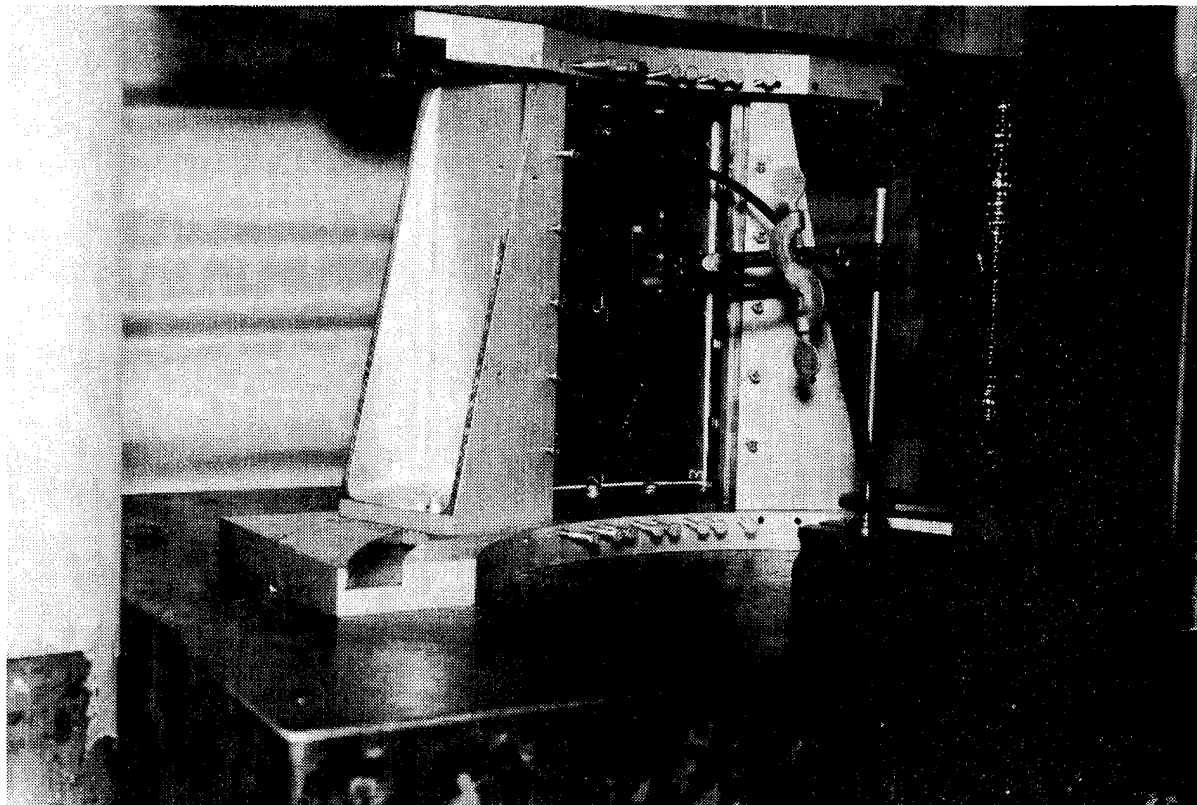


Figure 49 Vibration Setup Showing Closeup of Velocity Transducer

Typical photographs obtained during the vibration tests are included in Figure 50. All the photographs are given in Reference [7]. The fundamental frequency was obtained from these pictures using the following conversion formula:

$$\omega_o = \frac{N}{dRK}, \text{ cycles/record}$$

where: ω_o = fundamental frequency,

N = number of cycles counted,

d = distance on photograph to include N cycles,

R = ratio of object to image size to correct for photographic reproduction, and

K = constant set in on oscilloscope, seconds/cm

The actual process for measuring the distances on the photograph and converting the results, was accomplished on the Hewlett-Packard Data Reduction equipment. The final results are tabulated in Table VIII. The table shows panel number, laminate, the percent difference between experimental and results obtained using a 10 in.-lb./rad/in. elastic restraint on the straight sides, and the natural frequencies, including the clamped curved edge, simply supported straight edge classical results. The results show that the actual side support restraint makes a great deal of difference in the results.

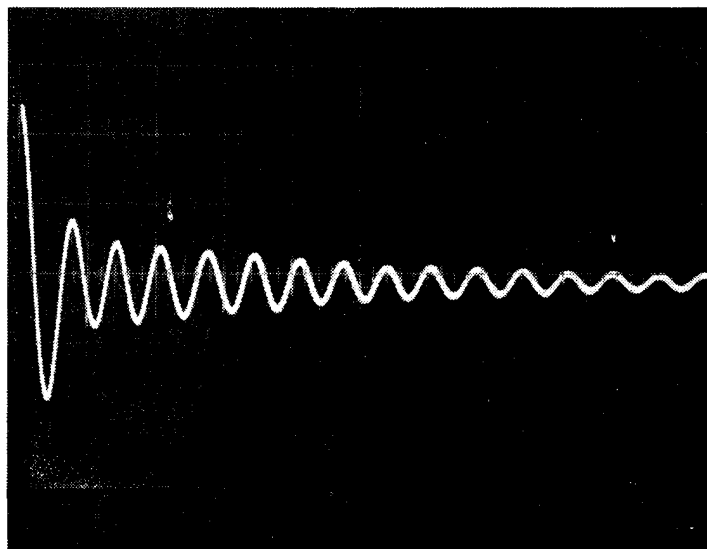
3.3.2 Dynamic Characteristics Program Tests

Some of the tests of Reference [13] were described in Section 3.1.2. The program also included tests of stiffened curved panels, unstiffened cylinders, and a stiffened cylinder.

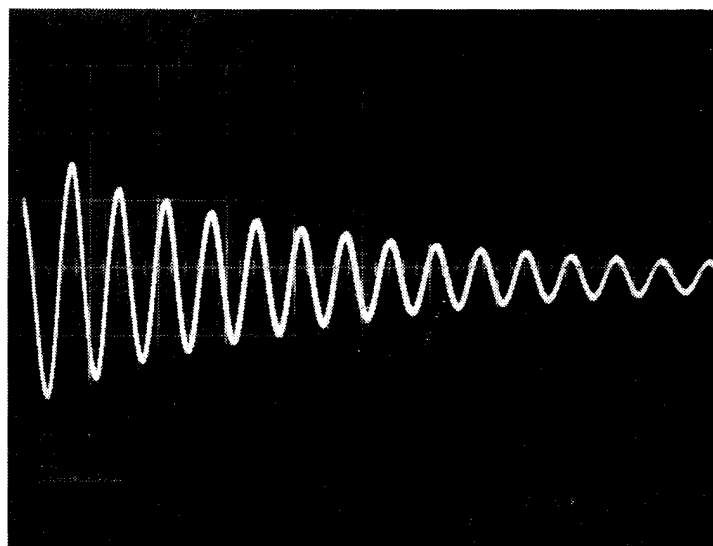
3.3.2.1 Cantilever Curved Panels

The specimens are described in Section 3.1.2 and shown in Figures 14-16. The specimens are designated 15, 16A, and 16B and have 15-inch spans and 24-ply, $[0/+45_4/90]_c$ laminates. Specimen 15 has a 15-inch chord and a 36-inch radius, while Specimens 16A and 16B have 6-inch chords and 36- and 12-inch radii, respectively.

Frequencies and mode shapes have been determined experimentally for the first six natural modes.



Panel 49A, Mode 1, 1



Panel 49A, Mode 1, 2

Figure 50 Velocity Traces for Panel 49A

Table VIII FUSELAGE PROGRAM VIBRATION TEST RESULTS

PANEL	LAYUP	% DIFF EXP-E.R.	MODE 1		MODE 2		
			NATURAL FREQUENCIES, HZ		EXPER.	ELAST. RES. C-C-ER-ER	CLASSICAL CCSS
			EXPER.	ELAST. RES. C-C-ER-ER			
19A	[+45] 2s	+ 1.3	771 (1, 2)	781			821
19D	[+45] 2s	+ 2.2	772 (1, 2)	789			831
21A	[0, 90] s	+13.1	335 (1, 3)	379	415 (1, 2)	342	392
23E	[+45] s	+ 7.4	486 (1, 3)	522			544
29E	[+45] 3s	+12.3	729 (1, 2)	819			927
33E	[+45] 4s	+ 4.5	583 (1, 2)	609			665
35A	[+45] 6s	+ 7.4	702 (1, 2)	754			849
39A	[-30] 4s	+ 8.1	595 (1, 2)	643	635 (1, 3)	726	780
41A	[-30] 6s	0	707 (1, 2)	707			836
45E	[0] 4s	- 5.4	423 (1, 2)	400			467
49A	[0, 90] 3s	+ 2.6	707 (1, 2)	720	708 (1, 1)	633	782
51A	[+30] s	+ 8.2	451 (1, 3)	488			497
53A	[+30] 2s	+ 6.5	634 (1, 3)	675	637 (1, 2)	683	739
55A	[+30] 3s	+11.9	649 (1, 2)	726			830
59A	[0, +60] s	+ 8.9	514 (1, 3)	560	573 (1, 2)	569	613

Preliminary analyses were performed with the DRR curved panel analysis procedure (SS8). Post-test analyses were performed with the USA procedure and NASTRAN. All of the analyses included stacking sequence effects. The test-theory correlation data for natural frequencies is shown in Table IX. As seen in the table, the DRR analysis is in good agreement for the bending modes, which are dominated by the spanwise stiffness. However, the effect of curvature on the torsional stiffness is evidently being over-predicted in each case, thereby raising the frequencies for the torsion modes. Although several possible causes for the discrepancies have been investigated, no satisfactory explanation has yet been found for the failure of the DRR procedure to correctly model the torsional stiffness.

The opposite is true for the finite-element procedures. That is, the USA and NASTRAN analyses of Specimen 16B are modeling the torsional stiffness accurately, but they are overestimating the spanwise stiffness. Both simulations used piecewise flat element systems to model the structure. The torsional modes are not greatly affected by the curvature, but the curvature effects dominate the bending deflections. Therefore, the discrepancies reflect an inadequate representation of the specimen curvature. The superiority of the USA analysis to the NASTRAN analysis is caused by the larger number of elements used.

The agreement for Specimen 16A was greatly improved for both the DRR and USA analyses. The DRR analysis overpredicted the first torsional frequency, and the USA analysis overpredicted the bending stiffness for the fundamental mode and the influence coefficients. The superior agreement is caused by the relatively narrow chord and low curvature.

The USA analysis of Specimen 15 follows the previously noted trends in that it correctly predicts the first torsional frequency and accurately predicts all of the mode shapes. In this case, the first bending mode frequency and all subsequent frequencies were predicted to be lower than measured. The simulation used was an equivalent thickness and stiffness sandwich model with 11 spars and 16 ribs. Skin elements were flat, constant stress triangles. Agreement is not as good as it is for Specimen 16A although the curvatures are the same. The increased chord width and included angle increased curvature effects and made the specimen more difficult to analyze with flat elements.

Also included in the results is a DRR analysis of Specimen 16 as a flat panel for comparison purposes. Percent differences for 16A and 16B are shown to demonstrate the effect of curvature.

Table IX NATURAL FREQUENCIES FOR
CURVED PANELS

SPEC. NO.	METHOD	FREQUENCY (Hz)						AVERAGE % ERROR
		1	2	3	4	5	6	
15	Mode	T	B	T	C	C	C	21.6 --
	DRR	86.0	107	226	293	313	459	
	EXP	61.0	94	178	246	271	405	
16*	Mode	B	T	B	T	B	C	--
	DRR	18.2	101	127	292	385	550	
16A	Mode	B	T	B	T	B	C	4.57 5.97
	DRR	27.8	123	163	344	438	609	
	USA	29.2	110	155	319	396	551	
	EXP	26.7	107	163	330	435	589	
16B	Mode	B	T	B	T	C	B	17.81 7.78 12.93 --
	DRR	64.5	187	345	428	754	790	
	USA	71.1	116	320	362	633	667	
	NAST	81.5	114	418	373	708	846	
	EXP	60.0	113	337	364	675	773	

Modes: T = Torsion, B = Bending, C = Coupled

*Analysis of 16 as a flat plate for comparison purposes -
not a test specimen.

3.3.2.2 Stiffened Panels

Free-free natural frequencies and mode shapes were measured for four stiffened panels, Specimens 33 through 36. One flat panel and one curved panel were fabricated. Each panel was 18 inches wide and 36 inches long, and the curved panel had a radius of 36 inches. Each panel was made of 12 plies of boron-epoxy oriented at $\pm 45/90$ degrees, resulting in plate bending stiffnesses $D_{11} = 155$, $D_{22} = 330$, and $D_{66} = 116 \text{ lb.-in}^2/\text{in}$. Specimens 33 and 35 (curved) have three aluminum channel stiffeners bonded to one side at the interior quarter points.

Each stiffener has a cross-sectional area of 0.07625 in.^2 and $EI = 9508 \text{ lb.-in.}^2$ about the centroid. Specimens 34 and 36 were made by bonding two additional stiffeners to the edges of Specimens 33 and 35 after they were tested. The specimens were suspended horizontally with surgical tubing attached to one side along the panel length; this tubing was located nine inches from each end. The rigid body frequencies of the panel were one Hz or less.

To determine the validity of the experimental boundary conditions, Specimen 33 was also tested with the panel suspended vertically. The supports were attached to one end and were located five inches from each side. Frequencies and mode shapes were the same as those measured with the panel suspended horizontally.

Available analytical and test results for the stiffened panels are given in Table X. DRR results are shown for the flat panels, Specimens 33 and 34, and for the same panel without stiffeners for comparison. Acceptable analytical results for the curved specimens were not generated because of problems with the DRR shell analysis procedure SS8. Experimental results are shown for the lowest seven to nine natural frequencies detected. Analytical results for the flat plate are not complete in that some higher mode shapes had frequencies lower than some of those shown. Agreement was excellent between the experimental and analytical natural frequencies and mode shapes for the flat stiffened panels.

3.3.2.3 Unstiffened Composite Cylinders

Two unstiffened cylinders, 15 inches in diameter and 16 inches in length, were designed to study the accuracy of the Rayleigh-Ritz shell procedure SS8 for full cylinders.

Table X NATURAL FREQUENCIES (Hz) FOR STIFFENED PANELS

MODE	FLAT PLATE		SPECIMEN 33				SPECIMEN 34			SPEC 35		SPEC 36	
	DRR		EXP	DRR	P.E.		EXP	DRR	P.E.	EXP		EXP	
2,0	8.8		39.8	40.1	0.8		48.4	48.0	-0.8	--		--	
3,0	25.1		95.7	100	4.5		126	129	2.4	--		--	
4,0	48.9		--	162	--		--	250	--	--		--	
1,1	17.0		18.1	17.1	-5.5		16.2	15.1	-6.8	19.6		18.3	
2,1	36.0		48.2	48.3	0.2		59.2	59.6	0.7	78.0		76.0	
3,1	61.7		--	101	--		--	146	--	--		169.4	
4,1	87.7		--	155	--		--	271	--	--		--	
0,2	57.8		54.5	54.3	-0.4		41.5	43.7	5.3	53.2		43.5	
1,2	67.8		61.4	63.6	3.6		54.0	53.4	-1.1	63.8		56.4	
2,2	92.9		93.6	93.2	-0.4		105.3	97.6	-8.2	84.8		82.6	
3,2	129.2		--	157	--		--	189	--	140.8		--	
0,3	158.9		--	143	--		120	122	1.7	144.1		121.6	
1,3	164.2		--	152	--		142	130	-8.4	--		--	
2,3	193.2		--	188	--		--	164	--	--		198.3	
AVERAGE P.E.			--	--	2.2		--	--	3.9	--		--	

Specimen 37 has six plies of boron-epoxy oriented at $0/\pm 45$ degrees, and Specimen 38 has four plies of boron-epoxy oriented at ± 45 degrees. Frequencies, mode shapes, and damping coefficients were determined for the natural modes of the specimen corresponding to longitudinal mode $m = 0, 1, 2$ and the frequency sweep from 0 to 525 Hz. The specimens were tested with free-free boundary conditions as shown in Figures 51-53.

The frequency correlations are shown in Table XI and Figures 54 and 55. The actual cylinder properties and the predicted properties are given in Table XII. Agreement is good everywhere except the $m = 2$ modes for Specimen 38. Although the lamina modulus in the fiber direction was increased from 30×10^6 psi to 33.7×10^6 psi to account for the apparent high fiber volume fraction, the reduction in thickness of the shell brought about a 10 percent lower longitudinal stiffness than predicted. This resulted in lower frequencies.

3.3.2.4 Stiffened Composite Cylinders

Specimen 39, which is the graphite-epoxy stiffened shell shown in Figure 56, and in Figure 57 with an unstiffened cylinder, was fabricated and dynamic tested to study the accuracy of the DRR procedure SS8 for shells with stiffeners. This specimen is 24 inches in diameter and 30 inches in length with an 8-ply graphite shell with orientations of ± 45 degrees. The plate bending stiffnesses for the shell are $D_{11} = D_{22} = 97$ and $D_{66} = 80$ lb-in²/in. The shell is stiffened by four equally spaced aluminum external longitudinal stringers with $EI = 2.3 \times 10^6$ lb-in.², two graphite internal rings at one-third and two-thirds of the length with $EI = 6.4 \times 10^5$ lb-in.², and two aluminum external rings at the ends with $EI = 1.6 \times 10^6$ lb-in.². Stiffener EI's were calculated about their centroids.

Attempts to analyze this cylinder with Procedure SS8 were unsuccessful. Analytical results were simply not reasonable for this specimen. To determine if the problem was numerical in origin, Procedure SS8 was converted to double precision, but there was no change in the results. The problem is probably in the ring stiffener formulation, but no error could be found. Therefore, there are no analytical results for this specimen.

The natural frequencies and descriptions of the mode shapes determined experimentally are shown in Table XIII. The stiffened cylinder was tested with free-free boundary conditions. The technique used was the same as that used on the unstiffened cylinders.

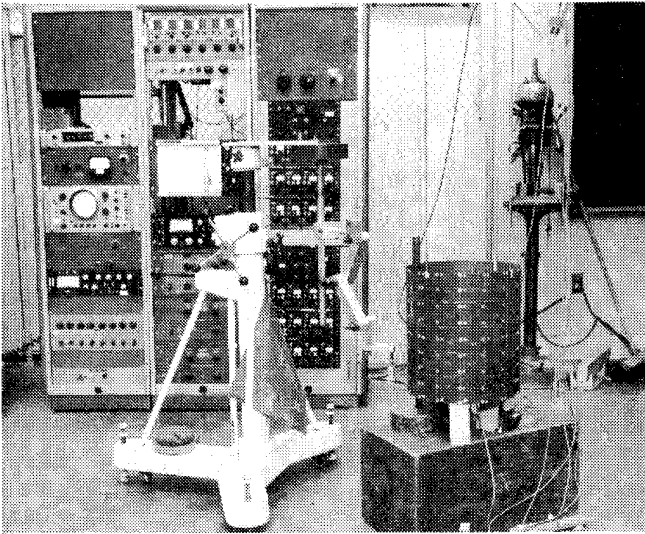


Figure 51 Dynamic Testing of a Cylinder

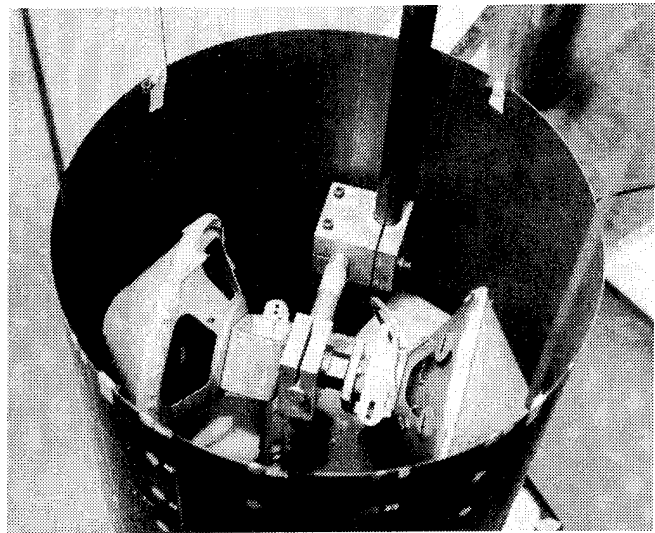


Figure 52 Dynamic Excitation of a Cylinder

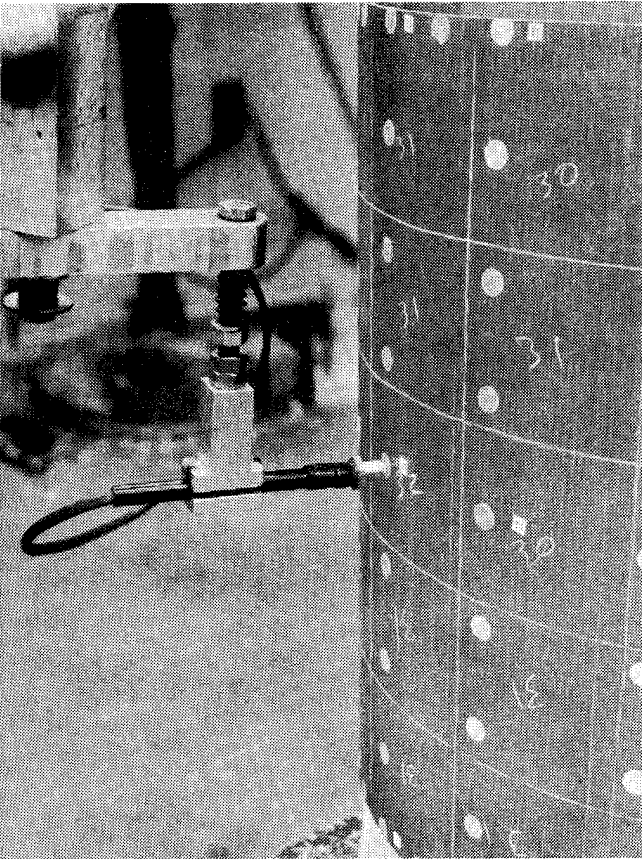


Figure 53 Modal Deflection Measurement

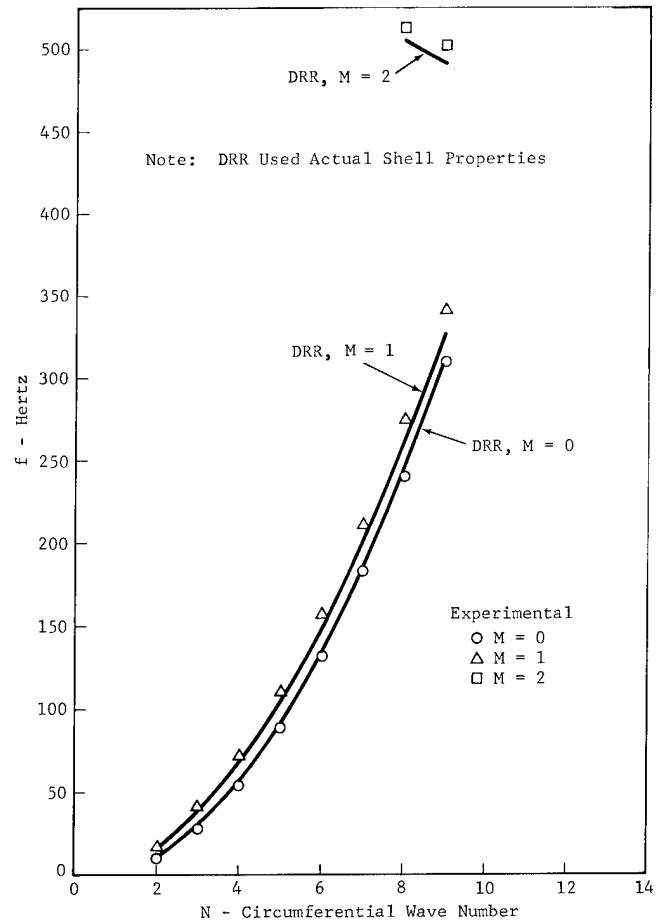


Figure 54 Frequency Correlation for Specimen 37

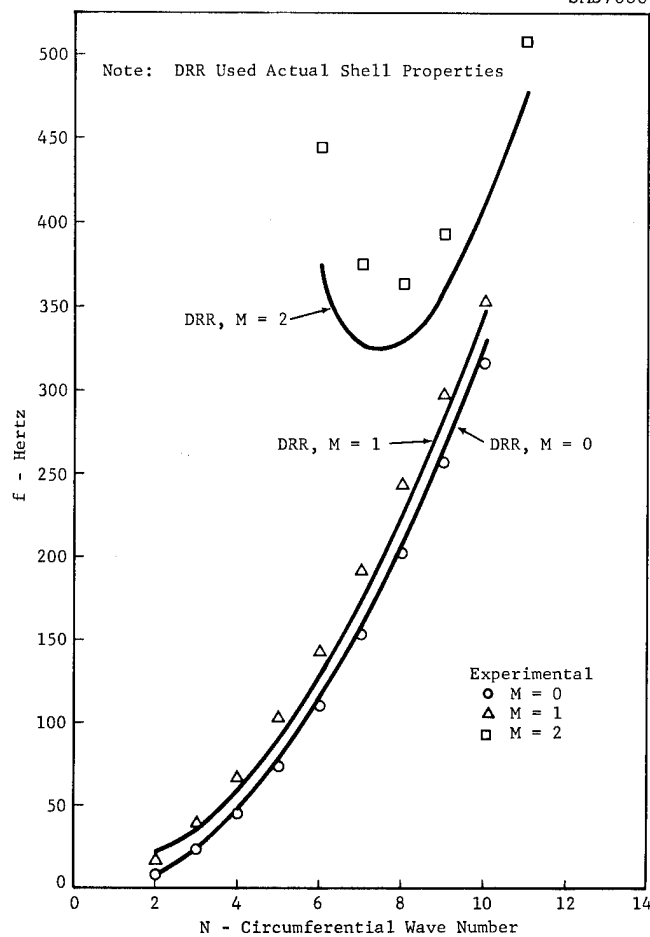


Figure 55 Frequency Correlation for Specimen 38

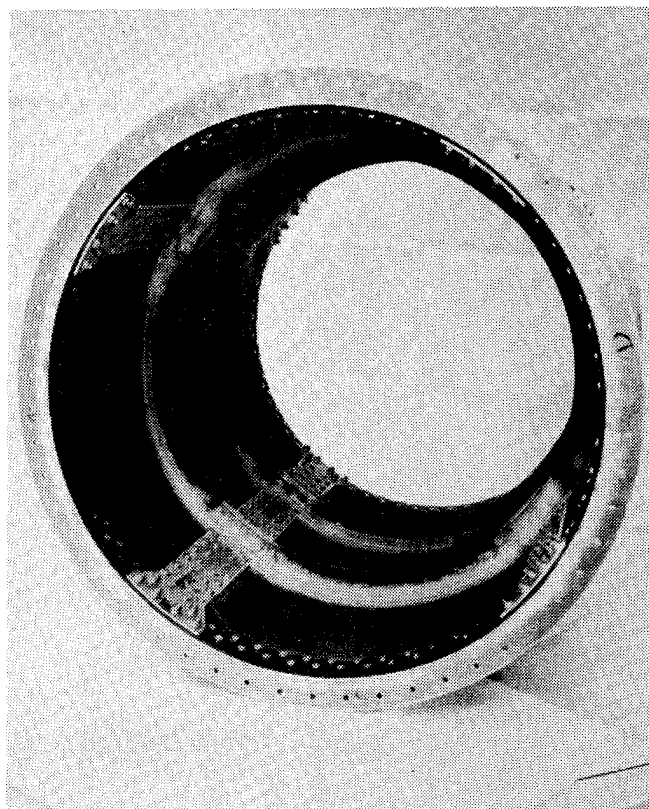


Figure 56 Graphite-Epoxy Stiffened Shell

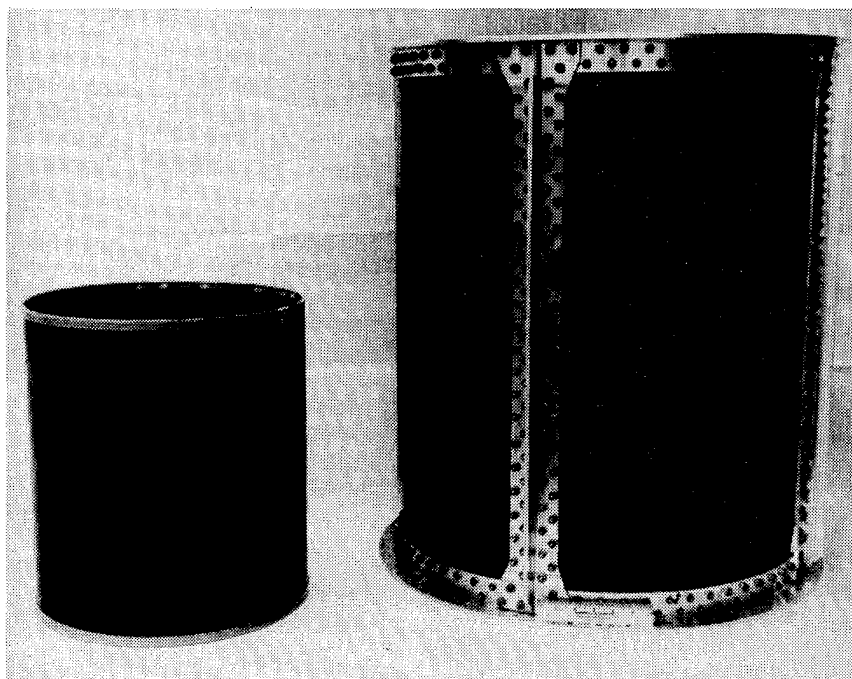


Figure 57 Stiffened and Unstiffened Cylinders

Table XI NATURAL FREQUENCIES (Hz) FOR UNSTIFFENED CYLINDERS

MODE	SPECIMEN 37			SPECIMEN 38		
	EXP	DRR	P.E.	EXP	DRR	P.E.
0,2	9.8	10.5	7.1	8.0	8.2	2.5
0,3	27.9	30.3	8.6	22.8	24.5	7.5
0,4	54.2	57.8	6.6	45.0	48.8	8.4
0,5	89.3	93.2	4.4	74.1	79.2	6.9
0,6	132	137	3.8	110	116	5.4
0,7	183	188	2.7	153	160	4.6
0,8	240	248	3.3	202	210	4.0
0,9	310	315	1.6	256	267	4.3
0,10	--	--	--	316	331	4.8
1,2	17.3	15.9	-8.1	15.5	22.7	37.6
1,3	41.5	38.5	-7.2	38.8	36.1	-7.0
1,4	72.9	68.0	-6.7	66.6	60.1	-9.8
1,5	111	104	-6.3	103	92.7	-10.0
1,6	157	148	-5.7	143	130	-9.1
1,7	211	200	-5.2	191	175	-8.4
1,8	274	260	-5.1	243	225	-7.4
1,9	341	327	-4.1	297	283	-4.7
1,10	--	--	--	353	347	-1.7
2,6	--	--	--	444	374	-15.8
2,7	--	--	--	375	327	-12.8
2,8	513	506	-1.4	363	329	-9.4
2,9	502	491	-2.2	392	362	-7.6
2,10	--	--	--	--	414	--
2,11	--	--	--	508	478	-5.9
Avg. P.E.	--	--	5.0	--	--	8.5

Table XII CYLINDER PROPERTIES

Property	Specimen 37		Specimen 38	
	Theory	Actual	Theory	Actual
W, lb.	1.648	1.678	1.099	1.089
t, in.	0.0312	0.03092	0.0208	0.0185
<i>l</i> , in.	16.0	16.0	16.0	16.0
R, in.	7.5	7.5	7.5	7.5

Table XIII STIFFENED CYLINDER FREQUENCIES (Hz)

Frequency	Damping	Mode
129	.004	0,2 Nodes between stringers
152	.004	0,2 Nodes at stringers
362	.012	0,3
384	.008	1,3
498	.008	0,4
508	.110	2,3 Nodes at internal rings (1/3)
550	.018	2,2
582	.044	2,3 Nodes 20% from ends
589	.014	1,4
716	.070	2,2 & 6
735	--	-- 1st mode for center panels
933	.009	-- Not identifiable
967	.009	3,4
1275	.017	4,2

S E C T I O N I V

S U M M A R Y

A Rayleigh-Ritz analysis for laminated anisotropic cylindrically curved shells has been performed. The analysis is formulated to solve static deflection, buckling, and natural vibration problems. Discrete energy contributions from stringers, rings, lumped masses, point loads, point and line moments, point and line springs, and elastic moment restraints have been included.

Digital computer Procedure SS8 has been written to compute the solutions to the above problems. The program has some limitations, mainly in regard to its treatment of free edges of a panel. The treatment of imperfection sensitivity in buckling should not be regarded as a final answer to the difficult problem of knockdown factors in compression, but did show promise. An assessment of the accuracy of the discrete ring stiffening capability was clouded by the problem of free edges. It is felt that the program serves a useful function as written, but that it needs more development work in certain areas.

Also described are various tests on curved panels and cylinders which in most cases were first attempts to discern the effects of curvature and anisotropy in laminated composites. Several interesting test methods were developed, including two applications of the Southwell method and an application of the Moire grid shadow technique.

R E F E R E N C E S

1. Ashton, J. E., Anisotropic Plate Analysis, General Dynamics Research and Development Report FZM-4899, October 1967.
2. Vlasov, V. Z., General Theory of Shells and Its Applications in Engineering, NASA Technical Translation, NASA-TTF-99, 1964.
3. Ashton, J. E.; Halpin, J. C.; and Petit, P. H., Primer on Composite Materials: Analysis, Technomic Publishing Company, Stamford, Connecticut, 1969.
4. Egle, D. M. and Soder, Jr., K. E., "A Theoretical Analysis of the Free Vibration of Discretely Stiffened Cylindrical Shells, With Arbitrary End Conditions," NASA CR-1316, 1969.
5. Ashton, J. E., "Analysis of Anisotropic Plates - II," J. Comp. Mat'l., 3, April 1969.
6. Ashton, J. E., Laminated Trapezoidal Plate Analysis, General Dynamics Research and Development Report FZM-5549, July 1970.
7. Love, T. S., and Brubaker, W. R., Advanced Composites - Buckling, Pressure and Natural Frequency Tests on Curved Panel Components, General Dynamics Test Laboratory Report FSG-739, December 1971.
8. Timoshenko, S. P. and Gere, J. M., Theory of Elastic Stability, Second Edition, McGraw-Hill, New York, 1961.
9. Dykes, B. C., "Analysis of Displacements in Large Plates by the Moire Grid-Shadow Technique," "Experimental Stress Analysis and its Influence on Design Conference, Cambridge England, April 1970, Proceedings, Institution of Mechanical Engineers, Publishers, London, 1970.
10. Tenerelli, D. J. and Horton, W. H., "An Experimental Study of the Local Buckling of Ring-Stiffened Cylinders Subject to Axial Compression," "Israel Journal of Technology, Vol. 7 No. 1-2, 1969, pp 181-194.

REFERENCES (CONT'D)

11. Galletly, G. D. and Reynolds, T. E., "A Simple Extension of Southwell's Method for Determining the Elastic General Instability Pressure," *Proceedings of the SESA*, 13, (2), pp 141-152.
12. Horton, W. H. and Craig, J. I., "Experimental Studies of the Effect of General Imperfections on the Elastic Stability of Thin Shells," *Israel Journal of Technology*, 7, (1-2), 91.
13. McCullers, L.A., Naberhaus, J. D., and Bensinger, C. T., "Dynamic Characteristics of Advanced Filamentary Composite Structures, Volume I, Test Specimen Program, "AFFDL-TR-73-XX, Convair Aerospace, February 1973.
14. Sewall, J. L., Vibration Analysis of Cylindrically Curved Panels with Simply Supported or Clamped Edges and Comparison with Some Experiments, NASA TN D-3791, January 1967.
15. Park, A. C., et al., Dynamics of Shell-Like Lifting Bodies Part II. The Experimental Investigation, Technical Report AFFDL-TR-65-17, Part II, Wright-Patterson AFB, Ohio, June 1965.
16. Bert, C. W.; Baker, J. L.; and Egle, D. M., Free Vibrations of Multilayer Anisotropic Cylindrical Shells, presented to the Fourth Annual Symposium on High Performance Composites, Washington University, St. Louis, Missouri, 8 to 9 April 1969.
17. Schnell, W. and Heinrichsbauer, The Determination of Free Vibrations of Longitudinally Stiffened Thin-Walled, Circular Cylindrical Shells, NASA TTF-8856, April 1964.
18. Egle, D. M. and Soder, K. E., A Theoretical Analysis of the Free Vibration of Discretely Stiffened Cylindrical Shells with Arbitrary End Conditions, ASME/AIAA Tenth Structures, Dynamics, and Materials Conference, New Orleans, Louisiana, 1969.
19. Parthan, S. and Johns, D. J., Effects of Inplane and Rotary Inertia on the Frequencies of Eccentrically Stiffened Cylindrical Shells, ASME/AIAA Tenth Structures, Dynamics and Materials Conference, New Orleans, Louisiana, 1969.

REFERENCES (CONT'D)

20. Forsberg, K., "Influence of Boundary Conditions on the Modal Characteristics of Thin Cylindrical Shells," AIAA J., 2, 12, pp 2150-2156, December 1964.
21. Yamaki, N., "Flexural Vibrations of Thin Cylindrical Shells," 11th Structural Mechanics Conference, Japan Society of Mech. Engr., Kyoto, July 1969.
22. Cooper, P. A., "Effect of Shallow Meridional Curvature on the Vibration of Nearly Cylindrical Shells," NASA TN D-5143, April 1969.
23. Stavsky, Y and Loewy, R., "On the Vibrations of Heterogeneous Orthotropic Cylindrical Shells," Technion, Israel Inst. of Tech., AD709239, August 1969.
24. Kunukasseril, V. X., "Vibration of Multi-Layered Anisotropic Cylindrical Shells," Watervliet Arsenal, AD649662, February 1967.
25. Dong, S. B., "Free Vibration of Laminated Orthotropic Cylindrical Shells," J. Acoustical Soc. of Amer., 44, 6, pp 1628-1635, 1968.
26. Tasi, J. and Roy, B. N., "Axisymmetric Vibrations of Finite Heterogeneous Cylindrical Shells," J. Sound Vib., 17, 1, pp 83-94, 1971.
27. Hsu, T. and Wang, J. T., "Rotationally Symmetrical Shells," J. Sound Vib., 16, 4, pp 473-487, 1971.
28. Stoneking, J. E., and Boresi, A. P., "A Theory for Free Vibration of Orthotropic Shells of Revolution," Nuclear Engr. & Design, 14, pp 271-285, 1970.
29. Sewall, J. L. and Naumann, E. C., "An Experimental and Analytical Vibration Study of Thin Cylindrical Shells with and Without Longitudinal Stiffeners," NASA TN D-4705, Sept. 1968.
30. Sewall, J. L., Thompson, Jr., W. G., and Pusey, C. G., "An Experimental and Analytical Vibration Study of Elliptical Cylindrical Shells," NASA TN D-6089, February 1971.

REFERENCES (CONT'D)

31. Sewall, J. L., Clary, R. R., and Leadbetter, S. A., "An Experimental and Analytical Vibration Study of a Ring-Stiffened Cylindrical Shell Structure With Various Support Conditions," NASA TN D-2398, August 1964.
32. Watkins, J. D. and Clary, R. R., "Vibrational Characteristics of Some Thin-Walled Cylindrical and Conical Frustum Shells," NASA TN D-2729, March 1965.
33. Maddox, N. R., Plumblee, H. E., and King, W. W., "Frequency Analysis of a Cylindrically Curved Panel With Clamped and Elastic Boundaries," J. Sound Vib., 12, 2, 225-249, 1970.
34. Gontkevich, V. S., Natural Vibrations of Plates and Shells, Naukova Dumka, Kiev, 1964, translated by Lockheed Missiles and Space Company.
35. Warburton, G. B., "Vibration of Thin Cylindrical Shells," J. Mech. Engr. Sci., 7, 4, 399-407, 1965.
36. Forsberg, K., "Axisymmetrical and Beam-Type Vibrations of Thin Cylindrical Shells," AIAA J. 7, 2, 221-227, February 1969.
37. Forsberg, K., "A Review of Analytical Methods Used To Determine the Modal Characteristics of Cylindrical Shells," NASA CR-613, Sept. 1966.
38. Nuckolls, C. E., and Egle, D. M., "The Influence of Elastic Boundary Conditions on the Resonant Response of Thin Cylindrical Shells," AIAA/ASME 12th Structures, Structural Dynamics, and Materials Conference, Anaheim, California, April 19-21, 1971.
39. Bray, F. M. and Egle, D. M., "An Experimental Investigation of The Free Vibration of Thin Cylindrical Shells with Discrete Longitudinal Stiffening," J. Sound Vib., 12, 2, 1970.
40. Basdekas, N. L., and Chi, M., "Response of Oddly-Stiffened Circular Cylindrical Shells," J. Sound Vib., 17, 2, 187-206, 1971.

REFERENCES (CONT'D)

41. McDonald, D., "A Problem in the Free Vibration of Stiffened Cylindrical Shells," AIAA J., 8, 2, 252-258, 1970.
42. Miller, P. R., "Free Vibration of a Stiffened Cylindrical Shell," Aeronautical Research Council L.A. 22, 19, 338, AD146359, 1957.
43. Miller, P. R., "Free Vibration of a Stiffened Cylindrical Shell," Aeronautical Research Council, R&M No. 3154, 1960.
44. Ligon, J. B., "Natural Frequencies of Stiffened Cylindrical Shells," Master's Thesis, University of Oklahoma, 1970.
45. Al-Najafi, A. M. J., and Warburton, G. B., "Free Vibration of Ring-Stiffened Cylindrical Shells," J. Sound Vib., 13, 1, 9-25, 1970.
46. Bert, C. W. and Egle, D. M., "Dynamics of Composite, Sandwich, and Stiffened Shell-Type Structures," J. Spacecraft & Rockets, 6, 12, 1345-1361, 1969.
47. Tsui, E. Y. W., "Natural Vibrations of Cylindrical Panels," J. Engr. Mech. Div., ASCE, 94, EM6, 1425-1445, 1968.
48. Reed, D. L., Point Stress Laminate Analysis, General Dynamics Research and Development Report FZM-5494, April 1970.
49. Tennyson, R. C., Chan, K. H., and Muggeridge, D. B., "The Effect of Axisymmetric Shape Imperfections on the Buckling of Laminated Anisotropic Circular Cylinders," Canadian Aeronautics and Space Institute, Transactions, 4, 2, September 1971.
50. Anon., "Buckling of Thin-Walled Circular Cylinders," NASA SP-8007, 1968.
51. Anon., System/360 Scientific Subroutine Package, H20-0205-3, IBM, 1968.

A P P E N D I X I

DESCRIPTION OF PROCEDURE SS8

The analysis described in Section II has been programed as IBM 370 Procedure SS8. Due to the large size of the program, a one-level, four-element overlay tree is used. The tree is shown in Figure 58. The longest resulting path is 418K bytes. All the subroutines are compiled under FORTRAN H, option 2, except subroutine ASEMBL, which is compiled with FORTRAN G.

Subroutines GSTART, PROB, SKIPPR, STATUS, and FREEFD are General Dynamics System Subroutines which perform I/O and timing functions. They would not be used elsewhere and are not discussed further. All other subroutines marked CF in Figure 58 are system-resident mathematical subroutines for matrix inversion or eigenvalue solutions. The purposes of the specially-written subroutines for SS8 are described below.

Main Program

The main program for SS8 serves only as a controller for implementing the necessary overlays. A blank common area and the labelled common blocks "CHECKS", "CNTROL", "NUMBER", "GEOM", "\$TIME", "ABD", "PARAM", "VALUES", "ARRAYS", "BLOCK", "STFVAL", and "FLEXBL" are used for communication between overlays.

Subroutine READ

This subroutine reads all input data, based on the requirements of the problem, checks the input data, and does some preliminary calculations.

Subroutine CYLNR

This subroutine calculates the appropriate running loads to be used when a force, torque, or bending moment is applied to a full cylinder. It should be noted that due to the uncoupling of

MAIN 'A'
 BLANK (C.B.)
 BLOCK (C.B.)
 ARRAYS (C.B.)
 VALUES (C.B.)
 CNTROL (C.B.)
 NUMBER (C.B.)
 GEOM (C.B.)
 \$TIME (C.B.)
 ABD (C.B.)
 PARAM (C.B.)
 CHECKS (C.B.)
 STFVAL (C.B.)
 FLEXBL (C.B.)
 GSTART (CF)
 PROB (CF)
 SKIPPR (CF)
 STATUS (CF)

- C.B. Denotes Common Block
- CF Denotes System Subroutines;
- ' ' Denotes Deck Identification Letter

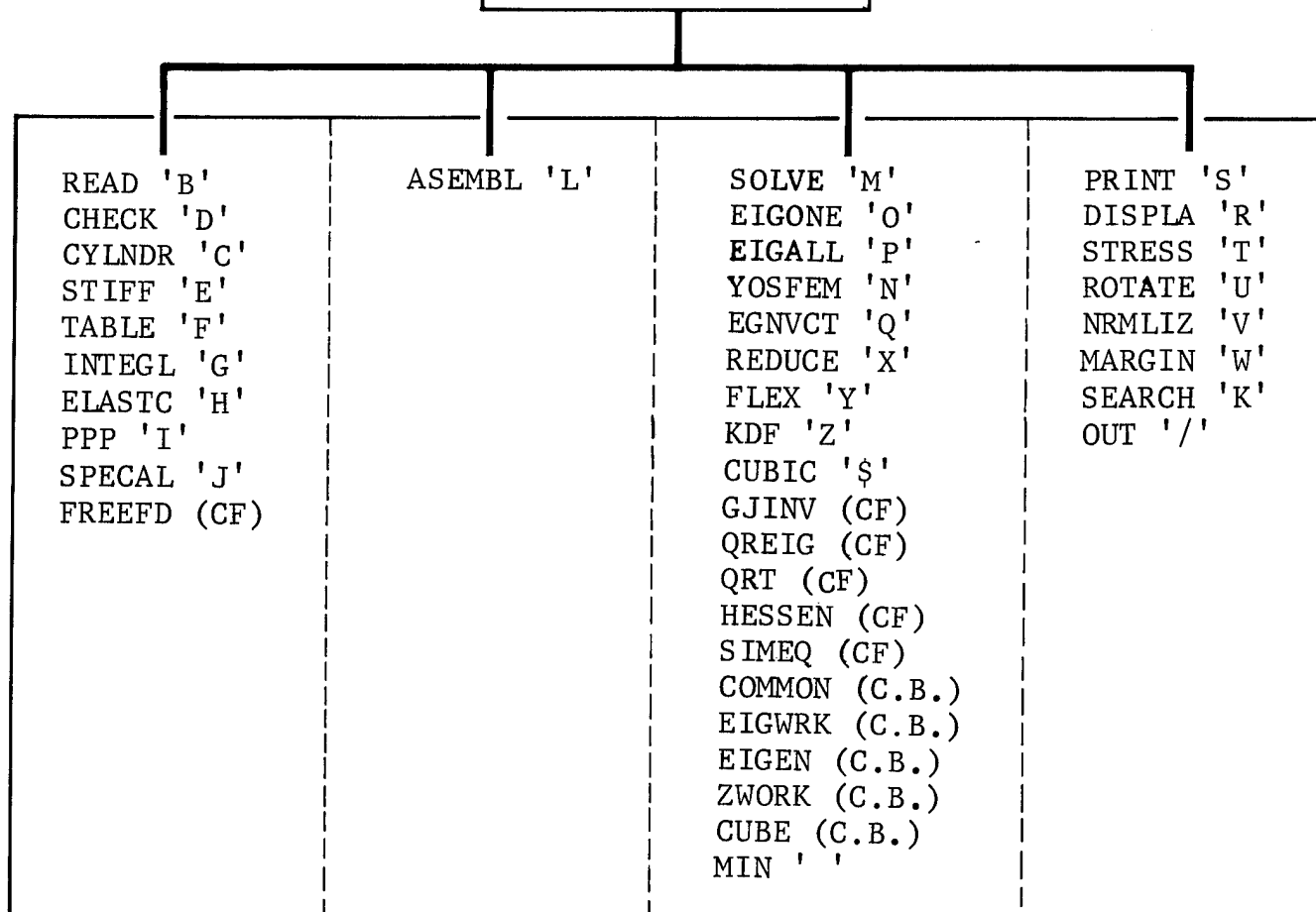


Figure 58 SS8 Overlay Structure

the axial and circumferential assumed mode shapes, torsional buckling results are not possible with SS8.

Subroutine CHECK

This subroutine writes a message and sets an error flag when subroutine READ detects an input error.

Subroutine STIFF

This subroutine calculates the A, B, and D stiffness terms as defined in Reference [3], and implemented in References [1] and [48], for a laminated plate.

Subroutine TABLE

This subroutine controls the calculation of the necessary integral tables of assumed modes in the x and y-directions.

Subroutine INTEGL

This subroutine, adapted from Reference [1], uses a highly efficient algorithm for calculating the necessary beam-mode integrals. By calling PPP and SPECAL, it calculates the single function integrals and the special cases for free-free and simple-free boundary conditions. At 625 points on the normalized shell surface, it calculates the value of the mode functions and their derivatives. At any stiffener locations, it calculates integrals, mode functions and derivatives.

Subroutine SPECAL

This subroutine calculates the integrals and mode constants for the simple-free and free-free boundary conditions.

Subroutine ELASTC

This subroutine implements the elastic moment restraint boundary condition by calculating the beam-mode constants which are dictated by the input moment restraint.

Subroutine PPP

This subroutine calculates the single-function beam-mode integrals.

Subroutine ASEMBL

Based on the input geometry and material properties and the calculated integrals, this subroutine assembles the matrices of potential energy, kinetic energy, lateral loads, and edge loads as required by the problem being performed. This assembly is done in submatrix fashion representing u, v, and w partitions.

Subroutine SOLVE

This subroutine uses the matrices from ASEMBL to solve the appropriate eigenvalue problem or simultaneous equations. It makes use of subroutines ARRAY, NROOT, and EIGEN from the IBM Scientific Subroutine Package.

Subroutine YOSFEM

This subroutine was written to perform multiplication of two large matrices by using a minimum amount of extra core storage. Optionally the product matrix may be stored in the premultiplier matrix or the postmultiplier matrix.

Subroutine EIGONE

For a single eigenvalue and eigenvector solution, the power method is an efficient algorithm. This method is used when a single buckling eigenvalue or frequency is desired.

Subroutine EIGALL

This subroutine finds all the eigenvalues of the matrix using the QR transform. The algorithm is programmed into three Convair Aerospace resident subroutines, HESSEN, QREIG, and QRT. Once the eigenvalues are found, the desired number of eigenvectors are found using a matrix decomposition technique in Subroutine EGNVCT.

Subroutine EGNVCT

Using the original matrix and a known eigenvalue, this routine uses matrix decomposition to find the corresponding eigenvector.

Subroutine PRINT

This subroutine performs various output functions, such as finding the dominant term in an eigenvector, calculating the problem execution time, and controlling other output subroutines.

Subroutine DISPLA

This subroutine calculates and prints deflections, curvatures, moments, shears, and edge reactions. All but edge reactions are printed at 625 equally-spaced points on the developed shell planform.

Subroutine OUT

This subroutine transforms the output arrays into a form for efficient printing.

Subroutine STRESS

This subroutine calculates stresses and strains at the 625 grid points.

Subroutine NRMLIZ

This subroutine finds the largest value in each output array and normalizes with respect to it.

Subroutine ROTATE

This subroutine performs a strain transformation of coordinates from one angle to another. It is used to check margins of safety in various directions.

Subroutine MARGIN

This subroutine calculates margins of safety according to the maximum strain theory of failure.

Subroutine SEARCH

This subroutine keeps track of the minimum margin of safety as well as its mode and location.

Subroutine FLEX

It is often desirable to determine an influence coefficient or flexibility matrix for a structure being analyzed. Since all of the problem types under consideration contain a term

$$[V] \{a\}$$

where $[V]$ is the varied strain energy density or the structural stiffness matrix in the generalized coordinates a_{imn} .

To obtain the point force-displacement flexibility matrix, the $[V]$ matrix must first be partially inverted to produce the lateral stiffness matrix $[S]$ in terms of the generalized lateral coordinates a_{3mn} . The stiffness matrix $[S]$ may then be inverted and transformed from shape to point coordinates. The transformation matrix can be found from the expression for the lateral displacement at a point:

$$\delta_i = \sum_m \sum_n a_{3mn} X_{3m}(x_i) Y_{3n}(y_i)$$

where (x_i, y_i) are the coordinates of the i^{th} point. For N equations, this may be expressed in matrix form as

$$\{\delta_i\} = [R] \{a\}$$

where $[R]$ is the required transformation matrix. The desired flexibility matrix $[F]$ can then be computed from

$$[F] = [R] [S]^{-1} [R]^T$$

at the N specified control points.

Subroutine REDUCE

This subroutine performs the partial inversion of the matrix containing membrane and bending degrees of freedom to reduce it to only its bending degrees of freedom.

Subroutine KDF

This subroutine uses the analysis of Reference [49] to account for imperfection sensitivity. It is an approximation since the Reference [49] analysis is done for a simply-supported full cylinder and relies on a precise definition of an axisymmetric imperfection. For the purpose of this study, the standard deviation of the thickness over the shell is used as a measure of imperfection, and the knockdown factor for the full cylinder is assumed to apply to any partial cylinder regardless of boundary conditions.

Subroutine CUBIC

This subroutine solves for the lowest real root of a cubic polynomial as required by KDF. This is done by Newton-Raphson iteration for the first root, and then by synthetic division and the quadratic formula for the other two.

Subroutine MIN

This is a general subroutine for determining the smallest element in a vector of values.

Subroutine SWITCH

This subroutine is used in the matrix operations of subroutine SOLVE. It changes diagonal elements in a matrix from 0. to 1. or vice-versa. It is used to prevent the singular matrices (which arise for some problems involving rigid-body modes) from inhibiting a solution.

A P P E N D I X I I

C U S T O M E R I N S T R U C T I O N S F O R S S 8

PROCEDURE SS8

Anisotropic Curved Panel Analysis Program

21 January 1970

D. J. Wilkins

PROBLEM DESCRIPTION

This procedure analyzes cylindrically curved panels with respect to dynamic response, buckling, and static deflection. Vlasov shell theory is used for the formulation and the Rayleigh-Ritz energy method is used for the solution. The integral generation scheme from Procedure RA5 is also employed.

The procedure is capable of analyzing flat plates, cylindrically curved panels, and full cylinders. All combinations of clamped, and simply supported edges, and some combinations of free edges may be specified. Elastic boundary restraint may also be specified.

The material may be isotropic, a laminate of identical orthotropic layers, a laminate of dissimilar orthotropic layers, or a sandwich with orthotropic facings. (No transverse shear effects are included, so that the sandwich analysis is only appropriate for stiff cores.) Discrete, eccentric rings and stringers may be specified.

Edge loads and lateral loads may be specified by up to tenth order polynomials. Point loads, point moments, and line moments may also be used, as well as point and line spring supports. In dynamics, the effects of lumped masses may be included.

In any one problem, the procedure can solve for natural frequencies and mode shapes, or the buckling stress resultants under complicated edge load distributions, or the static deflections (including stresses, strains, and margins of safety) under lateral and edge loads. A flexibility matrix at specified control points may be calculated on any type problem.

INPUT DATA

The program uses "free field" input as explained in the documentation for general purpose subroutine CF619. However, every number input as problem data is considered by the program to be a real number (card type "6" in free field). Therefore, every card of the input deck should have a "6" in column 1. It should be noted that if an input number is an integer, a decimal point is not necessary. The title card (Card No. 1) is not read in the free field mode but it also contains a "6" in column 1.

The general content of each card in a problem deck is as follows:

Column

1	The integer "6"
2 -66	Input data
67 - 72	The six-digit job number
73	The letter "P"
74 - 75	The problem number, beginning with 01
76 - 79	The card sequence number, beginning with 0001.

The input data varies according to the problem being run. A flow chart of the necessary data to run a given problem is shown in Figure 59. One or more cards may be required for each block of data, but each block must begin on a new card.

A description of the data blocks follows:

Block 1. Title

Printed with the output. Any Fortran characters may be used. (1 card only.)

Block 2. IFLAGD, IFLAGB, IFLAGW, IBCX, IBCY, NTX, NTY, ITX, ITY, NMODES, IMATL, NPLYS, IREACT, IOUT, IEDGE, NPNX, NPNY, IPRTN, NQTX, NQTY, IPRTQ, NSTRNG, NRING, NLMASS, NPTLDS, NPTMOM, NLNMOM, NPTSUP, NLNSPR, INTPT, IFLEX (31 integers)

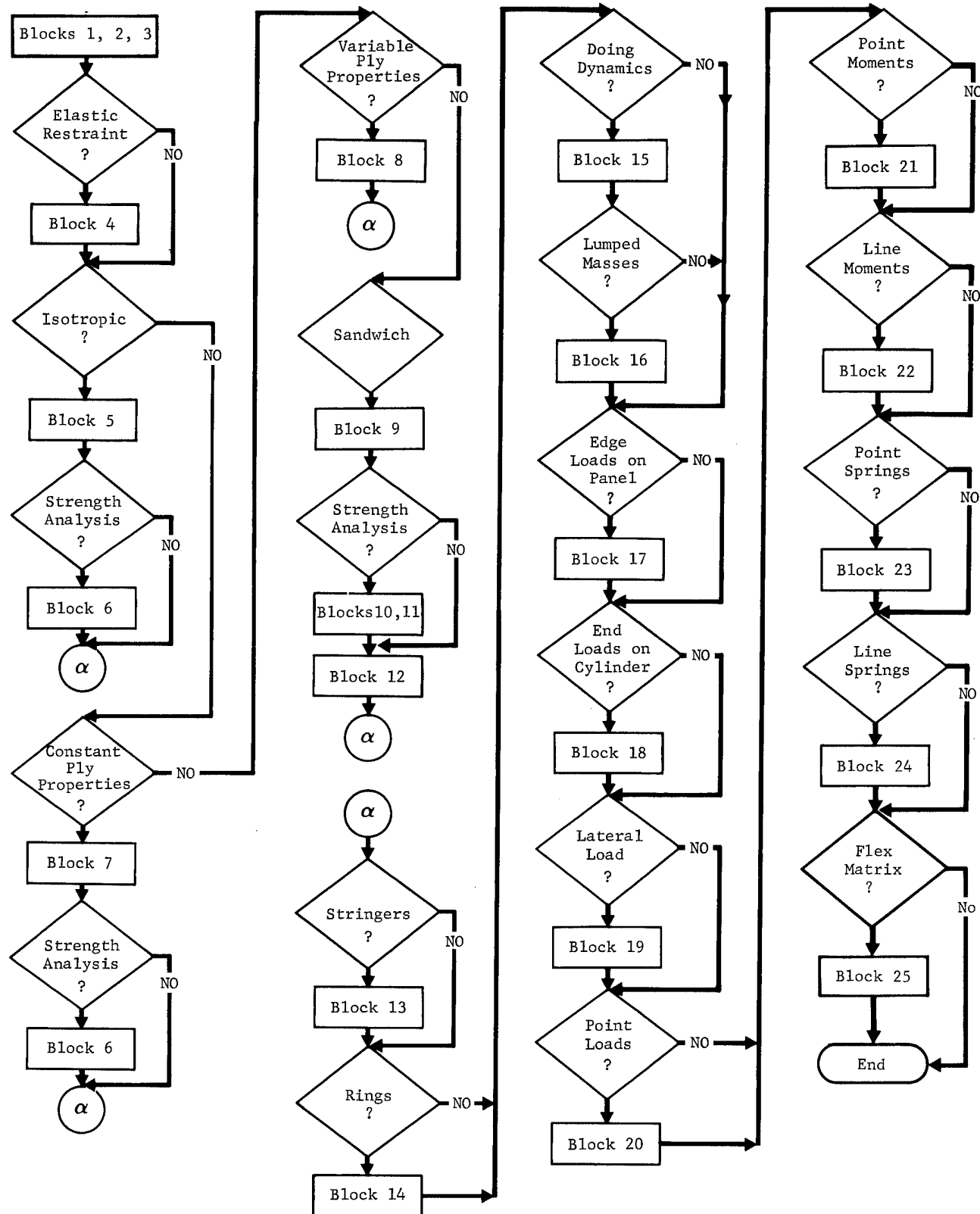


Figure 59 Input Data Flow Chart

IFLAGD = +1, if doing a dynamics problem
= +0, otherwise.

IFLAGB = +1, if 1 buckling eigenvalue is desired
= +2, if 2 buckling values are desired
(as for shear buckling)
= +3, if 1 buckling eigenvalue and an imperfection sensitivity analysis are desired
= +4, if 2 buckling eigenvalues and an imperfection sensitivity analysis are desired
= +0, otherwise.

IFLAGW = +1, if doing a deflection analysis with lateral pressure, q
= +2, if doing a deflection analysis with no lateral pressure, q
= +0, otherwise.

IBCX is a tag for the boundary condition in the x-direction.
= +1, for clamped-simply supported
= +2, for simply supported-simply supported
= +3, for clamped-clamped
= +4, for clamped-free
= +5, for simply supported-free
= +6, for free-free
= +7, for elastic restraint. ($w_{,xx} = \alpha_x w_{,x} \big|_{x=0}$,
 $w_{,xx} = \beta_x w_{,x} \big|_{x=a}$)

IBCY is a tag for the boundary condition in the y-direction.
= +0, for a full cylinder
= +1, for clamped-simply supported
= +2, for simply supported-simply supported
= +3, for clamped-clamped
= +4, for clamped-free
= +5, for simply supported-free
= +6, for free-free
= +7, for elastic restraint exactly the same as that in the x-direction
= +8, other elastic restraint. ($w_{,yy} = \alpha_y w_{,y} \big|_{y=0}$
 $w_{,yy} = \beta_y w_{,y} \big|_{y=b}$)

NTX = Number of terms in the assumed series for
u, v, and w, in the x-direction. $1 \leq \text{NTX} \leq 10$.

NTY = Number of terms in the assumed series for
u, v, and w, in the y-direction. $1 \leq \text{NTY} \leq 10$.

Note: Although the upper limit on each of the above two numbers is ten, the limit on the size of the matrices generated using them is 150. This means that $\text{NTX} * \text{NTY} \leq 50$.

ITX = The beginning term in the assumed series for
u, v, and w. This number sets the range of
m (axial wave number) to be considered in the
analysis, such that $\text{ITX} \leq m \leq \text{ITX} + \text{NTX} - 1$. The
range on ITX is $1 \leq \text{ITX} \leq 20$.

ITY = The beginning term in the assumed series for
u, v, and w. This number sets the range of
n (circumferential wave number) to be considered
in the analysis, such that $\text{ITY} \leq n \leq \text{ITY} + \text{NTY} - 1$.
The range on ITY is $1 \leq \text{ITY} \leq 20$.

NMODES = Number of mode shapes to be calculated in
a natural frequency problem. $1 \leq \text{NMODES} \leq 20$.
= +0, for a buckling or lateral loads problem.

IMATL = +1, for an isotropic material
= +2, for a laminate with constant ply properties
= +3, for a laminate with variable ply properties
= +4, for a sandwich with orthotropic facings.

NPLYS = Number of plies in the laminate
 $1 \leq \text{NPLYS} \leq 40$. For an isotropic material,
NPLYS = +1. For a sandwich, NPLYS = +3.

IREACT = +1 if the reactions (at the corners, or along
the edges of the panel, or at elastic supports)
are desired.
= +0, otherwise.

IOUT = An indicator that controls how much output
is given and also controls whether a lamina
strength analysis is performed. Each of the
following output quantities is printed at 625
points over the panel, with the x = 0 axis
across the top and the y = 0 axis down the
left hand side.

- = +1, for printing the normal deflection, w, only
- = +2, for printing w, u, and v (mid-surface deflections)
- = +3, for printing w, u, v, $\epsilon_x^0, \epsilon_y^0, \epsilon_{xy}^0$ (mid-surface strains) and K_x, K_y, K_{xy} (curvatures)
- = +4, for printing w, u, v, M_x, M_y, M_{xy} (moment resultants), Q_x, Q_y (transverse shear resultants), and $\sigma_x, \sigma_y, \sigma_{xy}$ (stresses, only for isotropic or sandwich)
- = +5, for printing w, u, v, $M_x, M_y, Q_x, Q_y, \epsilon_x^0, \epsilon_y^0, \epsilon_{xy}^0, K_x, K_y, K_{xy}, \sigma_x, \sigma_y, \sigma_{xy}$
- = +6, for printing w, $\sigma_x, \sigma_y, \sigma_{xy}$
- = +7, for printing w, $\epsilon_1, \epsilon_2, \epsilon_{12}$ (strains in lamina axes for each ply), M.S.1, M.S.2, M.S.12 (margins of safety for each ply according to the maximum strain theory)
- = +8, for printing w, $\sigma_x, \sigma_y, \sigma_{xy}, \epsilon_1, \epsilon_2, \epsilon_{12}, M.S.1, M.S.2, M.S.12$
- = +9, for printing w, u, v, $M_x, M_y, M_{xy}, Q_x, Q_y, \epsilon_x^0, \epsilon_y^0, \epsilon_{xy}^0, K_x, K_y, K_{xy}, \sigma_x, \sigma_y, \sigma_{xy}, \epsilon_1, \epsilon_2, \epsilon_{12}, M.S.1, M.S.2, M.S.12$.

IEDGE = +1, if edge loads are to be input
 = +2, if cylinder end loads (force, torque, bending moment are to be input)
 = +0, otherwise.

NPNX = Number of terms in the edge loads expressions in the x-direction. $1 \leq \text{NPNX} \leq 10$.
 = +0, if IEDGE = +0 or +2.

NPNY = Number of terms in the edge loads expressions in the y-direction. $1 \leq \text{NPNX} \leq 10$.
 = +0, if IEDGE = +0 or +2.

IPRTN = +1, if the distributions of the edge loads are to be printed at quarter points of the panel.
 = +0, otherwise.

NQTX = Number of terms in the distributed lateral loads expression in the x-direction. $1 \leq \text{NQTX} \leq 10$.
 = +0, if IFLAGW = +0 or +2.

NQTY = Number of terms in the distributed lateral loads expression in the y-direction. $1 \leq \text{NQTY} \leq 10$.
 = +0, if IFLAGW = +0 or +2.

IPRTQ = +1, if the distribution of the lateral loads is to be printed at quarter points of the panel.
 = +0, otherwise.

NSTRNG = Number of stringers. $0 \leq \text{NSTRNG} \leq 100$. (For equally-spaced identical stringers, precede number by a minus sign.)

NRING = Number of rings. $0 \leq \text{NRING} \leq 50$. (For equally-spaced identical rings, precede number by a minus sign.)

NLMASS = Number of lumped masses. $0 \leq \text{NLMASS} \leq 50$.

NPTLDS = Number of concentrated normal loads.
 $0 \leq \text{NPTLDS} \leq 50$.

NPTMOM = Number of concentrated point moments.
 $0 \leq \text{NPTMOM} \leq 50$.

NLNMOM = Number of concentrated line moments.
 $0 \leq \text{NLNMOM} \leq 50$.

NPTSUP = Number of point spring supports. $0 \leq \text{NPTSUP} \leq 50$.

NLNSPR = Number of line spring supports. $0 \leq \text{NLNSPR} \leq 50$.

INTPRT = +1, if the values of the calculated integrals, the matrices generated, and detailed timing information is to be printed.
 = +0, otherwise. (Usually, INTPRT = +0).

IFLEX = Number of points for which influence coefficients are desired.

Block 3. AA, [BB], RR, [MU]

AA = Dimension in the x-direction

BB = Dimension in the y-direction (Note: This is not input for a full cylinder.)

RR = Radius of panel.

MU = Standard deviation of panel thickness.

Block 4. [ALFAX, BETAX], [ALFAY, BETAY]

ALFAX = The constant describing the elastic restraint on the edge $x = 0$. $w_{,xx} = (\text{ALFAX})w_{,x}$.

BETAX = The constant describing the elastic restraint on the edge $x = a$. $w_{,xx} = (-\text{BETAX})w_{,x}$.

ALFAY = The constant describing the elastic restraint on the edge $y = 0$. $w_{,yy} = (\text{ALFAY})w_{,y}$.

BETAY = The constant describing the elastic restraint on the edge $y = b$. $w_{,yy} = (-\text{BETAY})w_{,y}$.

The elastic restraint constants are only input as needed, and if the y-direction quantities are identical to those in the x-direction, only ALFAX and BETAX need be input. All of these constants are input as positive for positive restraint.

Block 5. E, ν , T

E = Young's modulus, psi

ν = Poisson's ratio, dimensionless

T = Panel thickness, in.

Block 6. EC (1), EC(2), EC(3), ET(1), ET(2), ET(3)

EC(1) = Compressive strain allowable in the 1-direction, in/in.

EC(2) = Compressive strain allowable in the 2-direction, in/in.

EC(3) = Negative shear strain allowable, in/in.

ET(1) = Tensile strain allowable in the 1-direction, in/in.

ET(2) = Tensile strain allowable in the 2-direction, in/in.

ET(3) = Positive shear strain allowable, in/in.

Block 7. E1, E2, G, ν_{12} , H, (θ_i , $i = 1, 2, \dots, \text{NPLYS}$)

E1 = Modulus in the 0° direction, psi.

E2 = Modulus in the 90° direction, psi.

G = In-plane shear modulus, psi.

ν_{12} = Major Poisson's ratio, dimensionless.

H = Thickness of each ply, in.

θ_i = Orientation of the i^{th} ply, starting with the bottom or inner ply, degrees.

Block 8. ($E1$) $_i$, ($E2$) $_i$, G_i , (ν_{12}) $_i$, H_i , θ_i , [$EC(1)$ $_i$, $EC(2)$ $_i$, $EC(3)$ $_i$, $ET(1)$ $_i$, $ET(2)$ $_i$, $ET(3)$ $_i$], $i = 1, \dots, \text{NPLYS}$

$E1_i$ = Modulus in the 0° direction of the i^{th} ply, psi

$E2_i$ = Modulus in the 90° direction of the i^{th} ply, psi

G_i = Shear modulus of the i^{th} ply, psi

(ν_{12}) $_i$ = Major Poisson's ratio of the i^{th} ply, dimensionless

H_i = Thickness of the i^{th} ply, in.

θ_i = Orientation of the i^{th} ply, degrees.

(The following allowables are input only if a strength analysis is being performed, IOU ≥ 7 .)

$EC(1)_i$ = Compressive strain allowable in the 1-direction for the i^{th} ply, in/in.

$EC(2)_i$ = Compressive strain allowable in the 2-direction for the i^{th} ply, in./in.

$EC(3)_i$ = Negative shear strain allowable in the 1-2 plane for the i^{th} ply, in/in.

$ET(1)_i$ = Tensile strain allowable in the 1-direction
for the i^{th} ply, in/in.

$ET(2)_i$ = Tensile strain allowable in the 2-direction
for the i^{th} ply, in/in.

$ET(3)_i$ = Positive shear strain allowable in the 1-2
plane for the i^{th} ply, in/in.

Block 9. $E1$, $E2$, G , ν_{12} , H

$E1$ = Inner (outer) facing modulus in the 0°
direction, psi.

$E2$ = Inner (outer) facing modulus in the 90°
direction, psi.

G = Inner (outer) facing shear modulus, psi.

ν_{12} = Inner (outer) facing major Poisson's ratio,
dimensionless.

H = Inner (outer) facing thickness, in.

(If a strength analysis is not being performed, Block 9 is now repeated for the outer facing properties. If a strength analysis is being performed, Blocks 10 and 11 for the inner facing are now input, then Blocks 9, 10 and 11 are input for the outer facing.)

Block 10. $EC(1)$, $EC(2)$, $EC(3)$, $ET(1)$, $ET(2)$, $ET(3)$, $MCHK$

$EC(1)$ = Inner (outer) facing compressive strain allowable in the 1-direction, in/in.

$EC(2)$ = Inner (outer) facing compressive strain allowable in the 2-direction, in/in.

$EC(3)$ = Inner (outer) facing negative shear strain allowable in the 1-2 plane, in/in.

$ET(1)$ = Inner (outer) facing tensile strain allowable in the 1-direction, in/in.

$ET(2)$ = Inner (outer) facing tensile strain allowable in the 2-direction, in/in.

ET(3) = Inner (outer) facing positive shear strain allowable in the 1-2 plane, in/in.

MCHK = Number of orientations to be checked in the strength analysis of the inner (outer) facing.
 $1 \leq MCHK \leq 10$.

Block 11. ANGCHK_i, i = 1, MCHK

ANGCHK_i = Orientations to be checked in the strength analysis of the inner (outer) facing, degrees.

Block 12. H_c

H_c = Core thickness, in.

Block 13. [YSTRNG], YBAR, ZBAR, AS, XIYYS, XIYZS, XIZZS, ES, GJS, RHOS

YSTRNG = Distance of longitudinal stiffener from y = 0.
For variable stiffener spacing only.

YBAR = Location of stringer centroid in the y-direction with respect to its line of attachment to the shell, in.

ZBAR = Location of stringer centroid in the z-direction with respect to the middle surface of the shell at the line of attachment, in.

AS = Stringer cross-sectional area, in².

XIYYX = Moment of inertia of the stringer area about the mid-surface y- axis at the line of attachment, in⁴.

XIYZS = Product of inertia of the stringer area about the mid-surface y-z axis at the line of attachment, in⁴.

XIZZS = Moment of inertia of the stringer area about the z-axis at the line of attachment, in⁴.

ES = Stringer modulus of elasticity, psi.

GJS = Stringer torsional stiffness, lb-in.².

RHOS = Average density of stringer material,
lb-sec²/in⁴.

Block 13 is repeated 'NSTRNG' times, unless equally-spaced identical stringers were specified.

Block 14. [XRING], XBARR, ZBARR, AR, XIXXR, XIZZR, ER, GJR, RHOR

XRING = Distance of circumferential stiffener from
x = 0. For unequally spaced rings.

XBARR = Location of ring centroid in the x-direction
with respect to its line of attachment to the
shell, in.

ZBARR = Location of ring centroid in the z-direction
with respect to the middle surface of the
shell at the line of attachment, in.

AR = Ring cross-sectional area, in².

XIXXR = Moment of inertia of the ring area about the
mid-surface x-axis at the line of attachment,
in.⁴.

XIXZR = Product of inertia of the ring area about the
mid-surface x-z axis at the line of attach-
ment, in⁴.

XIZZR = Moment of inertia of the ring area about the
z-axis at the line of attachment, in⁴.

ER = Ring modulus of elasticity, psi.

GJR = Ring torsional stiffness, lb-in².

RHOR = Average density of ring material, lb-sec²/in⁴.

Block 14 is repeated 'NRING' time unless equally-spaced identical rings were specified.

Block 15. DENSE

DENSE = Average material density of the shell material,
such that (DENSE) (Vol. of shell) = (Mass of
shell), lb-sec²/in⁴.

Block 16. IX, IY, PMASS

IX = Grid coordinate in x-direction at which lumped mass is located, $1 \leq IX \leq 25$.

IY = Grid coordinate in y-direction at which lumped mass is located, $1 \leq IY \leq 25$.

PMASS = Mass, lb-sec²/in.

Block 16 is repeated 'NLMASS' times.

Block 17. PX(1,1), PY(1,1), PXY(1,1), PX(2,1), PY(2,1), PXY(2,1),
...PX(I,J), PY(I,J), PXY(I,J), I = 1, 2...NPNX, J = 1, 2...NPNY

The applied in-plane stress resultants are described by the relations

$$N_x(x,y) = \sum_{I=1}^{NPNX} \sum_{J=1}^{NPNY} P_x(I,J) \left(\frac{x}{a}\right)^{I-1} \left(\frac{y}{b}\right)^{J-1}$$

$$N_y(x,y) = \sum_{I=1}^{NPNX} \sum_{J=1}^{NPNY} P_y(I,J) \left(\frac{x}{a}\right)^{I-1} \left(\frac{y}{b}\right)^{J-1}$$

$$N_{xy}(x,y) = \sum_{I=1}^{NPNX} \sum_{J=1}^{NPNY} P_{xy}(I,J) \left(\frac{x}{a}\right)^{I-1} \left(\frac{y}{b}\right)^{J-1}$$

Note: Tension stress resultant are taken as positive.

TORQUE = Torque applied to cylinder, in-lb.

BNDMOM = Bending moment applied to cylinder, in-lb.

Block 19. Q(1,1), Q(2,1), Q(3,1), ...Q(I,J), I = 1, ..., NQTX
J = 1, 2..., NQTY

The distributed lateral load is described by the relation

$$q(x,y) = \sum_{I=1}^{NQTX} \sum_{J=1}^{NQTY} Q(I,J) \left(\frac{x}{a}\right)^{I-1} \left(\frac{y}{b}\right)^{J-1}$$

Note: positive loads are in the positive z-direction.

Block 20. IX, IY, PC

IX = Grid coordinate in x-direction, $1 \leq IX \leq 25$.

IY = Grid coordinate in y-direction, $1 \leq IY \leq 25$.

PC = Concentrated load, lb.

Block 20 is repeated 'NPTLDS' times.

Block 21. IX, IY, ITAG, FC

IX = Grid coordinate in x-direction, $1 \leq IX \leq 25$.

IY = Grid coordinate in the y-direction, $1 \leq IY \leq 25$.

ITAG = +1, if the moment is about the x-axis in a
vector sense (right-hand rule)
= +2, if the moment is about the y-axis.

FC = Moment, in-lb.

Block 21 is repeated 'NPTMOM' times.

Block 22. ITAG, IDIST, PLMOM

ITAG = +1, if the line moment is parallel to the x-axis.
= +2, if the line moment is parallel to the y-axis.

IDIST = Number of grid lines away from the $x = 0$ or
 $y = 0$ axis. $1 \leq IDIST \leq 25$.

PLMOM = Line moment per unit of length, in-lb/in.

Block 22 is repeated 'NLNMOM' times.

Block 23. IX, IY, PKC

IX = Grid coordinate in x-direction. $1 \leq IX \leq 25$.

IY = Grid coordinate in y-direction. $1 \leq IY \leq 25$.

PKC = Spring constant, lb/in.

Block 23 is repeated 'NPTSUP' times.

Block 24. ITAG, IDIST, PLINE

ITAG = +1, if the line spring is parallel to the x-axis.
 = +2, if the line spring is parallel to the y-axis.

IDIST = Number of grid lines away from the x=0 or y=0 axis. $1 \leq \text{IDIST} \leq 25$.

PLINE = Spring constant per unit length, lb/in².

Block 24 is repeated 'NLNSPR' times.

Block 25. XP(I), YP(I), I = 1, IFLEX

XP(I) = X-coordinate (in %) of Ith flexibility matrix control point.

YP(I) = Y-coordinate (in %) of Ith flexibility matrix control point.

OUTPUT DATA DESCRIPTION

Most of the output is labeled with the exception of the 'CONTRIBUTIONS OF THE SERIES TERMS'. These are the solution vectors used for the modal analysis. They are printed in the following order:

$a_{111}, a_{112}, a_{113}, \dots, a_{11(\text{NTY})}, a_{121}, a_{122}, \dots, a_{12(\text{NTY})},$
 $\dots, a_{1(\text{NTX})1}, a_{1(\text{NTX})2}, \dots, a_{1(\text{NTX})\text{NTY}}, a_{211}, a_{212},$
 $\dots, a_{2(\text{NTX})(\text{NTY})}, a_{311}, a_{312}, \dots, a_{3(\text{NTX})(\text{NTY})}$

where

$$\begin{aligned} u &= \sum_{m=M_i}^{M_f} \sum_{n=N_i}^{N_f} a_{1mn} X_{1m} Y_{1n} \\ v &= \sum_{m=M_i}^{M_f} \sum_{n=N_i}^{N_f} a_{2mn} X_{2m} Y_{2n} \\ w &= \sum_{m=M_i}^{M_f} \sum_{n=N_i}^{N_f} a_{3mn} X_{3m} Y_{3n} \end{aligned}$$

$$\begin{aligned}
M_i &= ITX. \\
M_f &= ITX + NTX - 1. \\
N_i &= ITY. \\
N_f &= ITY + NTY - 1.
\end{aligned}$$

For a buckling solution only the a_{3mn} are printed.

RESTRICTIONS

The ranges of the input parameters are described under INPUT DATA.

The main restriction is to keep in mind the assumptions of the analysis, particularly the small-deflection assumption. If the deflections found in a lateral loads problem are greater than the panel thickness, the results are questionable.

If a solution mode shape contains large contributions from the highest modal shape input, the solution is questionable, and the analysis should be rerun using the highest mode shape input as the initial term in the new analysis. Since the high-order modes are not sensitive to boundary conditions, the restriction to simply-supported or full cylinder boundary conditions will not make much difference in the results.

ESTIMATED RUNNING TIME

The run times may vary considerably depending solely on the size of the matrix to be inverted and solved for eigenvalues. A meaningful buckling problem may be solved in 10 to 20 seconds, while a large vibration problem with many mode shapes desired may run up to 10 minutes. For the static deflection and buckling problem, an estimate of the run time can be obtained as

$$t = 9.4 \quad 0.0666 (NTX*NTY) \quad \text{sec.}$$

The vibration problems normally run up to twice as long as the corresponding buckling problems, and can run longer when many modes are desired.

A P P E N D I X I I I

S A M P L E P R O B L E M S

6 59A
 6 ++1 +3+3 +5+5 +1+1 ++2+6 ++1+++++1+1+++++
 6 +12 +8 +12 +.0010
 6+21000000+1700000+650000+.21+.0070+-60+60+60-60+
 6 +1++

004602P540001
 004602P540002
 004602P540003
 004602P540004
 004602P540005

59A

THE BOUNDARY CONDITIONS AT X=0 AND X=A ARE
CLAMPED, CLAMPED

THE BOUNDARY CONDITIONS AT Y=0 AND Y=B ARE
CLAMPED, CLAMPED

THERE ARE 5 MODES IN THE X DIRECTION, STARTING WITH M = 1 :
THERE ARE 5 MODES IN THE Y DIRECTION, STARTING WITH N = 1 :

THE STIFFNESS MATRIX SIZE IS 75 BY 75

A SOLUTION UNDER LATERAL LOADS WILL BE SOUGHT

A = 12.00000

B = 8.00000

R = 12.00000

MU = 0.0

FOR THE 6 PLY LAMINATE

E1 = 0.210000E 08

E2 = 0.170000E 07

G = 0.650000E 06

NU12 = 0.2100

H(1) = 0.0070

T = 0.0420

THE ORIENTATIONS ARE
0.0

-60.0000

60.0000

60.0000

-60.0000

0.0

GENERAL DYNAMICS CONVAIR AEROSPACE DIVISION FORT WORTH OPERATION
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THE CONSTITUTIVE MATRIX IS

0.3762170E 06	0.1172375E 06	0.0	0.3906250E-02	0.2136230E-03	0.0
0.1172375E 06	0.3762169E 06	0.0	0.2136230E-03	0.0	0.0
0.0	0.0	0.1294858E 06	0.0	0.0	0.1678467E-03
0.3906250E-02	0.2136230E-03	0.0	0.9686734E 02	0.8888407E 01	-0.2862569E 01
0.2136230E-03	0.0	0.0	0.888847E 01	0.3043127E 02	-0.8644495E 01
0.0	0.0	0.1678467E-03	-0.2862569E 01	-0.8644495E 01	0.1068948E 02

THE LAMINATE PROPERTIES ARE

EX = 0.808769E 07 EY = 0.808769E 07 G = 0.308309E 07 NUXY = 0.3116 NUXX = 0.3116

Q(I,J) FOLLOWS
 1.0000E 00

GENERAL DYNAMICS
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CCNAVIR AEROSPACE DIVISION
PROBLEM 004602-54

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THE CONTRIBUTIONS OF THE SERIES TERMS TO REFLECTION FOLLOW

0.5184E-05	-0.3113E-16	0.3784E-06	0.4528E-16	0.1862E-06	0.1995E-16	0.9983E-09	-0.2213E-17	-0.1041E-08	-0.3966E-19
0.1313E-06	-0.3206E-17	0.3767E-07	0.2823E-17	0.3791E-07	0.5546E-17	-0.8079E-09	0.6264E-18	0.9691E-09	0.1576E-17
0.3827E-07	-0.1220E-17	0.1065E-07	-0.8611E-18	0.8614E-08	0.4368E-05	0.4131E-16	0.1860E-06	-0.4679E-16	-0.1867E-07
-0.6900E-15	-0.4840E-08	-0.4833E-17	0.8495E-09	0.1098E-17	0.1061E-05	0.1504E-17	0.1792E-06	-0.6508E-18	0.6608E-08
0.2420E-16	0.6866E-08	0.4198E-17	-0.4262E-08	0.3072E-19	0.4348E-06	0.4974E-17	0.8720E-07	0.5054E-17	0.1355E-07
0.3430E-03	0.3016E-14	0.7821E-04	-0.1067E-13	0.8165E-05	-0.5216E-14	-0.5493E-06	-0.1595E-14	0.2288E-06	0.3261E-15
0.1310E-03	-0.6141E-15	0.5687E-04	0.5607E-15	0.1286E-04	0.4071E-14	0.4955E-06	0.1628E-14	-0.1509E-05	0.8037E-15
0.6974E-04	-0.3629E-15	0.3075E-04	0.1811E-14	0.1175E-04					

GENERAL DYNAMICS
37C PROCEDURE S38

CONVAIR AEROSPACE DIVISION
PROBLEM 004002-54

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THE EXECUTION TIME FOR THIS PROBLEM WAS 0 MINUTES, 30 SECONDS.

6 SAMPLE PROBLEM - SHEAR BUCKLING
 6 +2+ +3+2 +5+10 +1+1 +2+8 +1 +1+1+1 ++++++
 6 +9 +16.45 +12
 6 +2100000 +1700000 +650000 +.21 +.007
 6 +45-45+45-45-45+45-45+45
 6 +++1

004602P010001
 004602P010002
 004602P010003
 004602P010004
 004602P010005
 004602P010006

SAMPLE PROBLEM - SHEAR BUCKLING

THE BOUNDARY CONDITIONS AT X=0 AND X=A ARE
 CLAMPED, CLAMPED

THE BOUNDARY CONDITIONS AT Y=0 AND Y=B ARE
 SIMPLE, SIMPLE

THERE ARE 5 MODES IN THE X DIRECTION, STARTING WITH M = 1 .
 THERE ARE 10 MODES IN THE Y DIRECTION, STARTING WITH N = 1 .

THE STIFFNESS MATRIX SIZE IS 150 BY 150

A STABILITY SOLUTION WILL BE SOUGHT

A = 9.00000

B = 16.45000

R = 12.00000

MU = 0.0

FOR THE 8 PLY LAMINATE

E1 = 0.210000E 08

E2 = 0.170000E 07

G = 0.650000E 06

NU12 = 0.2100

H(1) = 0.0070

T = 0.0560

THE ORIENTATIONS ARE
 45.0000

-45.0000

45.0000

-45.0000

-45.0000

45.0000

-45.0000

GENERAL DYNAMICS
370 PROCEDURE SS8

CONVAIR AEROSPACE DIVISION
PROBLEM 004602-01

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45.0000

GENERAL DYNAMICS
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CONVAIR AEROSPACE DIVISION
PROBLEM 004602-01
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THE CONSTITUTIVE MATRIX IS

0.3653700E 06	0.2925696E 06	0.0	0.3662109E-02	0.1220703E-03	0.1220703E-03
0.2925696E 06	0.3653695E 06	0.0	0.1220703E-03	0.2929688E-02	0.1220703E-03
0.0	0.0	0.3089061E 06	0.1220703E-03	0.1220703E-03	0.7324219E-03
0.3662109E-02	0.1220703E-03	0.1220703E-03	0.9548331E 02	0.7645819E 02	0.2657442E 02
0.1220703E-03	0.2929688E-02	0.1220703E-03	0.7645819E 02	0.9548315E 02	0.2657440E 02
0.1220703E-03	0.1220703E-03	0.7324219E-03	0.2657442E 02	0.2657440E 02	0.8072745E 02

THE LAMINATE PROPERTIES ARE

EX = 0.234098E 07 EY = 0.234098E 07 G = 0.551618E 07 NUXY = 0.8008 NUYX = 0.8007

PX(I,J) FOLLOWS
0.0

PY(I,J) FOLLOWS
0.0

PXY(I,J) FOLLOWS
1.0000E 00

THE BUCKLING EIGENVALUE IS 0.5006819E 03 FOR M = 1, N = 6.

THE CONTRIBUTIONS OF THE SERIES TERMS FOR W FOLLOW

-0.2243E-11	0.7644E-02	-0.1333E-10	0.4221E-01	-0.2644E-09	0.1142E 01	0.6323E-09	-0.6329E 00	-0.1261E-09	-0.1098E-01
-0.8917E-02	-0.5158E-11	-0.3619E-01	-0.4761E-11	-0.2724E 00	-0.4363E-09	0.1000E 01	0.4095E-09	-0.2227E 00	-0.1120E-10
0.3574E-11	-0.1415E-01	0.7597E-11	-0.1920E-01	0.2547E-10	-0.2264E 00	-0.2083E-09	0.3338E 00	0.9032E-10	-0.1029E-01
0.1386E-02	0.3442E-11	-0.3647E-02	0.9592E-11	-0.4007E-01	-0.4753E-10	0.1214E-01	0.2539E-11	0.4119E-01	0.8886E-11
0.1435E-11	-0.5456E-03	0.5684E-11	0.3906E-02	0.3032E-10	-0.4466E-01	-0.8372E-10	0.4226E-01	0.1792E-10	0.8568E-02

THE W DEFLECTIONS DIVIDED BY 0.471940E 01/10000 FOLLOW

[illegible]

GENERAL DYNAMICS
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CONVAIR AEROSPACE DIVISION
PROBLEM 004602-01

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THE BUCKLING EIGENVALUE IS -0.7427390E 03 FOR M = 1, N = 6.

THE CONTRIBUTIONS OF THE SERIES TERMS FOR W FOLLOW

0.3631E-11	-0.2483E-02	0.2058E-10	-0.6968E-01	0.5375E-09	0.1000E 01	-0.4853E-09	-0.2751E 00	0.1554E-11	-0.3611E-01
0.9910E-02	0.9287E-11	0.3884E-01	0.6842E-10	0.3470E 00	-0.4849E-09	-0.6145E 00	0.1527E-09	0.3848E-02	0.2147E-10
-0.5746E-11	0.1553E-02	-0.1276E-10	0.2179E-02	-0.4942E-10	-0.1588E 00	0.1306E-09	0.1111E 00	-0.3316E-11	0.2021E-01
-0.1692E-02	0.1568E-11	-0.6809E-03	0.1755E-10	0.4223E-01	-0.4988E-10	-0.3605E-01	0.4644E-11	-0.6943E-02	-0.1012E-13
-0.1235E-11	0.1412E-02	-0.3039E-11	0.4844E-02	-0.2492E-10	-0.2717E-01	0.4598E-10	0.1869E-01	0.5196E-12	0.4790E-02

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[illegible]

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CONVAIR AEROSPACE DIVISION
PROBLEM 004602-01

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THE EXECUTION TIME FOR THIS PROBLEM WAS 2 MINUTES, 48 SECONDS.

6 SAMPLE PROBLEM - PANEL VIBRATION
 6 +1+ +4+2 +3+3 +1+1 +3 +2+2++1 ++++++
 6 +6 +4 +20
 6 +30000000 +2700000 +650000 +.21 +.0053 +45-45
 6 +.00018

004602P020001
 004602P020002
 004602P020003
 004602P020004
 004602P020005

SAMPLE PROBLEM - PANEL VIBRATION

THE BOUNDARY CONDITIONS AT $X=0$ AND $X=A$ ARE
CLAMPED, FREE

THE BOUNDARY CONDITIONS AT $Y=0$ AND $Y=B$ ARE
SIMPLE, SIMPLE

THERE ARE 3 MODES IN THE X DIRECTION, STARTING WITH $M = 1$.
THERE ARE 3 MODES IN THE Y DIRECTION, STARTING WITH $N = 1$.

THE STIFFNESS MATRIX SIZE IS 27 BY 27

A DYNAMIC SOLUTION WILL BE SOUGHT

A = 6.00000

B = 4.00000

R = 20.00000

MU = 0.0

FOR THE 2 PLY LAMINATE

E1 = 0.300000E 08

E2 = 0.270000E 07

G = 0.650000E 06

NU12 = 0.2100

H(1) = 0.0053

T = 0.0106

THE ORIENTATIONS ARE
45.0000

-45.0000

GENERAL DYNAMICS CONVAIR AEROSPACE DIVISION FORT WORTH OPERATION
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THE CONSTITUTIVE MATRIX IS

0.9690731E 05	0.8312731E 05	0.0	0.0	0.0	0.0	-0.1924780E 03
0.8312731E 05	0.9690725E 05	0.0	0.0	0.0	0.0	-0.1924779E 03
0.0	0.0	0.8398313E 05	-0.1924780E 03	-0.1924779E 03	0.0	0.0
0.0	0.0	-0.1924780E 03	0.9073753E 00	0.7783483E 00	0.0	0.0
0.0	0.0	-0.1924779E 03	0.7783483E 00	0.9073747E 00	0.0	0.0
-0.1924780E 03	-0.1924779E 03	0.0	0.0	0.0	0.7863617E 00	0.0

THE LAMINATE PROPERTIES ARE

EX = 0.241514E 07 EY = 0.241514E 07 G = 0.7922294E 07 NUXY = 0.8578 NUYX = 0.8578

THE MATERIAL DENSITY = 0.18000000E-03 LB.-SEC.**2/IN.**4

FREQUENCY	M	N
0.17837E 03	1	1
0.22114E 03	1	2
0.44064E 03	2	2
0.53527E 03	1	3
0.69488E 03	2	3
0.96692E 03	2	1
0.99399E 03	2	1
0.10902E 04	3	3
0.14863E 04	3	1
0.13607E 05	2	1
0.18098E 05	1	1
0.25587E 05	3	2
0.30574E 05	1	1
0.37216E 05	2	2
0.39052E 05	1	1
0.48045E 05	3	3
0.51674E 05	1	2
0.57091E 05	2	1
0.62332E 05	2	3
0.63678E 05	1	2
0.71649E 05	3	1
0.77191E 05	1	3
0.80854E 05	2	2
0.90266E 05	1	3
0.96942E 05	3	2

GENERAL DYNAMICS
370 PROCEDURE SS8

CONVAIR AEROSPACE DIVISION
PROBLEM 004602-02

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0.10690E 06 2 3

0.12326E 06 3 3

GENERAL DYNAMICS
370 PROCEDURE SS8

CONVAIR AEROSPACE DIVISION
PROBLEM 004602-02

FORT WORTH OPERATION
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THE FREQUENCY IS 0.1783669E 03 CPS. FOR M = 1, N = 1.

THE CONTRIBUTIONS OF THE SERIES TERMS FOLLOW

-0.1106E-01	-0.8295E-03	-0.4571E-04	0.9215E-03	-0.1925E-04	0.5167E-05	0.1470E-03	0.2947E-05	-0.2778E-05	0.1866E-01
0.1068E-02	-0.5834E-04	-0.1127E-02	0.1236E-03	0.1372E-04	-0.1871E-03	-0.6356E-06	0.3680E-05	0.9776E 00	0.1939E 00
-0.2981E-01	0.4485E-01	0.2445E-01	0.3505E-02	0.5183E-01	0.1346E-02	-0.1478E-03			

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[illegible]

GENERAL DYNAMICS
370 PROCEDURE SS8

CUNVAIR AEROSPACE DIVISION
PROBLEM 004602-02

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THE FREQUENCY IS 0.221141E 03 CPS. FOR M = 1, N = 2.

THE CONTRIBUTIONS OF THE SERIES TERMS FOLLOW

0.4073E-02	-0.3105E-02	-0.4223E-03	-0.3826E-03	-0.9828E-05	0.6660E-04	-0.3544E-04	0.9751E-04	-0.2021E-04	-0.3748E-02
0.4950E-02	0.7037E-04	-0.1562E-03	0.1002E-03	0.2738E-04	0.1240E-03	-0.1352E-03	0.1602E-04	-0.1920E 00	0.9796E 00
0.8096E-02	-0.3797E-01	0.4220E-01	0.3574E-02	-0.1021E-01	0.1279E-02	0.8947E-03			

THE W DEFLECTIONS DIVIDED BY 0.297272E 01/10000 FOLLOW

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0</
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GENERAL DYNAMICS
370 PROCEDURE SS8

CONVAIR AEROSPACE DIVISION
PROBLEM 004602-02

FORT WORTH OPERATION
05/04/73 PAGE 0009

THE FREQUENCY IS 0.4406414E 03 CPS. FOR M = 2, N = 2.

THE CONTRIBUTIONS OF THE SERIES TERMS FOLLOW

0.2342E-02	0.6560E-03	-0.4196E-03	-0.1309E-04	-0.2959E-02	-0.2190E-03	-0.7851E-04	0.3729E-03	0.4559E-04	0.5082E-03
0.4210E-03	-0.2247E-03	0.9733E-03	0.5467E-02	0.1417E-03	-0.6676E-03	-0.2815E-03	0.1048E-03	-0.1788E-01	-0.4466E-01
-0.3510E-01	0.5143E-01	0.9952E 00	0.2964E-01	-0.3236E-01	0.3157E-01	0.2215E-01			

GENERAL DYNAMICS
370 PROCEDURE SS8

CONVAIR AEROSPACE DIVISION
PROBLEM 004602-02

FORT WORTH OPERATION
05/04/73 PAGE 0011

THE EXECUTION TIME FOR THIS PROBLEM WAS 0 MINUTES, 15 SECONDS.

A P P E N D I X I V

P R O G R A M L I S T I N G S

C	CONTROL PROGRAM FOR THE ANALYSIS OF ANISOTROPIC CURVED PANELS.	SS8A000
C		SS8A001
	CALL GSTART ('SS8',IDIOT)	SS8A002
1	CALL READ	SS8A003
	CALL TABLE	SS8A004
	CALL ASEMBL	SS8A005
	CALL SOLVE	SS8A006
	CALL PRINT	SS8A007
	GO TO 1	SS8A008
	END	SS8A009

CC = 00010

```

SUBROUTINE READ
C
C ** THIS SUBROUTINE READS ALL THE NECESSARY INPUT DATA, MAKES DATA
C ** CHECKS, AND WRITES PRELIMINARY DATA.
C
DIMENSION YSTRNG(100), YBARS(100), ZBARS(100), AS(100), SS8B005
1 XIYYS(100), XIYZS(100), XIZZS(100), ES(100), SS8B006
2 GJS(100), RHOS(100), PAXS(100), SS8B007
3 XRINGS(50), XBARR(50), ZBARR(50), AR(50), SS8B008
4 XIXXR(50), XIXZR(50), XIZZR(50), ER(50), SS8B009
5 GJR(50), RHOR(50), PAXR(50), SS8B010
8 PMASS(50), IPWW(50), IPWY(50), SS8B011
9 PX(10,10), PY(10,10), PXY(10,10), SS8B012
C PC(50), IPXX(50), IPYY(50), SS8B013
D FC(50), IFXX(50), IFYY(50), SS8B014
E ITAGCM(50), Q (10,10), SS8B015
F PLMOM(50), ITAGLM(50), IDISLM(50), SS8B016
G PKC(50), IGSPRX(50), IGSPRY(50), SS8B017
H PLINE(50), IDISLS(50), ITAGLS(50) SS8B018
DIMENSION ITIME(12), TIME(50) SS8B019
DIMENSION AMAT(3,3), BMAT(3,3), DMAT(3,3), H(40), SS8B020
1 THETA(40), E1(40), E2(40), G(40), SS8B021
2 XNU12(40) SS8B022
DIMENSION EC(3,40), ET(3,40), ANGCK(3,10), MCHK(3) SS8B023
DIMENSION V(2,10), PRTNX(5,5), PRTNY(5,5), SS8B024
1 PRTNXY(5,5), PRTQ(5,5) SS8B025
DIMENSION AI(3,3), A(3,3) SS8B026
COMMON U(50,50) SS8B027
COMMON / CHECKS / IERROR SS8B028
COMMON / CNTROL / IFLAGD, IFLAGB, IFLAGW, IBCX, IBCY, SS8B029
1 IMATL, IEDGE, IREACT, IOUT, IPRTN, SS8B030
2 IPRTQ, IELAST, INTPT, IKDF, IFLEX SS8B031
COMMON / NUMBER / NPLYS, NTUX, NTVX, NTWX, NTUY, SS8B032
1 NTVY, NTWY, NMODES, NSTRNG, NRING, SS8B033
2 NPNX, NPNY, NQTX,NQTY,NPTLDS, NPTMOM, SS8B034
3 NLNMOM, NLMASS, NPTSUP, NLNSPR, SS8B035
4 MATSIZ, MUVSIZ, MWSIZ, ITX, ITY SS8B036
COMMON / GEOM / AA, BB, RR, ALFAX, ALFAY, SS8B037
1 BETAX, BETAY, MU SS8B038
COMMON / $TIME / TIME, ITIME SS8B039
COMMON / ABD / AMAT, BMAT, DMAT, RHAB, THETA, SS8B040
1 H, E1, E2, G, XNU12, SS8B041
2 EC, ET, ANGCK, MCHK SS8B042
COMMON / PARAM / YBARS, ZBARS, AS, XIYYS, XIYZS, SS8B043
1 XIZZS, ES, GJS, RHOS, PAXS, SS8B044
3 XBARR, ZBARR, AR, XIXXR, XIXZR, SS8B045
4 XIZZR, ER, GJR, RHOR, PAXR, SS8B046
6 PMASS, IPWW, IPWY, PX, PY, SS8B047
7 PXY, PC, IPXX, IPYY, FC, SS8B048
8 IFXX, IFYY, ITAGCM, Q , PLMOM, SS8B049
9 ITAGLM, IDISLM, PKC, IGSPRX, IGSPRY, SS8B050
A PLINE, IDISLS, ITAGLS SS8B051
COMMON / STFVAL / ESV(10,100), ESW(10,100), ESDW(10,100), SS8B052
1 ERU(10,50), ERW(10,50), ERDW(10,50), SS8B053
2 YSTRNG, XRINGS SS8B054
COMMON / FLEXBL / XP(50), YP(50) SS8B055

```

	EQUIVALENCE (U(1),PRTNX(1)), (U(26),PRTNY(1)), (U(51),	SS8B056
1	PRTNXY(1)), (U(76),PRTQ(1)), (U(101),V(1))	SS8B057
C		SS8B058
	DATA XDIR / 'X' /, YDIR / 'Y' /	SS8B059
	DATA KIN / 'INN' /, KOUT / 'OUT' /	SS8B060
	REAL MU	SS8B061
C		SS8B062
1	CALL PROB	SS8B063
	CALL STATUS (ITIME)	SS8B064
	TIME(1) = .01*ITIME(8)	SS8B065
C **	READ AND WRITE TITLE	SS8B066
	READ (5,2)	SS8B067
2	FORMAT (1X,65H	SS8B068
1	)	SS8B069
	WRITE (6,2)	SS8B070
	CALL FREEFD	SS8B071
5	FORMAT (1X)	SS8B072
	READ (5,5) XFLAGD, XFLAGB, XFLAGW, XBCX , XBCY , XTUX , XTUY ,	SS8B073
1	XTX , XTY , XMODES, XMATL , XPLYS ,	SS8B074
2	XREACT, XOUT , XEDGE , XPNX , XPNY , XPRTN ,	SS8B075
3	XQTX , XQTY , XPRTQ , XSTRNG, XRING , XLMASS, XPTLDS,	SS8B076
4	XPTMOM, XLNMOM, XPTSUP, XLNSPR, XNTPRT, XFLEX	SS8B077
C **	CONVERT FROM REAL TO INTEGER	SS8B078
	INTPRT = XNTPRT + .1	SS8B079
	IFLAGD = XFLAGD + .1	SS8B080
	IFLAGB = XFLAGB + .1	SS8B081
	IKDF = 0	SS8B082
	IF (IFLAGB - 2) 4,4,3	SS8B083
3	IKDF = 1	SS8B084
	IFLAGB = IFLAGB - 2	SS8B085
4	CONTINUE	SS8B086
	IFLAGW = XFLAGW + .1	SS8B087
	IBCX = XBCX + .1	SS8B088
	IBCY = XBCY + .1	SS8B089
	IMATL = XMATL + .1	SS8B090
	IEDGE = XEDGE + .1	SS8B091
	IREACT = XREACT + .1	SS8B092
	IOUT = XOUT + .1	SS8B093
	IPRTN = XPRTN + .1	SS8B094
	IPRTQ = XPRTQ + .1	SS8B095
	NPLYS = XPLYS + .1	SS8B096
	NTUX = XTUX + .1	SS8B097
	NTVX = NTUX	SS8B098
	NTWX = NTUX	SS8B099
	NTUY = XTUY + .1	SS8B100
	NTVY = NTUY	SS8B101
	NTWY = NTUY	SS8B102
	ITX = XTX + .1	SS8B103
	ITY = XTY + .1	SS8B104
	NMODES = XMODES + .1	SS8B105
	IEQS = 0	SS8B106
	IEQR = 0	SS8B107
	IF (XSTRNG .LT. 0.) IEQS = 1	SS8B108
	XSTRNG = ABS (XSTRNG)	SS8B109
	IF (XRING .LT. 0.) IEQR = 1	SS8B110
	XRING = ABS (XRING)	SS8B111

NSTRNG = XSTRNG + .1	SS8B112
NRING = XRING + .1	SS8B113
NPNX = XPNX + .1	SS8B114
NPNY = XPNY + .1	SS8B115
NQTX = XQTX + .1	SS8B116
NQTY = XQTY + .1	SS8B117
NPTLDS = XPTLDS + .1	SS8B118
NPTMOM = XPTMOM + .1	SS8B119
NLNMOM = XLNMOM + .1	SS8B120
NLMASS = XLMASS + .1	SS8B121
NPTSUP = XPTSUP + .1	SS8B122
NLNSPR = XLNSPR + .1	SS8B123
IFLEX = XFLEX + .1	SS8B124
C ** TEST THE VALUES READ IN	SS8B125
IERROR = 0	SS8B126
IF (IFLAGD .LT. 0 .OR. IFLAGD .GT. 1) CALL CHECK ('IFLAGD')	SS8B127
IF (IFLAGB .LT. 0 .OR. IFLAGB .GT. 2) CALL CHECK ('IFLAGB')	SS8B128
IF (IFLAGW .LT. 0 .OR. IFLAGW .GT. 2) CALL CHECK ('IFLAGW')	SS8B129
IF (IBCX .LT. 1 .OR. IBCX .GT. 7) CALL CHECK ('IBCX')	SS8B130
IF (IBCY .LT. 0 .OR. IBCY .GT. 8) CALL CHECK ('IBCY')	SS8B131
IF (IMATL .LT. 1 .OR. IMATL .GT. 4) CALL CHECK ('IMATL')	SS8B132
IF (IEDGE .LT. 0 .OR. IEDGE .GT. 2) CALL CHECK ('IEDGE')	SS8B133
IF (IOUT .LT. 1 .OR. IOUT .GT. 9) CALL CHECK ('IOUT')	SS8B134
IF (IPRTN .LT. 0 .OR. IPRTN .GT. 1) CALL CHECK ('IPRTN')	SS8B135
IF (IPRTQ .LT. 0 .OR. IPRTQ .GT. 1) CALL CHECK ('IPRTQ')	SS8B136
IF (NPLYS .LT. 1 .OR. NPLYS .GT. 40) CALL CHECK ('NPLYS')	SS8B137
IF (NTUX .LT. 1 .OR. NTUX .GT. 10) CALL CHECK ('NTUX')	SS8B138
IF (NTVX .LT. 1 .OR. NTVX .GT. 10) CALL CHECK ('NTVX')	SS8B139
IF (NTWX .LT. 1 .OR. NTWX .GT. 10) CALL CHECK ('NTWX')	SS8B140
IF (NTUY .LT. 1 .OR. NTUY .GT. 10) CALL CHECK ('NTUY')	SS8B141
IF (NTVY .LT. 1 .OR. NTVY .GT. 10) CALL CHECK ('NTVY')	SS8B142
IF (NTWY .LT. 1 .OR. NTWY .GT. 10) CALL CHECK ('NTWY')	SS8B143
IF (ITX .LT. 0 .OR. ITX .GT. 20) CALL CHECK ('ITX')	SS8B144
IF (ITY .LT. 0 .OR. ITY .GT. 20) CALL CHECK ('ITY')	SS8B145
IF (NSTRNG .LT. 0 .OR. NSTRNG .GT. 100) CALL CHECK ('NSTRNG')	SS8B146
IF (NRING .LT. 0 .OR. NRING .GT. 50) CALL CHECK ('NRING')	SS8B147
IF (NPNX .LT. 0 .OR. NPNX .GT. 10) CALL CHECK ('NPNX')	SS8B148
IF (NPNY .LT. 0 .OR. NPNY .GT. 10) CALL CHECK ('NPNY')	SS8B149
IF (NQTX .LT. 0 .OR. NQTX .GT. 10) CALL CHECK ('NQTX')	SS8B150
IF (NQTY .LT. 0 .OR. NQTY .GT. 10) CALL CHECK ('NQTY')	SS8B151
IF (NPTLDS .LT. 0 .OR. NPTLDS .GT. 50) CALL CHECK ('NPTLDS')	SS8B152
IF (NPTMOM .LT. 0 .OR. NPTMOM .GT. 50) CALL CHECK ('NPTMOM')	SS8B153
IF (NLNMOM .LT. 0 .OR. NLNMOM .GT. 50) CALL CHECK ('NLNMOM')	SS8B154
IF (NLMASS .LT. 0 .OR. NLMASS .GT. 50) CALL CHECK ('NLMASS')	SS8B155
IF (NPTSUP .LT. 0 .OR. NPTSUP .GT. 50) CALL CHECK ('NPTSUP')	SS8B156
IF (NLNSPR .LT. 0 .OR. NLNSPR .GT. 50) CALL CHECK ('NLNSPR')	SS8B157
IF (IFLEX .LT. 0 .OR. IFLEX .GT. 50) CALL CHECK ('IFLEX')	SS8B158
MATSIZ = NTUX*NTUY + NTVX*NTVY + NTWX*NTWY	SS8B159
IF (MATSIZ .LT. 1 .OR. MATSIZ .GT. 150) CALL CHECK ('MATSIZ')	SS8B160
IF (NMODES .LT. 0 .OR. NMODES .GT. MATSIZ) CALL CHECK ('NMODES')	SS8B161
IF (IBCX .EQ. 6 .AND. ITX .EQ. 1) CALL CHECK ('ITX')	SS8B162
IF (IBCY .EQ. 6 .AND. ITY .EQ. 1) CALL CHECK ('ITY')	SS8B163
IF (IERROR .EQ. 1) GO TO 99999	SS8B164
MWSIZ = NTWX*NTWY	SS8B165
MUVSIZ = MATSIZ - MWSIZ	SS8B166
MU = 0.	SS8B167

IF (IBCY .EQ. 0) GO TO 8	SS88168
IF (IKDF .EQ. 0) READ (5,5) AA, BB, RR	SS88169
IF (IKDF .EQ. 1) READ (5,5) AA, BB, RR, MU	SS88170
GO TO 9	SS88171
8 IF (IKDF .EQ. 0) READ (5,5) AA, RR	SS88172
IF (IKDF .EQ. 1) READ (5,5) AA, RR, MU	SS88173
BB = 6.2831853 * RR	SS88174
9 CONTINUE	SS88175
C ** THE BOUNDARY CONDITIONS ARE PRINTED	SS88176
II = IBCX	SS88177
IF (IBCY.NE.0) GO TO 20	SS88178
WRITE (6,10)	SS88179
10 FORMAT ('OTHE BOUNDARY CONDITIONS OF THE COMPLETE CYLINDER AT X=0	SS88180
1AND X=A ARE')	SS88181
GO TO 40	SS88182
20 WRITE (6,150)	SS88183
IBCTAG = +1	SS88184
GO TO 40	SS88185
30 II=IBCY	SS88186
WRITE (6,160)	SS88187
IBCTAG = -1	SS88188
40 IF (II-2) 70,80,50	SS88189
50 IF (II-4) 90,100,60	SS88190
60 IF (II-6) 110,120,130	SS88191
70 WRITE (6,170)	SS88192
GO TO 140	SS88193
80 WRITE (6,180)	SS88194
GO TO 140	SS88195
90 WRITE (6,190)	SS88196
GO TO 140	SS88197
100 WRITE (6,200)	SS88198
GO TO 140	SS88199
110 WRITE (6,210)	SS88200
GO TO 140	SS88201
120 WRITE (6,220)	SS88202
GO TO 140	SS88203
130 WRITE (6,230)	SS88204
140 IF (IBCTAG.GT.0.AND.IBCY.NE.0) GO TO 30	SS88205
150 FORMAT('OTHE BOUNDARY CONDITIONS AT X=0 AND X=A ARE')	SS88206
160 FORMAT('OTHE BOUNDARY CONDITIONS AT Y=0 AND Y=B ARE')	SS88207
170 FORMAT(' CLAMPED, SIMPLE')	SS88208
180 FORMAT(' SIMPLE, SIMPLE')	SS88209
190 FORMAT(' CLAMPED, CLAMPED')	SS88210
200 FORMAT(' CLAMPED, FREE')	SS88211
210 FORMAT(' SIMPLE, FREE')	SS88212
220 FORMAT(' FREE, FREE')	SS88213
230 FORMAT(' ELASTIC RESTRAINT')	SS88214
WRITE (6,240) NTUX,ITX,NTUY,ITY,MATSIZ,MATSIZ	SS88215
240 FORMAT ('OTHER ARE' ,I3,' MODES IN THE X DIRECTION, STARTING WITH	SS88216
1 M =' ,I3,' .' / ' THERE ARE' ,I3,' MODES IN THE Y DIRECTION, STARTING	SS88217
2 WITH N =' ,I3,' .' / 'OTHE STIFFNESS MATRIX SIZE IS' I4,' BY' I4)	SS88218
IF (IFLAGD.NE.0) WRITE (6,250)	SS88219
250 FORMAT('OA DYNAMIC SOLUTION WILL BE SOUGHT')	SS88220
IF (IFLAGB.NE.0) WRITE (6,260)	SS88221
260 FORMAT('OA STABILITY SOLUTION WILL BE SOUGHT')	SS88222
IF (IFLAGW.NE.0) WRITE (6,270)	SS88223

270	FORMAT('0A SOLUTION UNDER LATERAL LOADS WILL BE SOUGHT')	SS8B224
	WRITE (6,280) AA, BB, RR, MU	SS8B225
280	FORMAT ('0A ='F20.5/'0B ='F20.5/'0R ='F20.5/'0MU ='F19.5)	SS8B226
C **	ELASTIC RESTRAINT	SS8B227
	IELAST = 1	SS8B228
	ALFAX = 0.	SS8B229
	BETAX = 0.	SS8B230
	ALFAY = 0.	SS8B231
	BETAY = 0.	SS8B232
	IF (IBCX.EQ.7.AND.IBCY.LT.7) GO TO 290	SS8B233
	IF (IBCX.EQ.7.AND.IBCY.EQ.7) GO TO 300	SS8B234
	IF (IBCX.NE.7.AND.IBCY.EQ.8) GO TO 310	SS8B235
	IF (IBCX.EQ.7.AND.IBCY.EQ.8) GO TO 320	SS8B236
	GO TO 330	SS8B237
290	IELAST = 2	SS8B238
	READ (5,5) ALFAX,BETAX	SS8B239
	GO TO 330	SS8B240
300	IELAST = 3	SS8B241
	READ (5,5) ALFAX,BETAX	SS8B242
	ALFAY = ALFAX	SS8B243
	BETAY = BETAX	SS8B244
	GO TO 330	SS8B245
310	IELAST = 4	SS8B246
	READ (5,5) ALFAY,BETAY	SS8B247
	GO TO 330	SS8B248
320	IELAST = 5	SS8B249
	READ (5,5) ALFAX,BETAX,ALFAY,BETAY	SS8B250
330	CONTINUE	SS8B251
	IF (IELAST.EQ.1) GO TO 350	SS8B252
	WRITE (6,340) ALFAX,BETAX,ALFAY,BETAY	SS8B253
340	FORMAT ('0THE ELASTIC RESTRAINT QUANTITIES ARE -- ' / ' ALFAX = ' 1 E16.8 / ' BETAX = ' E16.8 / ' ALFAY = ' E16.8 / ' BETAY = 'E16.8)	SS8B254
	SS8B255	
350	CONTINUE	SS8B256
C **	READ IN NECESSARY MATERIAL PROPERTIES THROUGH STATEMENT 470	SS8B257
	DO 360 I=1,3	SS8B258
	DO 360 J=1,3	SS8B259
	AMAT(I,J)=0.	SS8B260
	BMAT(I,J)=0.	SS8B261
	DMAT(I,J)=0.	SS8B262
360	CONTINUE	SS8B263
	IF (IMATL . EQ . 1) GO TO 370	SS8B264
	IF (IMATL . EQ . 2) GO TO 390	SS8B265
	IF (IMATL . EQ . 3) GO TO 450	SS8B266
C **	SANDWICH	SS8B267
	DO 361 J=1,3,2	SS8B268
	READ (5,5) E1(J), E2(J), G(J), XNU12(J), H(J)	SS8B269
	THETA(J) = 0.	SS8B270
	IF (IOUT .LT. 7) GO TO 361	SS8B271
	READ (5,5) (EC(I,J),I=1,3), (ET(I,J),I=1,3), XCHK	SS8B272
	MCHK(J) = XCHK + .1	SS8B273
	NCHK = MCHK(J)	SS8B274
	IF (NCHK .LT. 1 .OR.NCHK .GT. 10) CALL CHECK ('MCHK ')	SS8B275
	IF (IERROR .EQ. 1) GO TO 9999	SS8B276
	READ(5,5) (ANGCK(J,I), I=1,NCHK)	SS8B277
361	CONTINUE	SS8B278
	READ (5,5) H(2)	SS8B279

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E1(2) = 1. SS8B280
E2(2) = 1. SS8B281
G(2) = 1. SS8B282
XNU12(2) = .25 SS8B283
THETA(2) = 0. SS8B284
DO 362 J=1,3,2 SS8B285
NCHK = MCHK(J) SS8B286
IF ( J.EQ.1 ) K=KIN SS8B287
IF ( J.EQ.3 ) K=KOUT SS8B288
IF ( IOUT .LT. 7 ) WRITE(6,366) K,E1(J),E2(J),G(J),XNU12(J),H(J) SS8B289
366 FORMAT ('OFOR THE ',A3,'ER FACING OF THE SANDWICH, E1 =',E14.6 SS8B290
1,', E2 =',E14.6,', G =',E14.6,', NU12 =',F7.3,', H =',F8.3) SS8B291
IF ( IOUT .GE. 7 ) SS8B292
1WRITE (6,363) K, E1(J), E2(J), G(J), XNU12(J), H(J), SS8B293
1 ( EC(I,J), I=1,3), ( ET(I,J), I=1,3), SS8B294
2 ( ANGCK(J,I), I=1,NCHK ) SS8B295
363 FORMAT ('OFOR THE ',A3,'ER FACING OF THE SANDWICH, E1 =', SS8B296
1 E14.6,', E2 =',E14.6,', G =',E14.6,', NU12 =',F7.3, SS8B297
2 ', H =',F8.3//9X,'THE COMPRESSION ALLOWABLES IN THE 1, 2, SS8B298
3AND 12 DIRECTIONS ARE',3E15.6, ' IN./IN.'//9X, SS8B299
4 'THE TENSION ALLOWABLES IN THE 1, 2, AND 12 DIRECTIONS' SS8B300
5 ARE',3E15.6, ' IN./IN.'//9X,'THE ORIENTATIONS TO BE CHECKED' SS8B301
6 ARE',10F8.2) SS8B302
362 CONTINUE SS8B303
WRITE (6,364) H(2) SS8B304
364 FORMAT ('OTHE CORE THICKNESS IS',F9.3,' IN.') SS8B305
T = H(1) + H(2) + H(3) SS8B306
WRITE (6,365) T SS8B307
365 FORMAT ('OTHE TOTAL SANDWICH THICKNESS IS',F9.3,' IN.') SS8B308
GO TO 410 SS8B309
C ** ISOTROPIC - - READ E, NU, AND T SS8B310
370 READ (5,5) E1(1), XNU12(1), T SS8B311
IF ( IOUT .GE. 7 ) READ(5,5) (EC(I,1),I=1,3), (ET(I,1),I=1,3) SS8B312
WRITE (6,380) E1(1),XNU12(1),T SS8B313
380 FORMAT ('OFOR THE ISOTROPIC MATERIAL, E =',E16.7,', NU =',F7.4, SS8B314
1 ', T =',F9.4 ) SS8B315
IF ( IOUT .GE. 7 )WRITE(6,381)(EC(I,1),I=1,3), (ET(I,1),I=1,3) SS8B316
381 FORMAT ('O',8X,'THE COMPRESSION ALLOWABLES IN THE 1, 2, AND 12 DIR SS8B317
1ECTIONS ARE',3E15.6,' IN./IN.'//9X,'THE TENSION ALLOWABLES IN THE SS8B318
21, 2, AND 12 DIRECTIONS ARE',3E15.6,' IN./IN.') SS8B319
AMAT(1,1) = E1(1)*T/(1.-XNU12(1)*XNU12(1)) SS8B320
AMAT(2,2) = AMAT(1,1) SS8B321
AMAT(2,1) = XNU12(1)*AMAT(1,1) SS8B322
AMAT(1,2) = AMAT(2,1) SS8B323
AMAT(3,3) = E1(1)*T/2./(1.+XNU12(1)) SS8B324
DMAT(1,1) = E1(1)*T*T*T/12./(1.-XNU12(1)*XNU12(1)) SS8B325
DMAT(2,2) = DMAT(1,1) SS8B326
DMAT(2,1) = XNU12(1)*DMAT(1,1) SS8B327
DMAT(1,2) = DMAT(2,1) SS8B328
DMAT(3,3) = E1(1)*T*T*T/24./(1.+XNU12(1)) SS8B329
E2(1) = E1(1) SS8B330
H(1) = T SS8B331
G(1) = E1(1)/2./(1+XNU12(1)) SS8B332
THETA(1) = 0. SS8B333
GO TO 410 SS8B334
C ** LAMINATE WITH CONSTANT PLY PROPERTIES SS8B335

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390 READ (5,5) E1(1), E2(1), G(1), XNU12(1), H(1), SS88336
1      ( THETA(I), I=1,NPLYS ) SS88337
  IF ( IOUT .GE. 7 ) READ (5,5) (EC(I,1),I=1,3), (ET(I,1),I=1,3) SS88338
  T = H(1)*NPLYS SS88339
  WRITE (6,400) NPLYS, E1(1), E2(1), G(1), XNU12(1), H(1), SS88340
1      T, ( THETA(I), I=1,NPLYS ) SS88341
400 FORMAT ('O FOR THE ',I2,' PLY LAMINATE'/'OE1 =' E20.6 /'OE2 =' , SS88342
1      E20.6 / 'OG =' E20.6 / 'ONU12 =' F6.4 / 'OH(I) =' F9.4/ SS88343
2      'OT =' F9.4 / 'OTHE ORIENTATIONS ARE'/( ' F10.4/ ) ) SS88344
  IF ( IOUT .GE. 7 ) WRITE(6,381) (EC(I,1),I=1,3), (ET(I,1),I=1,3) SS88345
  DO 409 I=1,NPLYS SS88346
    E1(I) = E1(1) SS88347
    E2(I) = E2(1) SS88348
    G(I) = G(1) SS88349
    XNU12(I) = XNU12(1) SS88350
    H(I) = H(1) SS88351
    DO 409 J=1,3 SS88352
      EC(J,I) = EC(J,1) SS88353
      ET(J,I) = ET(J,1) SS88354
409 CONTINUE SS88355
410 CALL STIFF SS88356
420 WRITE (6,430) ((AMAT(I,J),J=1,3),(BMAT(I,J),J=1,3),I=1,3) SS88357
  WRITE (6,440) ((BMAT(I,J),J=1,3),(DMAT(I,J),J=1,3),I=1,3) SS88358
430 FORMAT ('THE CONSTITUTIVE MATRIX IS' / / / (6E16.7)) SS88359
440 FORMAT (6E16.7) SS88360
C ** FIX FOR ELASTIC RESTRAINT SS88361
  IF ( IELAST .EQ. 1 ) GO TO 431 SS88362
  ALFAX = ALFAX * AA / DMAT(1,1) SS88363
  BETAX = BETAX * AA / DMAT(1,1) SS88364
  ALFAY = ALFAY * BB / DMAT(2,2) SS88365
  BETAY = BETAY * BB / DMAT(2,2) SS88366
431 CONTINUE SS88367
  IF ( IMATL .EQ. 1 ) GO TO 470 SS88368
  DO 601 I=1,3 SS88369
    DO 601 J=1,3 SS88370
      601 A(I,J) = AMAT(I,J) SS88371
      DET = A(1,1)*A(2,2)*A(3,3) + A(1,2)*A(2,3)*A(3,1) SS88372
            + A(1,3)*A(2,1)*A(3,2) - A(1,3)*A(2,2)*A(3,1) SS88373
            - A(1,1)*A(2,3)*A(3,2) - A(1,2)*A(2,1)*A(3,3) SS88374
      AI(1,1) = ( A(2,2)*A(3,3) - A(2,3)*A(3,2) ) / DET SS88375
      AI(1,2) = ( A(2,3)*A(3,1) - A(2,1)*A(3,3) ) / DET SS88376
      AI(1,3) = ( A(2,1)*A(3,2) - A(2,2)*A(3,1) ) / DET SS88377
      AI(2,2) = ( A(1,1)*A(3,3) - A(1,3)*A(3,1) ) / DET SS88378
      AI(2,3) = ( A(1,2)*A(3,1) - A(1,1)*A(3,2) ) / DET SS88379
      AI(3,3) = ( A(1,1)*A(2,2) - A(1,2)*A(2,1) ) / DET SS88380
      EX = 1. / AI(1,1) / T SS88381
      EY = 1. / AI(2,2) / T SS88382
      GXY = 1. / AI(3,3) / T SS88383
      XNUXY = - AI(1,2) / AI(1,1) SS88384
      XNUYX = - AI(1,2) / AI(2,2) SS88385
      WRITE(6,441) SS88386
441 FORMAT ('OTHE LAMINATE PROPERTIES ARE') SS88387
      WRITE (6,442) EX,EY,GXY,XNUXY,XNUYX SS88388
442 FORMAT ('OEX =' ,E15.6,3X,'EY =' ,E15.6,3X,'G =' ,E15.6,3X,'NUXY =' , SS88389
1      F8.4,3X,'NUYX =' ,F8.4) SS88390
      GO TO 470 SS88391

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C ** LAMINATE WITH VARIABLE PLY PROPERTIES
450 IF ( IOUT .LT. 7 )
1 READ (5,5) ( E1(I), E2(I), G(I), XNU12(I), H(I), THETA(I), I=1, NPLYS)
IF ( IOUT .GE. 7 ) READ (5,5) ( E1(I), E2(I), G(I), XNU12(I),
1 H(I), THETA(I), (EC(J,I), J=1,3), (ET(J,I), J=1,3), I=1, NPLYS )
T = 0.
DO 461 I=1, NPLYS
WRITE(6,460) I, H(I), E1(I), E2(I), XNU12(I), G(I), THETA(I)
460 FORMAT('OPLY' I4, ' HAS A THICKNESS OF ' F11.7, ' E1=' E16.7, ' E2=' E16.
17/ ' NUI2=' F6.4, ' G=' E16.7, ' AND ORIENTATION=' F10.3, ' DEGR
2EES.')
IF ( IOUT .GE. 7 ) WRITE(6,381) (EC(J,I), J=1,3), (ET(J,I), J=1,3)
461 T = T + H(I)
WRITE (6,462) T
462 FORMAT ('OT = ', F9.4, ' IN.')
GO TO 410
470 CONTINUE
IF ( NSTRNG .EQ. 0 ) GO TO 490
C ** FOR STRINGERS
IF ( IEQS .EQ. 1 ) GO TO 471
READ (5,5) ( YSTRNG(L), YBARS(L), ZBARS(L), AS(L), XIYYS(L),
1 XIYZS(L), XIZZS(L), ES(L), GJS(L), RHOS(L),
2 L=1, NSTRNG )
WRITE (6,477)
477 FORMAT ('OTHE STRINGER PROPERTIES FOLLOW --')
WRITE(6,479)
479 FORMAT ('O', T2, 'L', T9, 'Y', T16, 'YBAR', T23, 'ZBAR', T30, 'AREA',
1 T40, 'IYY', T52, 'IYZ', T64, 'IZZ', T77, 'E', T88, 'GJ', T100,
2 'RHO'/)
WRITE(6,480) (L, YSTRNG(L), YBARS(L), ZBARS(L), AS(L), XIYYS(L),
1 XIYZS(L), XIZZS(L), ES(L), GJS(L), RHOS(L),
2 L=1, NSTRNG )
480 FORMAT (1X, OPI3, F9.2, 3F7.2, 1P6E12.4)
GO TO 489
471 READ (5,5) YBARS(1), ZBARS(1), AS(1), XIYYS(1), XIYZS(1),
1 XIZZS(1), ES(1), GJS(1), RHOS(1)
YSTRNG(1) = BB/(NSTRNG + 1)
IF ( IBCY .EQ. 0 ) YSTRNG(1) = BB/NSTRNG
DO 472 L=2, NSTRNG
YSTRNG(L) = L * YSTRNG(1)
YBARS(L) = YBARS(1)
ZBARS(L) = ZBARS(1)
AS(L) = AS(1)
XIYYS(L) = XIYYS(1)
XIYZS(L) = XIYZS(1)
XIZZS(L) = XIZZS(1)
ES(L) = ES(1)
GJS(L) = GJS(1)
472 RHOS(L) = RHOS(1)
WRITE (6,473) NSTRNG
473 FORMAT ('OTHER ARE ', I3, ' EQUALLY SPACED STRINGERS EACH OF WHICH
1 HAS THE FOLLOWING PROPERTIES --')
WRITE (6,474)
474 FORMAT ('O', T6, 'SPACING ', T16, 'YBAR', T23, 'ZBAR', T30, 'AREA',
1 T40, 'IYY', T52, 'IYZ', T64, 'IZZ', T77, 'E', T88, 'GJ', T100,
2 'RHO'/)

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WRITE (6,475) YSTRNG(1), YBARS(1), ZBARS(1), AS(1), XIYYS(1),	SS8B448
1 XIYZS(1), XIZZS(1), ES(1), GJS(1), RHOS(1)	SS8B449
475 FORMAT (4X,F9.2,3F7.2,1P6E12.4)	SS8B450
489 DO 476 L=1,NSTRNG	SS8B451
476 YSTRNG(L) = YSTRNG(L)/BB	SS8B452
490 CONTINUE	SS8B453
IF (NRING .EQ. 0) GO TO 510	SS8B454
C ** FOR RINGS	SS8B455
IF (IEQR .EQ. 1) GO TO 501	SS8B456
READ (5,5) (XRINGS(K), XBARR(K), ZBARR(K), AR(K), XIXXR(K),	SS8B457
1 XIXZR(K), XIZZR(K), ER(K), GJR(K), RHOR(K),	SS8B458
2 K=1,NRING)	SS8B459
WRITE (6,498)	SS8B460
498 FORMAT ('OTHE RING PROPERTIES FOLLOW --')	SS8B461
WRITE (6,500)	SS8B462
500 FORMAT ('O',T2,'K',T9,'X',T16,'XBAR',T23,'ZBAR',T30,'AREA',	SS8B463
1 T40,'IXX',T52,'IXZ',T64,'IZZ',T77,'E',T88,'GJ',T100,	SS8B464
2 'RHO'/)	SS8B465
WRITE(6,480)(K,XRINGS(K), XBARR(K), ZBARR(K), AR(K), XIXXR(K),	SS8B466
1 XIXZR(K), XIZZR(K), ER(K), GJR(K), RHOR(K),	SS8B467
2 K=1,NRING)	SS8B468
GO TO 509	SS8B469
501 READ (5,5) XBARR(1), ZBARR(1), AR(1), XIXXR(1), XIXZR(1),	SS8B470
1 XIZZR(1), ER(1), GJR(1), RHOR(1)	SS8B471
XRINGS(1) = AA/(NRING + 1)	SS8B472
DO 502 K=2,NRING	SS8B473
XRINGS(K) = K * XRINGS(1)	SS8B474
XBARR(K) = XBARR(1)	SS8B475
ZBARR(K) = ZBARR(1)	SS8B476
AR(K) = AR(1)	SS8B477
XIXXR(K) = XIXXR(1)	SS8B478
XIXZR(K) = XIXZR(1)	SS8B479
XIZZR(K) = XIZZR(1)	SS8B480
ER(K) = ER(1)	SS8B481
GJR(K) = GJR(1)	SS8B482
502 RHOR(K) = RHOR(1)	SS8B483
WRITE (6,503) NRING	SS8B484
503 FORMAT ('OTHERE ARE ',I2,' EQUALLY SPACED RINGS EACH OF WHICH HAS	SS8B485
1THE FOLLOWING PROPERTIES --')	SS8B486
WRITE (6,504)	SS8B487
504 FORMAT ('O',T6,'SPACING ',T16,'XBAR',T23,'ZBAR',T30,'AREA',	SS8B488
1 T40,'IXX',T52,'IXZ',T64,'IZZ',T77,'E',T88,'GJ',T100,	SS8B489
2 'RHO'/)	SS8B490
WRITE (6,475) XRINGS(1), XBARR(1), ZBARR(1), AR(1), XIXXR(1),	SS8B491
1 XIXZR(1), XIZZR(1), ER(1), GJR(1), RHOR(1)	SS8B492
509 DO 505 K=1,NRING	SS8B493
505 XRINGS(K) = XRINGS(K) / AA	SS8B494
510 CONTINUE	SS8B495
IF (IFLAGD .EQ. 0) GO TO 550	SS8B496
C ** IF DOING DYNAMICS, READ AVERAGE MATERIAL DENSITY	SS8B497
READ (5,5) DENSE	SS8B498
WRITE (6,520) DENSE	SS8B499
520 FORMAT ('OTHE MATERIAL DENSITY = 'E15.8,' LB.-SEC.**2/IN.**4')	SS8B500
RHAB = DENSE * T * AA * BB	SS8B501
IF (NLMASS .EQ. 0) GO TO 550	SS8B502
C ** HAVE LUMPED MASSES	SS8B503

DO 530 I=1,NLMASS	SS88504
READ (5,5) X, Y, PMASS(I)	SS88505
IPWW(I) = X + .1	SS88506
IPWY(I) = Y + .1	SS88507
530 WRITE (6,540) IPWW(I), IPWY(I), PMASS(I)	SS88508
540 FORMAT ('OTHER IS A LUMPED MASS AT COORDINATES 'I3,', 'I3,	SS88509
1 ' OF MAGNITUDE'E15.7,' LB-SEC**2/IN')	SS88510
550 CONTINUE	SS88511
IF (IEDGE .EQ. 0) GO TO 610	SS88512
C ** READ EDGE LOADS	SS88513
IF (IBCY .EQ. 0 .AND. IEDGE .EQ. 2) CALL CYLNDR (&571)	SS88514
IF (NPNX .GT. 0 .AND. NPNY .GT. 0) GO TO 570	SS88515
WRITE (6,560)	SS88516
560 FORMAT ('EDGE LOADS ARE TO BE INCLUDED BUT NPNX OR NPNY IS ZERO.'	SS88517
1 '/' THIS PROBLEM IS TERMINATED.')	SS88518
GO TO 99999	SS88519
570 READ (5,5) ((PX(J,I), PY(J,I), PXY(J,I), J=1,NPNX), I=1,NPNY)	SS88520
571 CONTINUE	SS88521
IEDGE = 1	SS88522
WRITE (6,580) ((PX(J,I), J=1,NPNX), I=1,NPNY)	SS88523
580 FORMAT ('OPX(I,J) FOLLOWS'/(1P10E12.4))	SS88524
WRITE (6,590) ((PY(J,I), J=1,NPNX), I=1,NPNY)	SS88525
590 FORMAT ('OPY(I,J) FOLLOWS'/(1P10E12.4))	SS88526
WRITE (6,600) ((PXY(J,I), J=1,NPNX), I=1,NPNY)	SS88527
600 FORMAT ('OPXY(I,J) FOLLOWS'/(1P10E12.4))	SS88528
IF (NSTRNG + NRING .EQ. 0) GO TO 610	SS88529
IF (NSTRNG .EQ. 0) GO TO 608	SS88530
DO 604 L=1,NSTRNG	SS88531
V(1,1) = 1.	SS88532
Y = YSTRNG(L)	SS88533
DO 602 K=2,NPNY	SS88534
602 V(1,K) = Y ** (K-1)	SS88535
XNX = 0.	SS88536
DO 603 K=1,NPNY	SS88537
603 XNX = XNX + PX(1,K) * V(1,K)	SS88538
604 PAXS(L) = XNX * AS(L) * ES(L) / EX / T	SS88539
IF (NPNY .EQ. 1 .AND. IEQS .EQ. 1) WRITE (6,605) PAXS(1)	SS88540
605 FORMAT ('OTHE AXIAL LOAD CARRIED BY EACH STRINGER IS ',E12.5,' LBS	SS88541
1.'')	SS88542
IF (NPNY .NE. 1 .OR. IEQS .EQ. 0) WRITE (6,606)	SS88543
606 FORMAT ('OTHE AXIAL LOADS (LBS.) CARRIED BY THE STRINGERS FOLLOW	SS88544
1 --')	SS88545
IF(NPNY.NE.1.OR.IEQS.EQ.0) WRITE(6,607)(L,PAXS(L),L=1,NSTRNG)	SS88546
607 FORMAT ('O',8(I3,E13.5))	SS88547
608 IF (NRING .EQ. 0) GO TO 610	SS88548
IF (IBCY .EQ. 0) GO TO 610	SS88549
V(1,1) = 1.	SS88550
DO 612 K=1,NRING	SS88551
X = XRINGS(K)	SS88552
DO 609 L=2,NPNX	SS88553
609 V(1,L) = X ** (L-1)	SS88554
XNY = 0.	SS88555
DO 611 L=1,NPNX	SS88556
611 XNY = XNY + PY(L,1) * V(1,L)	SS88557
612 PAXR(K) = XNY * AR(K) * ER(K) / EY / T	SS88558
IF (NPNX .EQ. 1 .AND. IEQR .EQ. 1) WRITE (6,613) PAXR(1)	SS88559

613	FORMAT ('OTHE LOAD CARRIED BY EACH RING IS ',E12.5,' LBS.')	SS8B560
	IF (NPNX .NE. 1 .OR. IEQR .EQ. 0) WRITE (6,614)	SS8B561
614	FORMAT ('OTHE LOADS (LBS.) CARRIED BY THE RINGS FOLLOW --')	SS8B562
	IF(NPNX.NE.1.OR.IEQR.EQ.0) WRITE(6,607)(K,PAXR(K),K=1,NRING)	SS8B563
610	CONTINUE	SS8B564
	IF (IFLAGW .NE. 1) GO TO 650	SS8B565
C **	READ LATERAL LOADS	SS8B566
	IF (NQTX .GT. 0 .AND. NQTY .GT. 0) GO TO 630	SS8B567
	WRITE (6,620)	SS8B568
620	FORMAT ('ILATERAL LOADS ARE TO BE INCLUDED BUT NQTX OR NQTY IS ZERO')	SS8B569
	10.' /' THIS PROBLEM IS TERMINATED.')	SS8B570
	GO TO 99999	SS8B571
630	READ (5,5) ((Q(J,I), J=1,NQTX), I=1,NQTY)	SS8B572
	WRITE(6,640)((Q(J,I), J=1,NQTX), I=1,NQTY)	SS8B573
640	FORMAT ('OQ(I,J) FOLLOWS' / (1P10E12.4))	SS8B574
650	CONTINUE	SS8B575
	IF (NPTLDS .EQ. 0) GO TO 680	SS8B576
C **	HAVE POINT LOADS	SS8B577
	DO 660 I=1,NPTLDS	SS8B578
	READ (5,5) X, Y, DUM	SS8B579
	IPXX(I) = X + .1	SS8B580
	IPYY(I) = Y + .1	SS8B581
	PC(I) = DUM	SS8B582
660	WRITE (6,670) IPXX(I), IPYY(I), PC(I)	SS8B583
670	FORMAT ('OTHER IS A CONCENTRATED LOAD AT COORDINATES'I3,', 'I3,	SS8B584
	1 ' OF MAGNITUDE'F12.5,' LBS.')	SS8B585
680	CONTINUE	SS8B586
	IF (NPTMOM .EQ. 0) GO TO 710	SS8B587
C **	HAVE POINT MOMENTS	SS8B588
	DO 690 I=1,NPTMOM	SS8B589
	READ (5,5) X, Y, TAG, DUM	SS8B590
	IFXX(I) = X + .1	SS8B591
	IFYY(I) = Y + .1	SS8B592
	FC(I) = DUM	SS8B593
	ITAGCM(I) = TAG + .1	SS8B594
	DIR = XDIR	SS8B595
	IF (ITAGCM(I) .EQ. 2) DIR = YDIR	SS8B596
690	WRITE (6,700) DIR, IFXX(I), IFYY(I), FC(I)	SS8B597
700	FORMAT ('OTHER IS A CONCENTRATED MOMENT ABOUT THE ',A1,' AXIS AT	SS8B598
	1COORDINATES'I3,', 'I3,' OF MAGNITUDE'E15.7,' IN.-LBS.')	SS8B599
710	CONTINUE	SS8B600
	IF (NLNMOM .EQ. 0) GO TO 750	SS8B601
C **	HAVE LINE MOMENTS	SS8B602
	DO 730 I=1,NLNMOM	SS8B603
	READ (5,5) TAG, DIST, PLMOM(I)	SS8B604
	ITAGLM(I) = TAG + .1	SS8B605
	IDISLM(I) = DIST + .1	SS8B606
	IF (ITAGLM(I) .EQ. 2) GO TO 720	SS8B607
	DIR = XDIR	SS8B608
	GO TO 730	SS8B609
720	DIR = YDIR	SS8B610
730	WRITE (6,740) DIR, IDISLM(I), PLMOM(I)	SS8B611
740	FORMAT ('OTHER IS A LINE MOMENT PARALLEL TO THE ',A1,' AXIS ON	SS8B612
	1RID LINE ', I2,' WITH A MAGNITUDE OF ',E15.7,' IN-LB/IN')	SS8B613
750	CONTINUE	SS8B614
	IF (NPTSUP .EQ. 0) GO TO 780	SS8B615

C **	HAVE POINT SPRINGS SPECIFIED AT GRID POINTS	SS8B616
	DO 760 I=1,NPTSUP	SS8B617
	READ (5,5) X, Y, PKC(I)	SS8B618
	IGSPRX(I) = X + .1	SS8B619
	IGSPRY(I) = Y + .1	SS8B620
	760 WRITE (6,770) IGSPRX(I), IGSPRY(I), PKC(I)	SS8B621
	770 FORMAT('OTHER IS AN ELASTIC SUPPORT AT COORDINATES',I3,',',I3,	SS8B622
	1 ' WITH A SPRING CONSTANT OF'E16.8,' LB/IN.')	SS8B623
	780 CONTINUE	SS8B624
	IF (NLNSPR .EQ. 0) GO TO 830	SS8B625
C **	HAVE LINE SPRINGS	SS8B626
	DO 810 I=1,NLNSPR	SS8B627
	READ (5,5) TAG, DIST, PLINE(I)	SS8B628
	ITAGLS(I) = TAG + .1	SS8B629
	IDISLS(I) = DIST + .1	SS8B630
	DIR = XDIR	SS8B631
	IF (ITAGLS(I) .EQ. 2) DIR = YDIR	SS8B632
	810 WRITE (6,820) DIR, IDISLS(I), PLINE(I)	SS8B633
	820 FORMAT ('OTHER IS A LINE SPRING PARALLEL TO THE ',A1,' AXIS ON	SS8B634
	GRID LINE ',I2,' WITH A SPRING CONSTANT OF ',E15.7,' LB/IN/IN.')	SS8B635
	830 CONTINUE	SS8B636
	IF (IPRTN + IPRTQ .EQ. 0) GO TO 950	SS8B637
	DO 890 I=1,5	SS8B638
	X = .25 * (I-1)	SS8B639
	V(1,1) = 1.	SS8B640
	DO 840 K=2,10	SS8B641
840	V(1,K) = X ** (K-1)	SS8B642
	DO 890 J=1,5	SS8B643
	Y = .25 * (J-1)	SS8B644
	V(2,1) = 1.	SS8B645
	DO 850 K=2,10	SS8B646
850	V(2,K) = Y ** (K-1)	SS8B647
	PRTNX(I,J) = 0.	SS8B648
	PRTNY(I,J) = 0.	SS8B649
	PRTNXY(I,J) = 0.	SS8B650
	PRTQ(I,J) = 0.	SS8B651
	IF (IPRTN .EQ. 0) GO TO 870	SS8B652
	DO 860 K=1,NPNX	SS8B653
	DO 860 L=1,NPNY	SS8B654
	PRTNX (I,J) = PRTNX (I,J) + PX (K,L) * V(1,K) * V(2,L)	SS8B655
	PRTNY (I,J) = PRTNY (I,J) + PY (K,L) * V(1,K) * V(2,L)	SS8B656
860	PRTNXY(I,J) = PRTNXY(I,J) + PXY(K,L) * V(1,K) * V(2,L)	SS8B657
870	IF (IPRTQ .EQ. 0) GO TO 890	SS8B658
	DO 880 K=1,NQTX	SS8B659
	DO 880 L=1,NQTY	SS8B660
880	PRTQ(I,J) = PRTQ(I,J) + Q(K,L) * V(1,K) * V(2,L)	SS8B661
890	CONTINUE	SS8B662
	IF (IPRTN .EQ. 0) GO TO 930	SS8B663
	WRITE (6,900)	SS8B664
900	FORMAT ('INX, NY, AND NXY, RESPECTIVELY, ARE PRINTED AT QUARTER POS	SS8B665
	INTS OF THE PANEL'//)	SS8B666
	WRITE (6,910) ((PRTNX(I,J), J=1,5), I=1,5)	SS8B667
910	FORMAT (' ',5E20.7)	SS8B668
	WRITE (6,920)	SS8B669
920	FORMAT ('0')	SS8B670
	WRITE (6,910) ((PRTNY(I,J), J=1,5), I=1,5)	SS8B671

WRITE (6,920)	SS88672
WRITE (6,910) ((PRTNXY(I,J), J=1,5), I=1,5)	SS88673
930 IF (IPRTQ .EQ. 0) GO TO 950	SS88674
WRITE (6,940)	SS88675
940 FORMAT ('THE LATERAL LOAD DISTRIBUTION IS PRINTED AT QUARTER POINTS OF THE PANEL'//)	SS88676
WRITE (6,910) ((PRTQ(I,J), J=1,5), I=1,5)	SS88677
950 CONTINUE	SS88678
IF (IFLEX .EQ. 0) GO TO 970	SS88679
READ (5,5) (XP(I), YP(I), I=1,IFLEX)	SS88680
WRITE (6,960) IFLEX, (XP(I), YP(I), I=1,IFLEX)	SS88681
960 FORMAT ('OTHER',I3,' NORMALIZED POINTS FOR THE FLEXIBILITY MATRIX ASSURE'//3(6X,1HX,10X,1HY,4X)/(/6F11.5))	SS88682
970 CONTINUE	SS88683
9999 RETURN	SS88684
99999 CALL SKIPPR	SS88685
GO TO 1	SS88686
END	SS88687
	SS88688
	SS88689

CC = 00690

C	SUBROUTINE CYLNDR (*)	SS8C000
C		SS8C001
C **	THIS SUBROUTINE CALCULATES THE NX, NY, AND NXY VALUES TO BE	SS8C002
C **	USED WHEN A SHELL IS LOADED BY AN AXIAL FORCE, A TORQUE,	SS8C003
C **	AND/OR A BENDING MOMENT.	SS8C004
C		SS8C005
C	DIMENSION PX(10,10), PY(10,10), PXY(10,10), V(10)	SS8C006
C		SS8C007
	COMMON / GEOM / AA, BB, RR	SS8C008
	COMMON / NUMBER / NNUM(10), NPNX, NPNY	SS8C009
	COMMON / PARAM / PDUM(1650), PX, PY, PXY	SS8C010
C		SS8C011
	DATA V(1) / 1.00225 /, V(2) / .140605 /, V(3) / -23.2379 /	SS8C012
	DATA V(4) / 19.8787 /, V(5) / 28.8562 /, V(6) / -3.39401 /	SS8C013
	DATA V(7) / -25.2977 /, V(8) / -15.1520 /, V(9) / 16.6307 /	SS8C014
	DATA V(10) / 1.57479 /	SS8C015
C		SS8C016
	TORQUE = 0.	SS8C017
	PI = 3.1415926536	SS8C018
	NPNX = 1	SS8C019
5	FORMAT (1X)	SS8C020
	READ (5,5) FAXIAL, BNDMOM	SS8C021
	WRITE (6,6) FAXIAL, TORQUE, BNDMOM	SS8C022
6	FORMAT ('0THE APPLIED CYLINDER LOADS ARE --'/	SS8C023
1	' ',T40,'AXIAL FORCE =',E15.6,T74,'LBS.'/	SS8C024
2	' ',T40,'TORQUE =',E15.6,T74,'IN-LBS.'/	SS8C025
3	' ',T40,'BENDING MOMENT =',E15.6,T74,'IN-LBS.'/	SS8C026
	PF = FAXIAL / 2. / PI / RR	SS8C027
	PT = TORQUE / 2. / PI / RR / RR	SS8C028
	PM = BNDMOM / PI / RR / RR	SS8C029
	IF (BNDMOM .GT. .0001) GO TO 10	SS8C030
	NPNY = 1	SS8C031
	PX (1,1) = PF	SS8C032
	PY (1,1) = 0.	SS8C033
	PXY(1,1) = PT	SS8C034
	RETURN 1	SS8C035
10	NPNY = 10	SS8C036
	DO 80 J=1,10	SS8C037
	PX(1,J) = V(J)*PM	SS8C038
	PY(1,J) = 0.	SS8C039
80	PXY(1,J)= 0.	SS8C040
	PX(1,1) = PX(1,1) + PF	SS8C041
	PXY(1,1)= PT	SS8C042
	RETURN 1	SS8C043
	END	SS8C044

CC = 00045

SUBROUTINE CHECK (A)	SS8D000
REAL*8 A	SS8D001
COMMON / CHECKS / IERROR	SS8D002
IERROR = 1	SS8D003
WRITE (6,6) A	SS8D004
6 FORMAT ('THE PROGRAM HAS READ AN UNACCEPTABLE VALUE FOR ',A6 /	SS8D005
1 ' THE NEXT PROBLEM WILL BE ATTEMPTED AFTER CHECKING THE CO	SS8D006
2NTROL VARIABLES')	SS8D007
RETURN	SS8D008
END	SS8D009

CC = 00010

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SUBROUTINE STIFF SS8E000
C THIS SUBROUTINE CALCULATES THE 6 BY 6 ARRAY OF STIFFNESS TERMS AT SS8E001
C A POINT FOR A LAMINATED PLATE. THE INPUT IS THE NUMBER OF PLIES SS8E002
C (MPLY), THE ORIENTATIONS OF THE PLIES (TETA( )), THE THICKNESS OF SS8E003
C EACH PLY (THICK), AND THE MATERIAL PROPERTIES OF THE ORTHOTROPIC SS8E004
C PLIES (E1,E2,G, AND POISSON'S RATIO (U1)). SS8E005
C ** REVISED FOR CURVED PANELS - - 8/69 SS8E006
C DIMENSION AH(41), CB(3,3,40) SS8E007
C DIMENSION C1(40), C2(40), C3(40), C11(40), C22(40), C12(40) SS8E008
C COMMON / ABD / A(3,3), DS(3,3), DP(3,3), RHAB, TETA(40), SS8E009
1 THICK(40), E1(40), E2(40), G(40), U1(40), SS8E010
2 EC(3,40), ET(3,40), ANGCK(3,10), MCHK(3), AH SS8E011
C COMMON / NUMBER / MPLY SS8E012
C COMMON / CNTRL / IDUM(5), IMATL SS8E013
C EQUIVALENCE (C1(1),E1(1)),(C2(1),E2(1)),(C3(1),U1(1)) SS8E014
C THE MIDDLE SURFACE IS LOCATED SS8E015
MPLY2= MPLY+1 SS8E016
AHK=0. SS8E017
DO 100 I=1, MPLY SS8E018
100 AHK= AHK + THICK(I)/2. SS8E019
AH(1)=-AHK SS8E020
DO 30 I=2, MPLY2 SS8E021
30 AH(I)= AH(I-1)+ THICK(I-1) SS8E022
C THE CBAR ARRAY IS CALCULATED FOR EACH PLY, USING DOUBLE-ANGLE SS8E023
C TRANSFORMATION FORMULAS. SS8E024
DO 40 N=1, MPLY SS8E025
U2= U1(N)*E2(N)/E1(N) SS8E026
DEL= 1.-U2*U1(N) SS8E027
CC1= E1(N)/DEL SS8E028
CC2= E2(N)/DEL SS8E029
CC3= CC1*U2 SS8E030
CC4= G(N) SS8E031
C11(N)= CC1 SS8E032
C22(N)= CC2 SS8E033
C12(N)= CC3 SS8E034
IF ( IMATL .EQ. 1 ) GO TO 40 SS8E035
COT = 2.*TETA(N)*.017453292519943 SS8E036
CO2= COS(COT) SS8E037
CO4= COS(2.*COT) SS8E038
SN2= SIN(COT) SS8E039
SN4= SIN(2.*COT) SS8E040
AJ1= CC1+CC2+2.*CC3 SS8E041
AJ2= CC4- CC3 SS8E042
CB(1,1,N)=.375*AJ1+.5*AJ2+(CC1-CC2)/2.*CO2+(AJ1/8.+AJ2/2.-CC4)*CO4 SS8E043
CB(1,2,N)=AJ1/8. -AJ2/2.+(CC4-AJ1/8.-AJ2/2.)*CO4 SS8E044
CB(2,1,N)= CB(1,2,N) SS8E045
CB(1,3,N)=(CC1- CC2)/4.*SN2 +(AJ1/8.+AJ2/2.- CC4)*SN4 SS8E046
CB(3,1,N)=CB(1,3,N) SS8E047
CB(2,2,N)= CB(1,1,N) +(CC2-CC1)*CO2 SS8E048
CB(2,3,N)= CB(1,3,N) -(AJ1/4.+AJ2-CC4*2.)*SN4 SS8E049
CB(3,2,N)= CB(2,3,N) SS8E050
CB(3,3,N)= AJ1/8. +AJ2/2. +(CC4 -AJ1/8.-AJ2/2.)*CO4 SS8E051
40 CONTINUE SS8E052
C THE A, DSTAR, AND D MATRICES ARE CALCULATED AND STORED IN A( , ), SS8E053
C DS( , ), AND DP( , ). SS8E054
IF ( IMATL .EQ. 1 ) GO TO 51 SS8E055

```

DO 50 I=1,3	SS8E056
DO 50 J=1,3	SS8E057
A(I,J)=0.	SS8E058
DS(I,J)=0.	SS8E059
DP(I,J)=0.	SS8E060
AX=AH(1)*AH(1)	SS8E061
DO 60 K=1,MPLY	SS8E062
A(I,J)=A(I,J)+ CB(I,J,K) *(AH(K+1)-AH(K))	SS8E063
AY=AX	SS8E064
AX=AH(K+1)*AH(K+1)	SS8E065
DP(I,J)= DP(I,J)+ CB(I,J,K)*(AX*AH(K+1)-AY*AH(K))	SS8E066
60 DS(I,J)= DS(I,J)+ CB(I,J,K)*(AX-AY)	SS8E067
DP(I,J)=DP(I,J)/3.	SS8E068
DS(I,J)= DS(I,J)/2.	SS8E069
DP(J,I)= DP(I,J)	SS8E070
DS(J,I)= DS(I,J)	SS8E071
50 A(J,I)= A(I,J)	SS8E072
51 CONTINUE	SS8E073
DO 70 N=1,MPLY	SS8E074
C1(N) = C11(N)	SS8E075
C2(N) = C22(N)	SS8E076
70 C3(N) = C12(N)	SS8E077
RETURN	SS8E078
END	SS8E079

CC = 00080

	SUBROUTINE TABLE	SS8F000
C		SS8F001
C **	THIS SUBROUTINE SERVES AS A CONTROL PROGRAM FOR THE CALCULATION	SS8F002
C **	OF THE TABLE OF INTEGRALS.	SS8F003
C		SS8F004
	DIMENSION AL(1,2,6,3,10,3,10), EVAL(4,2,3,10,25), TIME(50),	SS8F005
1	\$W(10,2,3,10,10), P(11,2,3,3,10), ITIME(12)	SS8F006
C		SS8F007
	COMMON / ARRAYS / P, AL, \$W	SS8F008
	COMMON / VALUES / EVAL	SS8F009
	COMMON / NUMBER / N1, NTUX, NTVX, NTWX, NTUY,	SS8F010
1	NTVY, NTWY, NMODES, NSTRNG, NRING,	SS8F011
2	NPNX, NPNY, NQTX, NQTY, N\$(9),	SS8F012
3	ITX, ITY	SS8F013
	COMMON / CNTROL / N3(3), IBCX, IBCY, N4(7), INTPRT	SS8F014
	COMMON / GEOM / ADUM(3), ALFAX, ALFAY, BETAX, BETAY	SS8F015
	COMMON / \$TIME / TIME, ITIME	SS8F016
C		SS8F017
	CALL STATUS (ITIME)	SS8F018
	TIME(3) = ITIME(8)/100.	SS8F019
	ET = TIME(3) - TIME(1)	SS8F020
	IF (INTPRT .EQ. 1) WRITE (6,10) ET	SS8F021
10	FORMAT ('OELAPSED TIME BEFORE TABLE GENERATION = 'F7.3)	SS8F022
	MAX\$X = MAXO (NPNX, NQTX, 1)	SS8F023
	MAX\$Y = MAXO (NPNY, NQTY, 1)	SS8F024
	MAX\$XY = MAXO (MAX\$X, MAX\$Y)	SS8F025
	MAXP1 = MAX\$XY + 1	SS8F026
C		SS8F027
	JBCX = IBCX	SS8F028
	JBCY = IBCY	SS8F029
	CALL INTEGL (ALFAX, BETAX, JBCX, NTUX, MAX\$X, 1, ITX)	SS8F030
	CALL INTEGL (ALFAY, BETAY, JBCY, NTUY, MAX\$Y, 2, ITY)	SS8F031
C		SS8F032
190	CALL STATUS (ITIME)	SS8F033
	TIME(4) = ITIME(8)/100.	SS8F034
	ET = TIME(4) - TIME(3)	SS8F035
	IF (INTPRT .EQ. 1) WRITE (6,200) ET	SS8F036
200	FORMAT ('OINTEGRAL EVALUATION TIME = 'F7.3)	SS8F037
	RETURN	SS8F038
	END	SS8F039

CC = 00040

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SUBROUTINE INTEGL ($ALFA,$BETA,MNIJ,NTERMS,IPOWER,IDEFNE,IZ)      SS8G000
C THIS SUBROUTINE COMPUTES AND RETURNS, WITH THE AID OF 'PPP',    SS8G001
C 'SPECIAL', AND ELASTC, THE INTEGRALS AND MODE SHAPE EVALUATIONS FORSS8G002
C ANY OF THE BEAM CONDITIONS CONSIDERED. THE INPUT IS $ALFA, $BETA,SS8G003
C AND MNIJ. $ALFA,$BETA ARE USED IN SUBROUTINE ELASTC IF AND ONLY  SS8G004
C IF MNIJ IS GREATER THAN 6. IF MNIJ IS LESS THAN 7, THE INITIAL  SS8G005
C FREQUENCY ESTIMATES ARE READ INTO EPI ). THESE ESTIMATES ARE USEDSS8G006
C WITH A NEWTON-RAPHSON ITERATION ON THE APPROPRIATE FREQUENCY    SS8G007
C EQUATION TO OBTAIN ACCURATE FREQUENCIES AND MODE SHAPES. THE    SS8G008
C RESULTS ARE RETURNED THROUGH THE COMMON BLOCK ARRAYS. THE ROUTINE SS8G009
C IS IN DOUBLE PRECISION .                                         SS8G010
C ** REVISED FOR CURVED PANELS - - 8/69                             SS8G011
C IMPLICIT REAL*8(A-H,O-Z), INTEGER (I-N)                          SS8G012
C DIMENSION C(4,4,3,10),CLASTC(4,10),FFF(10)                     SS8G013
C COMMON / BLOCK / AL(1,6,3,10,3,10), EVAL(4,3,10,25),           SS8G014
1      EVQ(4,3,2,25),      PZ(11,3,3,10),                        SS8G015
2      TH(10,4,4,3),      ALVA(11,11,2),      P(11,10),          SS8G016
3      CE(4,10), E(4,4), EP(10), CN(4), CM(4)                     SS8G017
C COMMON / ARRAYS / $P(11,2,3,3,10), $AL(1,2,6,3,10,3,10),      SS8G018
1      $W(10,2,3,10,10)                                           SS8G019
C COMMON / VALUES / $EVAL(4,2,3,10,25)                           SS8G020
C COMMON / NUMBER / NDUM(8), NSTRNG, NRING                        SS8G021
C COMMON / STFVAL / $ESV(10,100), $ESW(10,100), $ESDW(10,100),   SS8G022
1      $ERU(10,50), $ERW(10,50), $ERDW(10,50),                   SS8G023
2      $STRNG(100), $RINGS(50)                                     SS8G024
C COMMON / CNTROL / IFLAGD, IFLAGB                                SS8G025
C MNIJ IS A FLAG FOR BOUNDARY CONDITION                             SS8G026
C MNIJ = 0 FOR FULL CYLINDER                                       SS8G027
C MNIJ=1 FOR FIXED SIMPLE BEAM, =2 FOR SIMPLE-SIMPLE, =3 FOR FIXED- SS8G028
C FIXED, =4 FOR FIXED-FREE, =5 FOR SIMPLE FREE, AND = 6 FOR FREE-  SS8G029
C FREE. GREATER THAN 6 IS USED FOR ELASTICALLY RESTRAINED.        SS8G030
C PIE = 3.1415926535898                                           SS8G031
C S3 = DSQRT (3.00)                                               SS8G032
C IF(MNIJ .GT. 6) GO TO 700                                         SS8G033
C ASH= 0 ,IJKLM=-1,IKJ=1 FOR A SIMPLE-SIMPLE BEAM                SS8G034
C ASH=-1.,IJKLM= 0,IKJ=1 FOR A FIXED-FIXED BEAM                  SS8G035
C ASH=-1.,IJKLM=+1,IKJ=3 FOR A FREE-FREE BEAM                     SS8G036
C ASH=+1.,IJKLM= 0,IKJ=1 FOR A FIXED-FREE BEAM                    SS8G037
C ASH= 0 ,IJKLM=-2,IKJ=2 FOR A SIMPLE-FREE BEAM                   SS8G038
C ASH= 0 ,IJKLM=-3,IKJ=1 FOR A FIXED-SIMPLE BEAM                  SS8G039
C ICYL=0                                                            SS8G040
C IF(MNIJ.NE.0) GO TO 2999                                         SS8G041
C CYLINDER                                                         SS8G042
C ICYL=1                                                            SS8G043
C ASH = 0.                                                           SS8G044
C IJKLM = -1                                                         SS8G045
C IKJ = 1                                                            SS8G046
C I500 = 2                                                           SS8G047
C IF ( IFLAGB .NE. 0 ) GO TO 2997                                   SS8G048
C EP(1) = IZ * 6.28319                                             SS8G049
C DO 3000 I=2,NTERMS                                               SS8G050
3000 EP(I) = EP(I-1) + 6.283                                       SS8G051
C GO TO 3009                                                         SS8G052
2997 EP(1) = IZ * 3.14159                                           SS8G053
C DO 2998 I=2,NTERMS                                               SS8G054
2998 EP(I) = EP(I-1) + 3.14159                                       SS8G055

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	GO TO 3009	SS8G056
2999	IF(MNIJ.NE.1) GO TO 3001	SS8G057
C	CLAMPED - SIMPLE	SS8G058
	ASH=0.	SS8G059
	IJKLM=-3	SS8G060
	IKJ = 1	SS8G061
	EP(1) = (4.*IZ + 1.) * PIE / 4.	SS8G062
	GO TO 3007	SS8G063
3001	IF(MNIJ.NE.2)GO TO 3002	SS8G064
C	SIMPLE - SIMPLE	SS8G065
	ASH=0.	SS8G066
	IJKLM=-1	SS8G067
	IKJ=1	SS8G068
	EP(1) = IZ * 3.14159	SS8G069
	GO TO 3007	SS8G070
3002	IF(MNIJ.NE.3)GO TO 3003	SS8G071
C	CLAMPED - CLAMPED	SS8G072
	ASH=-1.	SS8G073
	IJKLM=0	SS8G074
	IKJ=1	SS8G075
	EP(1) = (2.*IZ + 1.) * PIE / 2.	SS8G076
	GO TO 3007	SS8G077
3003	IF(MNIJ.NE.4) GO TO 3004	SS8G078
C	CLAMPED - FREE	SS8G079
	ASH=1.	SS8G080
	IJKLM=0	SS8G081
	IKJ=1	SS8G082
	EP(1) = (2.*IZ - 1.) * PIE / 2.	SS8G083
	GO TO 3007	SS8G084
3004	IF(MNIJ.NE.5)GO TO 3005	SS8G085
C	SIMPLE - FREE	SS8G086
	ASH=0.	SS8G087
	IJKLM=-2	SS8G088
	IF (IZ .NE. 1) GO TO 3105	SS8G089
	IKJ= 2	SS8G090
	EP(1)= 3.	SS8G091
	EP(2)= 3.93	SS8G092
	GO TO 3007	SS8G093
3105	IKJ = 1	SS8G094
	EP(1) = (4.*IZ - 3.) * PIE / 4.	SS8G095
	GO TO 3007	SS8G096
3005	ASH= -1.	SS8G097
C	FREE - FREE	SS8G098
	IJKLM= 1	SS8G099
	IF (IZ .NE. 0) GO TO 3100	SS8G100
	IKJ=3	SS8G101
	EP(1)=3.	SS8G102
	EP(2)=2.	SS8G103
	EP(3)=4.73	SS8G104
	GO TO 3007	SS8G105
3100	IKJ = 1	SS8G106
	EP(1) = (2.*IZ - 1.) * PIE / 2.	SS8G107
3007	I500=IKJ+1	SS8G108
	DO 3008 I=I500,NTERMS	SS8G109
3008	EP(I) = EP(I-1)+3.142	SS8G110
C	COMPUTE ACCURATE FREQUENCIES FROM HERE TO 200	SS8G111

3009	CONTINUE	SS8G112
	DO 200 I=IKJ, NTERMS	SS8G113
	DO 200 J=1, 8	SS8G114
	DC=DCOS(EP(I))	SS8G115
	DS=DSIN(EP(I))	SS8G116
	DX=DEXP(EP(I))	SS8G117
	DCH=.5*(DX+1./DX)	SS8G118
	DSH=.5*(DX-1./DX)	SS8G119
	IF(IJKLM.LT.0) GO TO 450	SS8G120
	FX=DC*DCH+ASH	SS8G121
	FPX=-DS*DCH+DC*DSH	SS8G122
	GO TO 451	SS8G123
450	IF(IJKLM.EQ.-1)GO TO 452	SS8G124
	FX=DS/DC - DSH/DCH	SS8G125
	FPX=1./DC/DC -1./DCH/DCH	SS8G126
	GO TO 451	SS8G127
452	FX= DS	SS8G128
	FPX=DC	SS8G129
451	CONTINUE	SS8G130
	EP(I)=EP(I)-FX/FPX	SS8G131
200	CONTINUE	SS8G132
C	COMPUTE MODE SHAPE CONSTANTS FROM HERE TO 1	SS8G133
	DO 1 N=1, NTERMS	SS8G134
	SN=DSIN(EP(N))	SS8G135
	CS=DCOS(EP(N))	SS8G136
	DX=DEXP(EP(N))	SS8G137
	SH=.5*(DX-1./DX)	SS8G138
	CH=.5*(DX+1./DX)	SS8G139
	IF(ICYL.EQ.1) GO TO 9450	SS8G140
	IF(IJKLM.LT.0)GO TO 460	SS8G141
	IF(IJKLM.GT.0) GO TO 351	SS8G142
C	CLAMPED - CLAMPED	SS8G143
C	CLAMPED - FREE	SS8G144
	C(1,4,3,N)=(CH*ASH+CS)/(SN*ASH+SH)*ASH	SS8G145
	C(1,3,3,N)=-C(1,4,3,N)	SS8G146
	C(1,1,3,N)= 1.	SS8G147
	C(1,2,3,N)= -1.	SS8G148
	GO TO 1	SS8G149
C	FREE - FREE	SS8G150
351	C(1,1,3,N)= 1.	SS8G151
	C(1,2,3,N)= 1.	SS8G152
	C(1,3,3,N)= (-CS+CH)/(SN-SH)	SS8G153
	C(1,4,3,N)= C(1,3,3,N)	SS8G154
	GO TO 1	SS8G155
9450	C(1,2,3,N)= DSQRT(2.DO)	SS8G156
	C(1,1,3,N)= 0.	SS8G157
	C(1,3,3,N)= 0.	SS8G158
	C(1,4,3,N)= 0.	SS8G159
	GO TO 1	SS8G160
460	IF(IJKLM .EQ.-1) GO TO 453	SS8G161
	IF(IJKLM.EQ.-2)GO TO 454	SS8G162
C	CLAMPED - SIMPLE	SS8G163
	C(1,1,3,N)= 1.	SS8G164
	C(1,2,3,N)= -1.	SS8G165
	C(1,3,3,N)= (CS-CH)/(SH-SN)	SS8G166
	C(1,4,3,N)= -C(1,3,3,N)	SS8G167

	GO TO 1	SS8G168
C	SIMPLE - FREE	SS8G169
454	C(1,1,3,N)= 0.	SS8G170
	C(1,2,3,N)= 0.	SS8G171
	C(1,4,3,N)= 2.*SH/(-SN+SH)	SS8G172
	C(1,3,3,N)= C(1,4,3,N)-2.DO	SS8G173
	AV= DSQRT(C(1,4,3,N) + C(1,3,3,N))	SS8G174
	C(1,4,3,N)= C(1,4,3,N)/AV	SS8G175
	C(1,3,3,N)= C(1,3,3,N)/AV	SS8G176
	GO TO 1	SS8G177
C	SIMPLE - SIMPLE	SS8G178
453	C(1,1,3,N)= 0.	SS8G179
	C(1,2,3,N)= 0.	SS8G180
	C(1,3,3,N)= 0.	SS8G181
	C(1,4,3,N)= DSQRT(2.DO)	SS8G182
	1 CONTINUE	SS8G183
	GO TO 701	SS8G184
C	ELASTIC RESTRAINT	SS8G185
700	ALFA= \$ALFA	SS8G186
	BETA= \$BETA	SS8G187
C	FREQUENCIES AND SHAPE COEFFICIENTS ARE COMPUTED IN ELASTC.	SS8G188
	CALL ELASTC (CLASTC,ALFA,BETA,NTERMS)	SS8G189
	DO 7000 J=1,4	SS8G190
	DO 7000 N=1,NTERMS	SS8G191
7000	C(1,J,3,N) = CLASTC(J,N)	SS8G192
701	CONTINUE	SS8G193
C	THE COEFFICIENTS OF THE 'NORMALIZED' DERIVATIVES ARE PUT IN C()	SS8G194
	INIJ= MNIJ	SS8G195
	MNIJ= IDEFNE	SS8G196
	ID=IDEFNE	SS8G197
	DO 2 N=1,NTERMS	SS8G198
	C(2,1,3,N)= C(1,3,3,N)	SS8G199
	C(2,2,3,N)= C(1,4,3,N)	SS8G200
	C(2,3,3,N)= C(1,1,3,N)	SS8G201
	C(2,4,3,N)=-C(1,2,3,N)	SS8G202
	C(3,1,3,N)= C(1,1,3,N)	SS8G203
	C(3,2,3,N)=-C(1,2,3,N)	SS8G204
	C(3,3,3,N)= C(1,3,3,N)	SS8G205
2	C(3,4,3,N)=-C(1,4,3,N)	SS8G206
	IF(IDEFNE.EQ.2) GO TO 9910	SS8G207
	DO 9900 I=1,4	SS8G208
	DO 9900 N=1,NTERMS	SS8G209
	C(1,I,1,N) = C(2,I,3,N) * EP(N)	SS8G210
9900	C(1,I,2,N)=C(1,I,3,N)	SS8G211
	GO TO 9920	SS8G212
9910	DO 9915 I=1,4	SS8G213
	DO 9915 N=1,NTERMS	SS8G214
	C(1,I,1,N)=C(1,I,3,N)	SS8G215
9915	C(1,I,2,N) = C(2,I,3,N) * EP(N)	SS8G216
9920	DO 9930 I=1,2	SS8G217
	DO 9930 N=1,NTERMS	SS8G218
	C(2,1,I,N)= C(1,3,I,N)	SS8G219
	C(2,2,I,N)= C(1,4,I,N)	SS8G220
	C(2,3,I,N)= C(1,1,I,N)	SS8G221
	C(2,4,I,N)=-C(1,2,I,N)	SS8G222
	C(3,1,I,N)= C(1,1,I,N)	SS8G223

C(3,2,I,N)=-C(1,2,I,N)	SS8G224
C(3,3,I,N)= C(1,3,I,N)	SS8G225
9930 C(3,4,I,N)=-C(1,4,I,N)	SS8G226
C FACTORIAL GENERATION	SS8G227
IPOWER = IPOWER+1	SS8G228
DO 2001 I=1,IPOWER	SS8G229
DO 2002 L=1,I	SS8G230
ALVA(I,L,2)=0.	SS8G231
J=I-1	SS8G232
K=I-L	SS8G233
DFAC = 1.	SS8G234
FAC=1.	SS8G235
IF(J.LE.1)GO TO 2003	SS8G236
DO 2004 JJ=2,J	SS8G237
AMTP= JJ	SS8G238
2004 FAC= FAC*AMTP	SS8G239
2003 IF(K.LE.1)GO TO 2005	SS8G240
DO 2006 KK=2,K	SS8G241
AMTP= KK	SS8G242
2006 DFAC = AMTP*DFAC	SS8G243
2005 ALVA(I,L,1)= ((-1.)**(L+1))*FAC/DFAC	SS8G244
2002 CONTINUE	SS8G245
2001 ALVA(I,I,2)=ALVA(I,I,1)	SS8G246
PI=3.1415926535898/2.	SS8G247
DO 1001 IUVW=1,3	SS8G248
DO 1001 JUVW=1,3	SS8G249
DO 1001 M=1,NTERMS	SS8G250
EPM = EP(M)	SS8G251
DO 1001 N=1,NTERMS	SS8G252
EPN= EP(N)	SS8G253
OMEGA1= EPM+ EPN	SS8G254
OMEGA2= EPN- EPM	SS8G255
EX1= .25*DEXP(OMEGA1)	SS8G256
EMX1=1./EX1/16.	SS8G257
EX2 =.25*DEXP(OMEGA2)	SS8G258
EMX2=1./EX2/16.	SS8G259
SN1 = DSIN(OMEGA1)/2.	SS8G260
SN2 = DSIN(OMEGA2)/2.	SS8G261
CS1=DCOS(OMEGA1)/2.	SS8G262
CS2=DCOS(OMEGA2)/2.	SS8G263
FACTOR=1.	SS8G264
DO 1002 I=1,IPOWER	SS8G265
FACTOR= FACTOR*I	SS8G266
O1I = (OMEGA1)**I	SS8G267
FFF(I) = EX1/O1I	SS8G268
T111= 0.0	SS8G269
T112= ((-1.)**I)*EMX1/O1I	SS8G270
T113= (1.-(-1.)**(I+1))/2./O1I /2.	SS8G271
1003 T121=0.	SS8G272
T122=(DSIN(I*PI)*SN1 +DCOS(I*PI)*CS1)/O1I	SS8G273
T123= DCOS(I*PI)/2./O1I	SS8G274
IF(M.EQ.N) GO TO 1004	SS8G275
O2I= (OMEGA2)**I	SS8G276
T211= EX2/O2I	SS8G277
T212= ((-1.)**I)*EMX2/O2I	SS8G278
T213= (1.-(-1.)**(I+1))/4./O2I	SS8G279

IF(DABS(T211).GE. DABS(T212)) GO TO 1005	SS8G280
TX15= T211	SS8G281
T211= T212	SS8G282
T212= TX15	SS8G283
1005 T221= 0.	SS8G284
T222= (DSIN(I*PI)*SN2 + DCOS(I*PI)*CS2)/O2I	SS8G285
T223= DCOS(I*PI)/2./O2I	SS8G286
GO TO 1006	SS8G287
1004 T211= 0.	SS8G288
T221= 0.	SS8G289
T212= .5/FACTOR	SS8G290
T222= T212	SS8G291
T213=0.	SS8G292
T223= 0.	SS8G293
1006 TH(1,1,1,1) = T111 + T211	SS8G294
TH(1,1,1,2) = T112 + T212	SS8G295
TH(1,2,2,1) = T121 + T221	SS8G296
TH(1,2,2,2) = T122 + T222	SS8G297
TH(1,3,3,1) = T111 - T211	SS8G298
TH(1,3,3,2) = T112 - T212	SS8G299
TH(1,4,4,1) = -T121 + T221	SS8G300
TH(1,4,4,2) = -T122 + T222	SS8G301
TH(1,1,1,3) = T113 + T213	SS8G302
TH(1,2,2,3) = T123 + T223	SS8G303
TH(1,3,3,3) = T113 - T213	SS8G304
1002 TH(1,4,4,3) = -T123 + T223	SS8G305
IFLAG= -1	SS8G306
1007 EPSAVE = EPN	SS8G307
EPN = EPM	SS8G308
EPM = EPSAVE	SS8G309
OMEGA1 =EPM+EPN	SS8G310
OMEGA2 =EPN-EPM	SS8G311
EX1= .25*DEXP(OMEGA1)	SS8G312
EMX1= 1./EX1/16.	SS8G313
EX2 = DEXP(OMEGA2)/4.	SS8G314
EMX2= 1./EX2/16.	SS8G315
SN1= DSIN(OMEGA1)/2.	SS8G316
SN2= DSIN(OMEGA2)/2.	SS8G317
CS1= DCOS(OMEGA1)/2.	SS8G318
CS2= DCOS(OMEGA2)/2.	SS8G319
DELO= EPM*EPM+ EPN*EPN	SS8G320
DELI1= 1.	SS8G321
DELI2= 0.	SS8G322
EPEPN = DEXP(EPN)/2.	SS8G323
EMEPN = 1./EPEPN/4.	SS8G324
SNEPM= DSIN(EPM)	SS8G325
CSEPM= DCOS(EPM)	SS8G326
DO 1008 I=1,IPOWER	SS8G327
DELI1S = EPN*DELI1 - EPM*DELI2	SS8G328
DELI2 = EPM*DELI1 + EPN*DELI2	SS8G329
DELI1 = DELI1S	SS8G330
OII = (OMEGA1)**I	SS8G331
DELOI =(DELO)**I	SS8G332
TH(1,3,1,1) = 0.0	SS8G333
TH(1,3,1,2)=((-1.)**(I+1))*EMX1/OII	SS8G334
TH(1,3,1,3)= (1.-(-1.)**I)/2./OII/2.	SS8G335

TH(I,4,2,1) = 0.	SS8G336
TH(I,4,2,2) = (-DSIN(I*PI)*CS1 + DCOS(I*PI)*SN1)/O1I	SS8G337
TH(I,4,2,3) = -DSIN(I*PI)/2./O1I	SS8G338
TH(I,1,2,1) = EPEPN/DELOI*(DELI1*CSEPM + DELI2*SNEPM)	SS8G339
TH(I,1,2,2) = EMEPN/DELOI*(((1.-1.)*I)*DELI1*CSEPM	SS8G340
1 + (((1.-1.)*I)*DELI2*SNEPM)	SS8G341
TH(I,1,2,3) = DELI1/2./DELOI*(1.+((1.-1.)*I))	SS8G342
TH(I,3,2,3) = DELI1/2./DELOI*(1.-((1.-1.)*I))	SS8G343
TH(I,3,2,1) = TH(I,1,2,1)	SS8G344
TH(I,3,2,2) = -TH(I,1,2,2)	SS8G345
TH(I,1,4,1) = EPEPN/DELOI*(DELI1*SNEPM -DELI2*CSEPM)	SS8G346
TH(I,1,4,2) = EMEPN/DELOI*(((1.-1.)*I)*DELI2*CSEPM	SS8G347
1 + (((1.-1.)*I)*DELI1*SNEPM)	SS8G348
TH(I,1,4,3) = DELI2/2./DELOI*(1.-((1.-1.)*I))	SS8G349
TH(I,3,4,3) = DELI2/2./DELOI*(1.-((1.-1.)*I))	SS8G350
TH(I,3,4,1) = TH(I,1,4,1)	SS8G351
TH(I,3,4,2) = -TH(I,1,4,2)	SS8G352
IF(M.EQ.N) GO TO 1009	SS8G353
O2I=(OMEGA2)**I	SS8G354
TBIG =EX2/O2I	SS8G355
TSMALL= (((1.-1.)*I)*EMX2/O2I	SS8G356
TH(I,3,1,3) = TH(I,3,1,3) + (1.-((1.-1.)*I))/2./O2I/2.	SS8G357
TH(I,4,2,2) = TH(I,4,2,2) + (-DSIN(I*PI)*CS2+DCOS(I*PI)*SN2)/O2I	SS8G358
TH(I,4,2,3) = TH(I,4,2,3) -DSIN(I*PI)/2./O2I	SS8G359
IF(DABS(TBIG).GE.DABS(TSMALL))GO TO 1010	SS8G360
TX15 =TBIG	SS8G361
TBIG = TSMALL	SS8G362
TSMALL = TX15	SS8G363
1010 TH(I,3,1,1) = TH(I,3,1,1) + TBIG	SS8G364
TH(I,3,1,2) = TH(I,3,1,2) + TSMALL	SS8G365
1009 CONTINUE	SS8G366
1008 CONTINUE	SS8G367
IF(IFLAG.GT. 0) GO TO 1011	SS8G368
IFLAG = +1	SS8G369
DO 1012 I=1,IPOWER	SS8G370
DO 1012 J=1,3	SS8G371
TH(I,1,3,J) = TH(I,3,1,J)	SS8G372
TH(I,2,4,J) = TH(I,4,2,J)	SS8G373
TH(I,2,1,J) = TH(I,1,2,J)	SS8G374
TH(I,2,3,J) = TH(I,3,2,J)	SS8G375
TH(I,4,1,J) = TH(I,1,4,J)	SS8G376
1012 TH(I,4,3,J) = TH(I,3,4,J)	SS8G377
GO TO 1007	SS8G378
1011 CONTINUE	SS8G379
C TH(I,K,J) ARE NOW STORED	SS8G380
DO 1001 K=1,6	SS8G381
IF(K-2)25,26,27	SS8G382
27 IF(K-4)28,29,30	SS8G383
30 IF(K-6)31,32,32	SS8G384
25 NN=1	SS8G385
MM=1	SS8G386
GO TO 6	SS8G387
26 NN=2	SS8G388
MM=2	SS8G389
GO TO 6	SS8G390
28 NN=3	SS8G391

	MM=3	SS8G392
	GO TO 6	SS8G393
29	NN=2	SS8G394
	MM=1	SS8G395
	GO TO 6	SS8G396
31	NN=3	SS8G397
	MM=1	SS8G398
	GO TO 6	SS8G399
32	NN=3	SS8G400
	MM=2	SS8G401
6	DO 7 J=1,4	SS8G402
	CN(J)=C(NN,J,IUVW,N)	SS8G403
7	CM(J)=C(MM,J,JUVW,M)	SS8G404
	EXYZ = (EPN**(NN-1))*(EPM**(MM-1))	SS8G405
	DO 8 J=1,4	SS8G406
	DO 8 I=1,4	SS8G407
8	E(J,I)= CN(J)*CM(I)*EXYZ	SS8G408
	SAVEIT= (CN(1)+CN(3))*(CM(1)+CM(3))*EXYZ	SS8G409
	I = 1	SS8G410
	AL(I,K,IUVW,N,JUVW,M)=0.	SS8G411
	SAVE1= 0.	SS8G412
	SAVE2= 0.	SS8G413
	SAVE3= 0.	SS8G414
	SAVE4=0.	SS8G415
	DO 1114 L=1,I	SS8G416
	SAVE1 = SAVE1 + SAVEIT*ALVA(I,L,1)*FFF(L)	SS8G417
	DO 1114 IT=1,4	SS8G418
	DO 1114 IU=1,4	SS8G419
	SAVE4= SAVE4 + E(IT,IU)*ALVA(I,L,1)*TH(L,IT,IU,1)	SS8G420
	SAVE2= SAVE2 + E(IT,IU)*ALVA(I,L,1)*TH(L,IT,IU,2)	SS8G421
1114	SAVE3= SAVE3 + E(IT,IU)*ALVA(I,L,2)*TH(L,IT,IU,3)	SS8G422
1014	AL(I,K,IUVW,N,JUVW,M)= SAVE1 + SAVE2 - SAVE3 + SAVE4	SS8G423
	IF (K .LE. 2) KK=K	SS8G424
	IF (K .EQ. 3) GO TO 1001	SS8G425
	IF (K .EQ. 4) KK=3	SS8G426
	IF (K .GE. 5) GO TO 1001	SS8G427
	IF(IUVW.NE.3) GO TO 1001	SS8G428
	IF(JUVW.NE.3) GO TO 1001	SS8G429
	DO 6000 I=1,IPOWER	SS8G430
	\$W(I,ID,KK,N,M) = 0.	SS8G431
	SAVE1 = 0.	SS8G432
	SAVE2 = 0.	SS8G433
	SAVE3 = 0.	SS8G434
	SAVE4 = 0.	SS8G435
	DO 5000 L=1,I	SS8G436
	SAVE1 = SAVE1 + SAVEIT * ALVA(I,L,1) * FFF(L)	SS8G437
	DO 5000 IT=1,4	SS8G438
	DO 5000 IU=1,4	SS8G439
	SAVE4 = SAVE4 + E(IT,IU) * ALVA(I,L,1) * TH(L,IT,IU,1)	SS8G440
	SAVE2= SAVE2 + E(IT,IU) * ALVA(I,L,1) * TH(L,IT,IU,2)	SS8G441
5000	SAVE3 = SAVE3 + E(IT,IU) * ALVA(I,L,2) * TH(L,IT,IU,3)	SS8G442
6000	\$W(I,ID,KK,N,M) = SAVE1 + SAVE2 - SAVE3 + SAVE4	SS8G443
1001	CONTINUE	SS8G444
C	THE P INTEGRALS ARE NOW EVALUATED, AND ALSO ANY SPECIAL CASES.	SS8G445
	IPO2= IPOWER+1	SS8G446
	IN = 1	SS8G447

IF (INIJ .EQ. 5 .AND. IZ .EQ. 1) IN = INIJ - 3	SS8G448
IF (INIJ .EQ. 6 .AND. IZ .EQ. 0) IN = INIJ - 3	SS8G449
DO 811 NUVW=1,3	SS8G450
DO 806 I=1,4	SS8G451
DO 806 J=1,NTERMS	SS8G452
806 CE(I,J)=C(1,I,NUVW,J)	SS8G453
CALL PPP (IN,NTERMS,IPOWER,ID,NUVW, 1)	SS8G454
DO 807 I=1,IPO2	SS8G455
DO 807 J=1,NTERMS	SS8G456
IF (IN .EQ. 1) GO TO 807	SS8G457
PZ(I,1,NUVW,J) = P(I,J)	SS8G458
807 \$P(I,ID,1,NUVW,J) = P(I,J)	SS8G459
DO 808 I=1,4	SS8G460
DO 808 J=1,NTERMS	SS8G461
808 CE(I,J)=C(2,I,NUVW,J)*EP(J)	SS8G462
CALL PPP (IN,NTERMS,IPOWER,ID,NUVW, 2)	SS8G463
DO 809 I=1,IPO2	SS8G464
DO 809 J=1,NTERMS	SS8G465
IF (IN .EQ. 1) GO TO 809	SS8G466
PZ(I,2,NUVW,J) = P(I,J)	SS8G467
809 \$P(I,ID,2,NUVW,J) = P(I,J)	SS8G468
DO 810 I=1,4	SS8G469
DO 810 J=1,NTERMS	SS8G470
810 CE(I,J)=C(3,I,NUVW,J)*EP(J)*EP(J)	SS8G471
CALL PPP (IN,NTERMS,IPOWER,ID,NUVW, 3)	SS8G472
DO 811 I=1,IPO2	SS8G473
DO 811 J=1,NTERMS	SS8G474
IF (IN .EQ. 1) GO TO 811	SS8G475
PZ(I,3,NUVW,J) = P(I,J)	SS8G476
811 \$P(I,ID,3,NUVW,J) = P(I,J)	SS8G477
IF (IN .EQ. 1) GO TO 805	SS8G478
CALL SPECIAL (IPOWER,NTERMS,INIJ,IDEFNE)	SS8G479
IN=IN-1	SS8G480
805 I=1	SS8G481
DO 33 IUUVW=1,3	SS8G482
DO 33 JUVW=1,3	SS8G483
DO 33 K=1,6	SS8G484
DO 33 N=1,NTERMS	SS8G485
DO 33 M=1,NTERMS	SS8G486
\$AL(I,MNIJ,K,IUUVW,N,JUVW,M)=AL(I,K,IUUVW,N,JUVW,M)	SS8G487
33 CONTINUE	SS8G488
C THE MODE SHAPES AND ITS DERIVATIVES ARE EVALUATED AT 25 PCINTS.	SS8G489
DO 707 N=1,3	SS8G490
DO 40 J=1 ,NTERMS	SS8G491
C(4,1,N,J)=C(3,3,N,J)	SS8G492
C(4,2,N,J)=C(3,4,N,J)	SS8G493
C(4,3,N,J)=C(3,1,N,J)	SS8G494
C(4,4,N,J)=-C(3,2,N,J)	SS8G495
DO 2750 I=1,4	SS8G496
SAVE1 = C(I,1,N,J)	SS8G497
C(I,1,N,J)=C(I,1,N,J)+C(I,3,N,J)	SS8G498
2750 C(I,3,N,J)=C(I,3,N,J) - SAVE1	SS8G499
DO 40 L=1,25	SS8G500
YU=L-1	SS8G501
YU=YU/24.	SS8G502
AA=DEXP(EP(J)*YU)	SS8G503

CN(1)=.5*(AA	SS8G504
CN(3)=.5*(-1./AA)	SS8G505
CN(2)=DCOS(EP(J)*YU)	SS8G506
CN(4)=DSIN(EP(J)*YU)	SS8G507
DO 40 I=1,4	SS8G508
EVAL(I,N,J,L)=0.DO	SS8G509
DO 40 K=1,4	SS8G510
40 EVAL(I,N,J,L)=EVAL(I,N,J,L)+CN(K)*C(I,K,N,J)*(EP(J)**(I-1))	SS8G511
IF (INIJ .EQ. 5 .AND. IZ .EQ. 1) GO TO 816	SS8G512
IF (INIJ .EQ. 6 .AND. IZ .EQ. 0) GO TO 816	SS8G513
GO TO 815	SS8G514
816 DO 817 J=1,IN	SS8G515
DO 817 L=1,25	SS8G516
DO 817 I=1,4	SS8G517
817 EVAL(I,N,J,L)=EVQ(I,N,J,L)	SS8G518
815 CONTINUE	SS8G519
41 CONTINUE	SS8G520
DO 707 K=1,NTERMS	SS8G521
DO 707 L=1,25	SS8G522
DO 707 I=1,4	SS8G523
707 \$EVAL(I,MNIJ,N,K,L)=EVAL(I,N,K,L)	SS8G524
IF (MNIJ .EQ. 1) GO TO 59	SS8G525
IF (NSTRNG .EQ. 0) GO TO 90	SS8G526
DO 50 L=1,NSTRNG	SS8G527
DO 50 J=1,NTERMS	SS8G528
Y = \$STRNG(L)	SS8G529
AA = DEXP(EP(J)*Y)	SS8G530
CN(1) = .5*AA	SS8G531
CN(3) = -.5/AA	SS8G532
CN(2) = DCOS(EP(J)*Y)	SS8G533
CN(4) = DSIN(EP(J)*Y)	SS8G534
\$ESV(J,L) = 0.	SS8G535
\$ESW(J,L) = 0.	SS8G536
\$ESDW(J,L)= 0.	SS8G537
DO 50 K=1,4	SS8G538
\$ESV(J,L) = \$ESV(J,L) + CN(K) * C(1,K,2,J)	SS8G539
\$ESW(J,L) = \$ESW(J,L) + CN(K) * C(1,K,3,J)	SS8G540
50 \$ESDW(J,L)= \$ESDW(J,L)+ CN(K) * C(2,K,3,J)*EP(J)	SS8G541
IF (INIJ .NE. 5) GO TO 52	SS8G542
IF (IZ .NE. 1) GO TO 52	SS8G543
DO 51 L=1,NSTRNG	SS8G544
\$ESV(1,L) = S3	SS8G545
\$ESW(1,L) = S3 * \$STRNG(L)	SS8G546
51 \$ESDW(1,L) = S3	SS8G547
GO TO 90	SS8G548
52 IF (INIJ .NE. 6) GO TO 90	SS8G549
IF (IZ .NE. 0) GO TO 90	SS8G550
DO 53 L=1,NSTRNG	SS8G551
\$ESV(1,L) = 0.	SS8G552
\$ESV(2,L) = -2.*S3	SS8G553
\$ESW(1,L) = 1.	SS8G554
\$ESW(2,L) = S3 * (1. - 2. * \$STRNG(L))	SS8G555
\$ESDW(1,L)= 0.	SS8G556
53 \$ESDW(2,L)= -2.*S3	SS8G557
GO TO 90	SS8G558
59 IF (NRING .EQ. 0) GO TO 90	SS8G559

DO 60 L=1,NRING	SS8G560
DO 60 J=1,NTERMS	SS8G561
X = \$RINGS(L)	SS8G562
AA = DEXP(EP(J)*X)	SS8G563
CN(1) = .5*AA	SS8G564
CN(3) = -.5/AA	SS8G565
CN(2) = DCOS(EP(J)*X)	SS8G566
CN(4) = DSIN(EP(J)*X)	SS8G567
\$ERU(J,L) = 0.	SS8G568
\$ERW(J,L) = 0.	SS8G569
\$ERDW(J,L) = 0.	SS8G570
DO 60 K=1,4	SS8G571
\$ERU(J,L) = \$ERU(J,L) + CN(K) * C(1,K,1,J)	SS8G572
\$ERW(J,L) = \$ERW(J,L) + CN(K) * C(1,K,3,J)	SS8G573
60 \$ERDW(J,L) = \$ERDW(J,L) + CN(K) * C(2,K,3,J)*EP(J)	SS8G574
IF (INIJ .NE. 5) GO TO 62	SS8G575
IF (IZ .NE. 1) GO TO 62	SS8G576
DO 61 L=1,NRING	SS8G577
\$ERU(1,L) = S3	SS8G578
\$ERW(1,L) = S3*\$RINGS(L)	SS8G579
61 \$ERDW(1,L) = S3	SS8G580
GO TO 90	SS8G581
62 IF (INIJ .NE. 6) GO TO 90	SS8G582
IF (IZ .NE. 0) GO TO 90	SS8G583
DO 63 L=1,NRING	SS8G584
\$ERU(1,L) = 0.	SS8G585
\$ERU(2,L) = -2.*S3	SS8G586
\$ERW(1,L) = 1.	SS8G587
\$ERW(2,L) = S3*(1.-2.*\$RINGS(L))	SS8G588
\$ERDW(1,L) = 0.	SS8G589
63 \$ERDW(2,L) = -2.*S3	SS8G590
90 CONTINUE	SS8G591
RETURN	SS8G592
END	SS8G593

CC = 00594

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SUBROUTINE ELASTC(RETURN,ALFA,BETA,N)                                SS8H000
C THIS SUBROUTINE COMPUTES THE FREQUENCIES (STORED IN EPI ) ) AND  SS8H001
C MODE SHAPES FOR A BEAM WITH ELASTIC MOMENT RESTRAINT AT BOTH ENDS. SS8H002
C THE MODE SHAPES ARE DEFINED BY MEANS OF FOUR CONSTANTS FOR EACH  SS8H003
C FREQUENCY, WHICH ARE RETURNED IN THE ARRAY NAMED RETURN( ). THE  SS8H004
C RESTRAINT IS SPECIFIED IN TERMS OF THE INPUT QUANTITIES ALPHA AND SS8H005
C BETA. AT THE ZERO END, THE RESTRAINED BOUNDARY CONDITION IS THAT  SS8H006
C THE SLOPE = ALFA*CURVATURE. AT THE OTHER END, THE CONSTANT OF    SS8H007
C PROPORTIONALITY IS -BETA. THE ROOTS OF THE CHARACTERISTIC       SS8H008
C EQUATION ARE FOUND IN DOUBLE PRECISION USING AN INTERVAL HALFING SS8H009
C TECHNIQUE. THE INTERVAL IS HALVED 70 TIMES, SO THAT THE FINAL   SS8H010
C INTERVAL IS 1.6/(2**70)                                         SS8H011
C ** REVISED FOR CURVED PANELS - - 8/69                          SS8H012
C IMPLICIT REAL*8(A-H,O-Z), INTEGER(I-N)                         SS8H013
COMMON / BLOCK / AL(1,6,3,10,3,10), EVAL(4,3,10,25),          SS8H014
1 EVQ(4,3,2,25), PZ(11,3,3,10), SS8H015
2 TH(10,4,4,3), ALVA(11,11,2), P(11,10), SS8H016
3 CE(4,10), E(4,4), EP(10), CN(4), CM(4) SS8H017
DIMENSION C(2,4), F(4), RETURN(4,10) SS8H018
BETA = -BETA SS8H019
AA=1. SS8H020
C(1,3)=0. SS8H021
C(1,4)=1. SS8H022
C(2,3)=1. SS8H023
C(2,4)=0. SS8H024
DO 4 L=1,N SS8H025
ELEFT=L SS8H026
ELEFT=ELEFT*3.1415 SS8H027
ERIGHT=ELEFT+1.6 SS8H028
I=0 SS8H029
EPZ=ELEFT SS8H030
GO TO 13 SS8H031
11 ELEFX=PTE SS8H032
12 EPZ=(ELEFT+ ERIGHT)/2. SS8H033
13 I=I+1 SS8H034
G1=ALFA/2./EPZ SS8H035
G4=G1*BETA SS8H036
C(1,1)=G1 SS8H037
C(1,2)= -G1 SS8H038
C(2,1)=G1 SS8H039
C(2,2)=-G1 SS8H040
EX=DEXP(EPZ) SS8H041
EXX=1./EX SS8H042
F(1)=.5*(EX+EXX) SS8H043
F(2)=DCOS(EPZ) SS8H044
F(3)=.5*(EX-EXX) SS8H045
F(4)=DSIN(EPZ) SS8H046
PTE= -G4*2.*(1. -F(1)*F(2)) +(ALFA -BETA) *( F(1)*F(4) - F(3)* SS8H047
1F(2)) + 2.*EPZ*F(3)*F(4) SS8H048
IF(I.LT.2) GO TO 11 SS8H049
IF(PTE*ELEFX)16,17,18 SS8H050
16 ERIGHT = EPZ SS8H051
GO TO 19 SS8H052
18 ELEFT= EPZ SS8H053
ELEFX = PTE SS8H054
19 IF(I.LT.30)GO TO 12 SS8H055

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17 CONTINUE
8 PTE = 0.
  PJA = 0.
  DO 9 J=1,4
    PTE= PTE+ C(2,J)*F(J)
9 PJA= PJA+ C(1,J)*F(J)
  CC=-PJA/PTE
  BB=-(AA+CC)*G1
  DD=-BB
  RETURN(1,L) = DD
  RETURN(2,L) = BB
  RETURN(3,L) = CC
  RETURN(4,L) = AA
  EP(L) = EPZ
4 CONTINUE
  RETURN
  END

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SS8H056
SS8H057
SS8H058
SS8H059
SS8H060
SS8H061
SS8H062
SS8H063
SS8H064
SS8H065
SS8H066
SS8H067
SS8H068
SS8H069
SS8H070
SS8H071
SS8H072

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CC = 00073

	SUBROUTINE PPP (IN, NTERMS, IPOWER, ID, NUVW, IR)	SS8I000
C	THIS SUBROUTINE COMPUTES THE 'P' INTEGRALS--THE INTEGRALS OF A	SS8I001
C	SINGLE MODE SHAPE OR ITS DERIVATIVE. THE INPUT IS IN (THE NUMBER	SS8I002
C	OF SPECIAL CASES PLUS ONE), THE ARRAY CE() WHICH CONTAINS THE	SS8I003
C	FOUR COEFFICIENTS OF THE MODE SHAPE (OR ITS DERIVATIVE) WHICH IS	SS8I004
C	TO BE INTEGRATED. THE OUTPUT IS THE ARRAY P() CONTAINING THE	SS8I005
C	INTEGRALS. THE ROUTINE ALSO NEEDS THE VALUES OF EP(), ENTERED	SS8I006
C	THROUGH COMMON. THE ROUTINE IS IN DOUBLE PRECISION.	SS8I007
C **	REVISED FOR CURVED PANELS -- 8/69	SS8I008
	IMPLICIT REAL*8(A-H,O-Z), INTEGER (I-N)	SS8I009
	COMMON / BLOCK / AL(1,6,3,10,3,10), EVAL(4,3,10,25),	SS8I010
1	EVQ(4,3,2,25), PZ(11,3,3,10),	SS8I011
2	TH(10,4,4,3), ALVA(11,11,2), P(11,10),	SS8I012
3	CE(4,10), E(4,4), EP(10), CN(4), CM(4)	SS8I013
	DIMENSION G(4), C(12,4,10), F(4)	SS8I014
	IPOW2=IPOWER+1	SS8I015
	PETE=3.	SS8I016
	AQB= -1.	SS8I017
	S3=DSQRT(PETE)	SS8I018
	IF(IN.EQ.3) GO TO 60	SS8I019
	IF(IN.EQ.2) GO TO 50	SS8I020
	IF(IN.EQ.1) GO TO 61	SS8I021
C	SPECIAL CASES ARE COMPUTED FIRST.	SS8I022
50	IF(NUVW.EQ.3) GO TO 210	SS8I023
	IF(ID.NE.1) GO TO 230	SS8I024
	IF(NUVW.NE.1) GO TO 210	SS8I025
190	DO 200 I=1, IPOW2	SS8I026
	T=I	SS8I027
	P(I,1) = S3/T	SS8I028
	IF (IR .NE. 1) P(I,1) = 0.00	SS8I029
200	CONTINUE	SS8I030
	GO TO 61	SS8I031
210	DO 220 I=1, IPOW2	SS8I032
	T=I+1	SS8I033
	IF (IR .EQ. 1) P(I,1) = S3/T	SS8I034
	IF (IR .EQ. 2) P(I,1) = S3/(T-1.)	SS8I035
	IF (IR .EQ. 3) P(I,1) = 0.00	SS8I036
220	CONTINUE	SS8I037
	GO TO 61	SS8I038
230	IF(NUVW.EQ.1) GO TO 210	SS8I039
	GO TO 190	SS8I040
60	IF (NUVW.EQ.3) GO TO 310	SS8I041
	IF (ID.NE.1) GO TO 330	SS8I042
	IF (NUVW.NE.1) GO TO 310	SS8I043
290	DO 300 I=1, IPOW2	SS8I044
	T=I	SS8I045
	P(I,1) = 0.00	SS8I046
	P(I,2) = 0.00	SS8I047
	IF (IR .EQ. 1) P(I,2) = -2.00*S3/T	SS8I048
300	CONTINUE	SS8I049
	GO TO 61	SS8I050
310	DO 320 I=1, IPOW2	SS8I051
	T=I	SS8I052
	TT= 1./T -2./(T+1.)	SS8I053
	P(I,1) = 0.00	SS8I054
	P(I,2) = 0.00	SS8I055

IF (IR .EQ. 1) P(I,1) = 1.D0/T	SS8I056
IF (IR .EQ. 1) P(I,2) = S3*TT	SS8I057
IF (IR .EQ. 2) P(I,2) = -2.D0*S3/T	SS8I058
320 CONTINUE	SS8I059
GO TO 61	SS8I060
330 IF (NUVW.EQ.1) GO TO 310	SS8I061
GO TO 290	SS8I062
61 INN= IN	SS8I063
G(1)=1.	SS8I064
G(2)=1.	SS8I065
G(3)=0.	SS8I066
G(4)=0.	SS8I067
DO 1 L=INN, NTERMS	SS8I068
EX=DEXP(EP(L))	SS8I069
SH=.5*(EX-1./EX)	SS8I070
SN=DSIN(EP(L))	SS8I071
CS=DCOS(EP(L))	SS8I072
CH=.5*(EX+1./EX)	SS8I073
DO 2 J=1, IPOW2, 2	SS8I074
C(J,1,L)=CE(3,L)/(EP(L)**J)	SS8I075
C(J,3,L)=CE(1,L)/(EP(L)**J)	SS8I076
C(J+1,1,L)=CE(1,L)/(EP(L)**(J+1))	SS8I077
2 C(J+1,3,L)=CE(3,L)/(EP(L)**(J+1))	SS8I078
IJK=0	SS8I079
DO 10 J=1, IPOW2, 2	SS8I080
IJK= IJK+ 1	SS8I081
C(J,2,L)= (AQB**IJK)*CE(4,L)/(EP(L)**J)	SS8I082
C(J+1,2,L)= (AQB**IJK)*CE(2,L)/(EP(L)**(J+1))	SS8I083
C(J,4,L)=-(AQB** IJK)*CE(2,L)/(EP(L)**J)	SS8I084
10 C(J+1,4,L)= (AQB** (IJK))*CE(4,L)/(EP(L)**(J+1))	SS8I085
F(1)=CH	SS8I086
F(2)=CS	SS8I087
F(3)=SH	SS8I088
F(4)=SN	SS8I089
DO 4 I=1, IPOW2	SS8I090
4 P(I,L)=0.	SS8I091
DO 1 I=1, 4	SS8I092
DO 1 JJ=1, IPOW2	SS8I093
DO 100 KK =1, JJ	SS8I094
100 P(JJ,L) = P(JJ,L) + C(KK,I,L)*F(I)*ALVA(JJ, KK, 1)	SS8I095
1 P(JJ,L) = P(JJ,L) - C(JJ,I,L)*G(I)*ALVA(JJ, JJ, 2)	SS8I096
RETURN	SS8I097
END	SS8I098

CC = 00099

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SUBROUTINE SPECIAL (IPOWER, NTERMS, MNIJ, IDEFNE)      SS8J000
C THIS SUBROUTINE COMPUTES THE 'SPECIAL' CASES INTEGRALS FOR FREE- SS8J001
C FREE AND SIMPLE FREE BEAM SHAPES. THE INPUT NECESSARY IS THE SS8J002
C 'P' INTEGRALS FROM SUBROUTINE PPP FOR THE CONDITION THE SUBROUTINE SS8J003
C IS BEING USED FOR (MNIJ=5 FOR SIMPLE-FREE, 6 FOR FREE-FREE). THE SS8J004
C SUBROUTINE RETURNS THE INTEGRALS IN THE ARRAY ALL. THE MODE SHAPE SS8J005
C EVALUATIONS, AND DERIVATIVE EVALUATIONS, FOR THE SPECIAL CASES ARE SS8J006
C MADE AND RETURNED IN EVQ. THE ROUTINE IS IN DOUBLE PRECISION. SS8J007
C ** REWRITTEN FOR CURVED PANELS - - 8/69 SS8J008
IMPLICIT REAL*8(A-H,O-Z), INTEGER (I-N) SS8J009
COMMON / BLOCK / AL( 6,3,10,3,10), EXAL(4,3,10,25), SS8J010
1 EVAL(4,3,2,25), P(11,3,3,10), SS8J011
2 TH(10,4,4,3), ALVA(11,11,2), PDUM(11,10), SS8J012
3 CE(4,10), E(4,4), EP(10), CN(4), CM(4) SS8J013
COMMON / ARRAYS / $P(11,2,3,3,10), $AL(1,2,6,3,10,3,10), SS8J014
1 $W(10,2,3,10,10) SS8J015
ID=IDEFNE SS8J016
IF(ID.EQ.1) JD=2 SS8J017
IF(ID.EQ.2) JD=1 SS8J018
S3 = DSQRT ( 3.DO ) SS8J019
C THE INTEGRALS ARE EVALUATED FROM HERE TO STATEMENT 1 . SS8J020
I = 1 SS8J021
T=I SS8J022
C SIMPLE - FREE BOUNDARY CONDITION SS8J023
IF (MNIJ.NE.5) GO TO 200 SS8J024
DO 90 K=1,6 SS8J025
DO 90 IUVW=1,3 SS8J026
DO 90 JUVW=1,3 SS8J027
DO 90 M=1, NTERMS SS8J028
AL(K, IUVW, 1, JUVW, M) = 0.DO SS8J029
90 AL(K, IUVW, M, JUVW, 1) = 0.DO SS8J030
AL(1, ID, 1, ID, 1) = 3.DO SS8J031
AL(1, ID, 1, ID, 1) = 1.5DO SS8J032
AL(1, ID, 1, 3, 1) = 1.5DO SS8J033
AL(1, JD, 1, ID, 1) = 1.5DO SS8J034
AL(4, JD, 1, ID, 1) = 3.DO SS8J035
AL(1, JD, 1, JD, 1) = 1.DO SS8J036
AL(2, JD, 1, JD, 1) = 3.DO SS8J037
AL(4, JD, 1, JD, 1) = 1.5DO SS8J038
AL(1, JD, 1, 3, 1) = 1.DO SS8J039
AL(2, JD, 1, 3, 1) = 3.DO SS8J040
AL(4, JD, 1, 3, 1) = 1.5DO SS8J041
AL(1, 3, 1, ID, 1) = 1.5DO SS8J042
AL(4, 3, 1, ID, 1) = 3.DO SS8J043
AL(1, 3, 1, JD, 1) = 1.DO SS8J044
AL(2, 3, 1, JD, 1) = 3.DO SS8J045
AL(4, 3, 1, JD, 1) = 1.5DO SS8J046
AL(1, 3, 1, 3, 1) = 1.DO SS8J047
AL(2, 3, 1, 3, 1) = 3.DO SS8J048
AL(4, 3, 1, 3, 1) = 1.5DO SS8J049
IF ( NTERMS.EQ.1 ) GO TO 101 SS8J050
DO 100 M=2, NTERMS SS8J051
AL(1, ID, 1, ID, M) = S3*P(1,1, ID, M) SS8J052
AL(1, ID, 1, JD, M) = S3*P(1,1, JD, M) SS8J053
AL(1, ID, 1, 3, M) = S3*P(1,1, 3, M) SS8J054
AL(1, ID, M, ID, 1) = S3*P(1,1, ID, M) SS8J055

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AL(4, ID, M, ID, 1)= S3*P(1, 2, ID, M)	SS8J056
AL(5, ID, M, ID, 1)= S3*P(1, 3, ID, M)	SS8J057
AL(1, ID, M, JD, 1)= S3*P(2, 1, ID, M)	SS8J058
AL(2, ID, M, JD, 1)= S3*P(1, 2, ID, M)	SS8J059
AL(4, ID, M, JD, 1)= S3*P(2, 2, ID, M)	SS8J060
AL(5, ID, M, JD, 1)= S3*P(2, 3, ID, M)	SS8J061
AL(6, ID, M, JD, 1)= S3*P(1, 3, ID, M)	SS8J062
AL(1, ID, M, 3 , 1)= S3*P(2, 1, ID, M)	SS8J063
AL(2, ID, M, 3 , 1)= S3*P(1, 2, ID, M)	SS8J064
AL(4, ID, M, 3 , 1)= S3*P(2, 2, ID, M)	SS8J065
AL(5, ID, M, 3 , 1)= S3*P(2, 3, ID, M)	SS8J066
AL(6, ID, M, 3 , 1)= S3*P(1, 3, ID, M)	SS8J067
AL(1, JD, 1, ID, M)= S3*P(2, 1, ID, M)	SS8J068
AL(2, JD, 1, ID, M)= S3*P(1, 2, ID, M)	SS8J069
AL(4, JD, 1, ID, M)= S3*P(1, 1, ID, M)	SS8J070
AL(1, JD, 1, JD, M)= S3*P(2, 1, JD, M)	SS8J071
AL(2, JD, 1, JD, M)= S3*P(1, 2, JD, M)	SS8J072
AL(4, JD, 1, JD, M)= S3*P(1, 1, JD, M)	SS8J073
AL(1, JD, 1, 3 , M)= S3*P(2, 1, 3 , M)	SS8J074
AL(2, JD, 1, 3 , M)= S3*P(1, 2, 3 , M)	SS8J075
AL(4, JD, 1, 3 , M)= S3*P(1, 1, 3 , M)	SS8J076
AL(1, JD, M, ID, 1)= S3*P(1, 1, JD, M)	SS8J077
AL(4, JD, M, ID, 1)= S3*P(1, 2, JD, M)	SS8J078
AL(5, JD, M, ID, 1)= S3*P(1, 3, JD, M)	SS8J079
AL(1, JD, M, JD, 1)= S3*P(2, 1, JD, M)	SS8J080
AL(2, JD, M, JD, 1)= S3*P(1, 2, JD, M)	SS8J081
AL(4, JD, M, JD, 1)= S3*P(2, 2, JD, M)	SS8J082
AL(5, JD, M, JD, 1)= S3*P(2, 3, JD, M)	SS8J083
AL(6, JD, M, JD, 1)= S3*P(1, 3, JD, M)	SS8J084
AL(1, JD, M, 3 , 1)= S3*P(2, 1, JD, M)	SS8J085
AL(2, JD, M, 3 , 1)= S3*P(1, 2, JD, M)	SS8J086
AL(4, JD, M, 3 , 1)= S3*P(2, 2, JD, M)	SS8J087
AL(5, JD, M, 3 , 1)= S3*P(2, 3, JD, M)	SS8J088
AL(6, JD, M, 3 , 1)= S3*P(1, 3, JD, M)	SS8J089
AL(1, 3 , 1, ID, M)= S3*P(2, 1, ID, M)	SS8J090
AL(2, 3 , 1, ID, M)= S3*P(1, 2, ID, M)	SS8J091
AL(4, 3 , 1, ID, M)= S3*P(1, 1, ID, M)	SS8J092
AL(1, 3 , 1, JD, M)= S3*P(2, 1, JD, M)	SS8J093
AL(2, 3 , 1, JD, M)= S3*P(1, 2, JD, M)	SS8J094
AL(4, 3 , 1, JD, M)= S3*P(1, 1, JD, M)	SS8J095
AL(1, 3 , 1, 3 , M)= S3*P(2, 1, 3 , M)	SS8J096
AL(2, 3 , 1, 3 , M)= S3*P(1, 2, 3 , M)	SS8J097
AL(4, 3 , 1, 3 , M)= S3*P(1, 1, 3 , M)	SS8J098
AL(1, 3 , M, ID, 1)= S3*P(1, 1, 3 , M)	SS8J099
AL(4, 3 , M, ID, 1)= S3*P(1, 2, 3 , M)	SS8J100
AL(5, 3 , M, ID, 1)= S3*P(1, 3, 3 , M)	SS8J101
AL(1, 3 , M, JD, 1)= S3*P(2, 1, 3 , M)	SS8J102
AL(2, 3 , M, JD, 1)= S3*P(1, 2, 3 , M)	SS8J103
AL(4, 3 , M, JD, 1)= S3*P(2, 2, 3 , M)	SS8J104
AL(5, 3 , M, JD, 1)= S3*P(2, 3, 3 , M)	SS8J105
AL(6, 3 , M, JD, 1)= S3*P(1, 3, 3 , M)	SS8J106
AL(1, 3 , M, 3 , 1)= S3*P(2, 1, 3 , M)	SS8J107
AL(2, 3 , M, 3 , 1)= S3*P(1, 2, 3 , M)	SS8J108
AL(4, 3 , M, 3 , 1)= S3*P(2, 2, 3 , M)	SS8J109
AL(5, 3 , M, 3 , 1)= S3*P(2, 3, 3 , M)	SS8J110
AL(6, 3 , M, 3 , 1)= S3*P(1, 3, 3 , M)	SS8J111

100 CONTINUE	SS8J112
101 CONTINUE	SS8J113
DO 122 I=1,IPOWER	SS8J114
T = I	SS8J115
\$W(I,ID,1,1,1) = 3./(2.+T)	SS8J116
\$W(I,ID,2,1,1) = 3./T	SS8J117
\$W(I,ID,3,1,1) = 3./(1.+T)	SS8J118
IF (NTERMS.EQ.1) GO TO 125	SS8J119
DO 122 M=2,NTERMS	SS8J120
Z = S3*P(I+1,1,3,M)	SS8J121
\$W(I,ID,1,1,M) = Z	SS8J122
\$W(I,ID,1,M,1) = Z	SS8J123
Z = S3*P(I,2,3,M)	SS8J124
\$W(I,ID,2,1,M) = Z	SS8J125
\$W(I,ID,2,M,1) = Z	SS8J126
\$W(I,ID,3,1,M) = S3*P(I,1,3,M)	SS8J127
\$W(I,ID,3,M,1) = S3*P(I+1,2,3,M)	SS8J128
122 CONTINUE	SS8J129
GO TO 125	SS8J130
C FREE - FREE BOUNDARY CONDITION	SS8J131
200 CONTINUE	SS8J132
DO 205 K=1,6	SS8J133
DO 205 KUVW=1,2	SS8J134
DO 205 IUVW=1,3	SS8J135
DO 205 JUVW=1,3	SS8J136
DO 205 M=1,NTERMS	SS8J137
AL(K, IUVW,KUVW,JUVW,M)=0.DO	SS8J138
AL(K, IUVW,M,JUVW,KUVW)=0.DO	SS8J139
205 CONTINUE	SS8J140
S = S3	SS8J141
T = 2.DO*S3	SS8J142
AL(1,ID,2,ID,2)= 12.DO	SS8J143
AL(1,ID,2,JD,1)= -T	SS8J144
AL(1,ID,2,3,1)= -T	SS8J145
AL(1,JD,1,ID,2)= -T	SS8J146
AL(1,JD,1,JD,1)= 1.DO	SS8J147
AL(1,JD,1,3,1)= 1.DO	SS8J148
AL(4,JD,2,ID,2)= 12.DO	SS8J149
AL(4,JD,2,JD,1)= -T	SS8J150
AL(1,JD,2,JD,2)= 1.DO	SS8J151
AL(2,JD,2,JD,2)= 12.DO	SS8J152
AL(4,JD,2,3,1)= -T	SS8J153
AL(1,JD,2,3,2)= 1.DO	SS8J154
AL(2,JD,2,3,2)= 12.DO	SS8J155
AL(1,3,1,ID,2)= -T	SS8J156
AL(1,3,1,JD,1)= 1.DO	SS8J157
AL(1,3,1,3,1)= 1.DO	SS8J158
AL(4,3,2,ID,2)= 12.DO	SS8J159
AL(4,3,2,JD,1)= -T	SS8J160
AL(1,3,2,JD,2)= 1.DO	SS8J161
AL(2,3,2,JD,2)= 12.DO	SS8J162
AL(4,3,2,3,1)= -T	SS8J163
AL(1,3,2,3,2)= 1.DO	SS8J164
AL(2,3,2,3,2)= 12.DO	SS8J165
DO 210 M=3,NTERMS	SS8J166
AL(1,ID,2,ID,M)= -T*P(1,1,ID,M)	SS8J167

AL(1, ID, 2, JD, M) =	-T*P(1, 1, JD, M)	SS8J168
AL(1, ID, 2, 3, M) =	-T*P(1, 1, 3, M)	SS8J169
AL(1, ID, M, ID, 2) =	-T*P(1, 1, ID, M)	SS8J170
AL(4, ID, M, ID, 2) =	-T*P(1, 2, ID, M)	SS8J171
AL(5, ID, M, ID, 2) =	-T*P(1, 3, ID, M)	SS8J172
AL(1, ID, M, JD, 1) =	P(1, 1, ID, M)	SS8J173
AL(4, ID, M, JD, 1) =	P(1, 2, ID, M)	SS8J174
AL(5, ID, M, JD, 1) =	P(1, 3, ID, M)	SS8J175
AL(1, ID, M, JD, 2) =	S*P(1, 1, ID, M) -T*P(2, 1, ID, M)	SS8J176
AL(2, ID, M, JD, 2) =	-T*P(1, 2, ID, M)	SS8J177
AL(4, ID, M, JD, 2) =	S*P(1, 2, ID, M) -T*P(2, 2, ID, M)	SS8J178
AL(5, ID, M, JD, 2) =	S*P(1, 3, ID, M) -T*P(2, 3, ID, M)	SS8J179
AL(6, ID, M, JD, 2) =	-T*P(1, 3, ID, M)	SS8J180
AL(1, ID, M, 3, 1) =	P(1, 1, ID, M)	SS8J181
AL(4, ID, M, 3, 1) =	P(1, 2, ID, M)	SS8J182
AL(5, ID, M, 3, 1) =	P(1, 3, ID, M)	SS8J183
AL(1, ID, M, 3, 2) =	S*P(1, 1, ID, M) -T*P(2, 1, ID, M)	SS8J184
AL(2, ID, M, 3, 2) =	-T*P(1, 2, ID, M)	SS8J185
AL(4, ID, M, 3, 2) =	S*P(1, 2, ID, M) -T*P(2, 2, ID, M)	SS8J186
AL(5, ID, M, 3, 2) =	S*P(1, 3, ID, M) -T*P(2, 3, ID, M)	SS8J187
AL(6, ID, M, 3, 2) =	-T*P(1, 3, ID, M)	SS8J188
AL(1, JD, 1, ID, M) =	P(1, 1, ID, M)	SS8J189
AL(1, JD, 1, JD, M) =	P(1, 1, JD, M)	SS8J190
AL(1, JD, 1, 3, M) =	P(1, 1, 3, M)	SS8J191
AL(1, JD, 2, ID, M) =	S*P(1, 1, ID, M) -T*P(2, 1, ID, M)	SS8J192
AL(2, JD, 2, ID, M) =	-T*P(1, 2, ID, M)	SS8J193
AL(4, JD, 2, ID, M) =	-T*P(1, 1, ID, M)	SS8J194
AL(1, JD, 2, JD, M) =	S*P(1, 1, JD, M) -T*P(2, 1, JD, M)	SS8J195
AL(2, JD, 2, JD, M) =	-T*P(1, 2, JD, M)	SS8J196
AL(4, JD, 2, JD, M) =	-T*P(1, 1, JD, M)	SS8J197
AL(1, JD, 2, 3, M) =	S*P(1, 1, 3, M) -T*P(2, 1, 3, M)	SS8J198
AL(2, JD, 2, 3, M) =	-T*P(1, 2, 3, M)	SS8J199
AL(4, JD, 2, 3, M) =	-T*P(1, 1, 3, M)	SS8J200
AL(1, JD, M, ID, 2) =	-T*P(1, 1, JD, M)	SS8J201
AL(4, JD, M, ID, 2) =	-T*P(1, 2, JD, M)	SS8J202
AL(5, JD, M, ID, 2) =	-T*P(1, 3, JD, M)	SS8J203
AL(1, JD, M, JD, 1) =	P(1, 1, JD, M)	SS8J204
AL(4, JD, M, JD, 1) =	P(1, 2, JD, M)	SS8J205
AL(5, JD, M, JD, 1) =	P(1, 3, JD, M)	SS8J206
AL(1, JD, M, JD, 2) =	S*P(1, 1, JD, M) -T*P(2, 1, JD, M)	SS8J207
AL(2, JD, M, JD, 2) =	-T*P(1, 2, JD, M)	SS8J208
AL(4, JD, M, JD, 2) =	S*P(1, 2, JD, M) -T*P(2, 2, JD, M)	SS8J209
AL(5, JD, M, JD, 2) =	S*P(1, 3, JD, M) -T*P(2, 3, JD, M)	SS8J210
AL(6, JD, M, JD, 2) =	-T*P(1, 3, JD, M)	SS8J211
AL(1, JD, M, 3, 1) =	P(1, 1, JD, M)	SS8J212
AL(4, JD, M, 3, 1) =	P(1, 2, JD, M)	SS8J213
AL(5, JD, M, 3, 1) =	P(1, 3, JD, M)	SS8J214
AL(1, JD, M, 3, 2) =	S*P(1, 1, JD, M) -T*P(2, 1, JD, M)	SS8J215
AL(2, JD, M, 3, 2) =	-T*P(1, 2, JD, M)	SS8J216
AL(4, JD, M, 3, 2) =	S*P(1, 2, JD, M) -T*P(2, 2, JD, M)	SS8J217
AL(5, JD, M, 3, 2) =	S*P(1, 3, JD, M) -T*P(2, 3, JD, M)	SS8J218
AL(6, JD, M, 3, 2) =	-T*P(1, 3, JD, M)	SS8J219
AL(1, 3, 1, ID, M) =	P(1, 1, ID, M)	SS8J220
AL(1, 3, 1, JD, M) =	P(1, 1, JD, M)	SS8J221
AL(1, 3, 1, 3, M) =	P(1, 1, 3, M)	SS8J222
AL(1, 3, 2, ID, M) =	S*P(1, 1, ID, M) -T*P(2, 1, ID, M)	SS8J223

AL(2,3,2,ID,M)= -T*P(1,2,ID,M)	SS8J224
AL(4,3,2,ID,M)= -T*P(1,1,ID,M)	SS8J225
AL(1,3,2,JD,M)= S*P(1,1,JD,M) -T*P(2,1,JD,M)	SS8J226
AL(2,3,2,JD,M)= -T*P(1,2,JD,M)	SS8J227
AL(4,3,2,JD,M)= -T*P(1,1,JD,M)	SS8J228
AL(1,3,2,3,M)= S*P(1,1,3,M) -T*P(2,1,3,M)	SS8J229
AL(2,3,2,3,M)= -T*P(1,2,3,M)	SS8J230
AL(4,3,2,3,M)= -T*P(1,1,3,M)	SS8J231
AL(1,3,M,ID,2)= -T*P(1,1,3,M)	SS8J232
AL(4,3,M,ID,2)= -T*P(1,2,3,M)	SS8J233
AL(5,3,M,ID,2)= -T*P(1,3,3,M)	SS8J234
AL(1,3,M,JD,1)= P(1,1,3,M)	SS8J235
AL(4,3,M,JD,1)= P(1,2,3,M)	SS8J236
AL(5,3,M,JD,1)= P(1,3,3,M)	SS8J237
AL(1,3,M,JD,2)= S*P(1,1,3,M) -T*P(2,1,3,M)	SS8J238
AL(2,3,M,JD,2)= -T*P(1,2,3,M)	SS8J239
AL(4,3,M,JD,2)= S*P(1,2,3,M) -T*P(2,2,3,M)	SS8J240
AL(5,3,M,JD,2)= S*P(1,3,3,M) -T*P(2,3,3,M)	SS8J241
AL(6,3,M,JD,2)= -T*P(1,3,3,M)	SS8J242
AL(1,3,M,3,1)= P(1,1,3,M)	SS8J243
AL(4,3,M,3,1)= P(1,2,3,M)	SS8J244
AL(5,3,M,3,1)= P(1,3,3,M)	SS8J245
AL(1,3,M,3,2)= S*P(1,1,3,M) -T*P(2,1,3,M)	SS8J246
AL(2,3,M,3,2)= -T*P(1,2,3,M)	SS8J247
AL(4,3,M,3,2)= S*P(1,2,3,M) -T*P(2,2,3,M)	SS8J248
AL(5,3,M,3,2)= S*P(1,3,3,M) -T*P(2,3,3,M)	SS8J249
AL(6,3,M,3,2)= -T*P(1,3,3,M)	SS8J250
210 CONTINUE	SS8J251
DO 236 I=1,IPOWER	SS8J252
T = I	SS8J253
\$W(I,ID,1,1,1) = 1./T	SS8J254
\$W(I,ID,2,1,1) = 0.	SS8J255
\$W(I,ID,3,1,1) = 0.	SS8J256
\$W(I,ID,1,1,2) = S3*(1./T-2./((T+1.))	SS8J257
\$W(I,ID,2,1,2) = 0.	SS8J258
\$W(I,ID,3,1,2) = 0.	SS8J259
\$W(I,ID,1,2,1) = S3*(1./T-2./((T+1.))	SS8J260
\$W(I,ID,2,2,1) = 0.	SS8J261
\$W(I,ID,3,2,1) = -2.*S3/T	SS8J262
\$W(I,ID,1,2,2) = 3.*(1./T-4./((T+1.))+4./((T+2.))	SS8J263
\$W(I,ID,2,2,2) = 12./T	SS8J264
\$W(I,ID,3,2,2) = -6.*(1./T-2./((T+1.))	SS8J265
IF (M.LE.2) GO TO 236	SS8J266
DO 235 M=3,NTERMS	SS8J267
\$W(I,ID,1,1,M) = P(I,1,3,M)	SS8J268
\$W(I,ID,2,1,M) = 0.	SS8J269
\$W(I,ID,3,1,M) = 0.	SS8J270
\$W(I,ID,1,M,1) = P(I,1,3,M)	SS8J271
\$W(I,ID,2,M,1) = 0.	SS8J272
\$W(I,ID,3,M,1) = P(I,2,3,M)	SS8J273
\$W(I,ID,1,2,M) = S3*(P(I,1,3,M)-2.*P(I+1,1,3,M))	SS8J274
\$W(I,ID,2,2,M) = -2.*S3*P(I,2,3,M)	SS8J275
\$W(I,ID,3,2,M) = -2.*S3*P(I,1,3,M)	SS8J276
\$W(I,ID,1,M,2) = S3*(P(I,1,3,M)-2.*P(I+1,1,3,M))	SS8J277
\$W(I,ID,2,M,2) = -2.*S3*P(I,2,3,M)	SS8J278
235 \$W(I,ID,3,M,2) = S3*(P(I,2,3,M)-2.*P(I+1,2,3,M))	SS8J279

236	CONTINUE	SS8J280
125	CONTINUE	SS8J281
C	CALCULATE MODE SHAPES AND DERIVATIVES	SS8J282
	DO 400 I=1,25	SS8J283
	W=I-1	SS8J284
	W=W/24.	SS8J285
	IF(MNIJ.NE.5) GO TO 300	SS8J286
	EVAL(1,3,1,I)= S3*W	SS8J287
	EVAL(2,3,1,I)= S3	SS8J288
	EVAL(1,JD,1,I)= S3*W	SS8J289
	EVAL(2,JD,1,I)= S3	SS8J290
	EVAL(1,ID,1,I)= S3	SS8J291
	EVAL(2,ID,1,I)= 0.00	SS8J292
	GO TO 400	SS8J293
300	EVAL(1,3,1,I)= 1.00	SS8J294
	EVAL(2,3,1,I)= 0.00	SS8J295
	EVAL(1,3,2,I)= S3*(1.00-2.00*W)	SS8J296
	EVAL(2,3,2,I)= -2.00*S3	SS8J297
	EVAL(1,JD,1,I)= 1.00	SS8J298
	EVAL(2,JD,1,I)= 0.00	SS8J299
	EVAL(1,JD,2,I)= S3*(1.00-2.00*W)	SS8J300
	EVAL(2,JD,2,I)= -2.00*S3	SS8J301
	EVAL(1,ID,1,I)= 0.	SS8J302
	EVAL(2,ID,1,I)= 0.00	SS8J303
	EVAL(1,ID,2,I)= -2.00*S3	SS8J304
	EVAL(2,ID,2,I)= 0.00	SS8J305
400	CONTINUE	SS8J306
	INNN=MNIJ-4	SS8J307
	DO 500 L=1,25	SS8J308
	DO 500 J=1,INNN	SS8J309
	DO 500 K=3,4	SS8J310
	DO 500 I=1,3	SS8J311
500	EVAL(K,I,J,L) = 0.00	SS8J312
	RETURN	SS8J313
	END	SS8J314

CC = 00315

	SUBROUTINE SEARCH (KEY1, KEY2, M1,M2,MM,KM,LM,IM,NM,FMIN)	SS8K000
C **		SS8K001
C **	THIS SUBROUTINE KEEPS TRACK OF THE MINIMUM MARGIN OF SAFETY.	SS8K002
C **		SS8K003
	DIMENSION F(15,25,25)	SS8K004
	COMMON / ARRAYS / F	SS8K005
C		SS8K006
	FH = FMIN	SS8K007
	DO 10 M=M1,M2	SS8K008
	DO 10 K=1,25	SS8K009
	DO 10 L=1,25	SS8K010
	IF (FH .LT. F(M,K,L)) GO TO 10	SS8K011
	FH = F(M,K,L)	SS8K012
	MH = M	SS8K013
	KH = K	SS8K014
	LH = L	SS8K015
10	CONTINUE	SS8K016
	IF (FMIN .LE. FH) RETURN	SS8K017
	FMIN = FH	SS8K018
	MM = MH	SS8K019
	KM = KH	SS8K020
	LM = LH	SS8K021
	IM = KEY1	SS8K022
	NM = KEY2	SS8K023
	RETURN	SS8K024
	END	SS8K025

CC = 00026

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SUBROUTINE ASEMBL
C
C ** THIS SUBROUTINE ASSEMBLES THE POTENTIAL ENERGY MATRIX ( V ),
C ** THE KINETIC ENERGY MATRIX ( TT ), THE EDGE LOADS MATRIX ( U ),
C ** AND THE LATERAL LOADS VECTOR ( Q ).
C
  DIMENSION V(150,150), TT(150,150), VHOLD(150,150)
  DIMENSION U(50,50), Q(150), S(150)
  DIMENSION QHOLD(150), SHOLD(150)
  DIMENSION AL(2,6,3,10,3,10), EVAL(4,2,3,10,25),
1 $W(10,2,3,10,10), P(11,2,3,3,10)
  DIMENSION A(3,3), B(3,3), D(3,3)
  DIMENSION YBARS(100), ZBARS(100), AS(100),
1 XIYYS(100), XIYZS(100), XIZZS(100), ES(100),
2 GJS(100), RHOS(100), PAXS(100),
3 XBARR(50), ZBARR(50), AR(50),
4 XIXXR(50), XIXZR(50), XIZZR(50), ER(50),
5 GJR(50), RHOR(50), PAXR(50),
A PMASS(50), IPWW(50), IPWY(50),
B PX(10,10), PY(10,10), PXY(10,10),
C PC(50), IPXX(50), IPYY(50),
D FC(50), IFXX(50), IFYY(50),
E ITAGCM(50), QQ(10,10),
F PLMOM(50), ITAGLM(50), IDISLM(50),
G PKC(50), IGSPRX(50), IGSPRY(50),
H PLINE(50), IDISLS(50), ITAGLS(50)
  DIMENSION ITIME(12), TIME(50)
  DIMENSION X(50), Y(50)
C
  COMMON U
  COMMON / BLOCK / TT
  COMMON / ARRAYS / P, AL, $W
  COMMON / VALUES / EVAL
  COMMON / CNTROL / IFLAGD, IFLAGB, IFLAGW, IBCX, IBCY,
1 N1, IEDGE, IREACT, N2(3), IELAST, INTPRT
  COMMON / NUMBER / NPLYS, NTUX, NTVX, NTWX, NTUY,
1 NTVY, NTWY, NMODES, NSTRNG, NRING,
2 NPNX, NPNY, NQTX, NQTY, NPTLDS,
3 NPTMOM, NLNMOM, NLMASS, NPTSUP, NLNSPR,
4 MATSIZ, MUVSIZ, MWSIZ
  COMMON / GEOM / AA, BB, RR, ALFAX, ALFAY,
1 BETAX, BETAY
  COMMON / $TIME / TIME, ITIME
  COMMON / ABD / A, B, D, RHAB
  COMMON / PARAM / YBARS, ZBARS, AS, XIYYS, XIYZS,
1 XIZZS, ES, GJS, PAXS,
3 XBARR, ZBARR, AR, XIXXR, XIXZR,
4 XIZZR, ER, GJR, RHOR, PAXR,
6 PMASS, IPWW, IPWY, PX, PY,
7 PXY, PC, IPXX, IPYY, FC,
8 IFXX, IFYY, ITAGCM, QQ, PLMOM,
9 ITAGLM, IDISLM, PKC, IGSPRX, IGSPRY,
A PLINE, IDISLS, ITAGLS
  COMMON / STFVAL / ESV(10,100), ESW(10,100), ESDW(10,100),
1 ERU(10,50), ERW(10,50), ERDW(10,50)
  EQUIVALENCE ( VHOLD(1),P(1) )

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EQUIVALENCE (QHOLD(1), YBARS(1)), (SHOLD(1), ZBARS(51))	SS8L056
DATA NAMEV/'V ' /,NAMETT/'TT ' /,NAMEU/'U ' /,NAMEQ/'Q ' /	SS8L057
DATA NAMES / 'S ' /	SS8L058
C	SS8L059
ITHERY = 2	SS8L060
IF (INTPT .NE. 1) GO TO 1001	SS8L061
IF (ITHERY .EQ. 1) WRITE (6,11)	SS8L062
11 FORMAT ('O USING NOVOZHILOV SHELL THEORY')	SS8L063
IF (ITHERY .EQ. 2) WRITE (6,12)	SS8L064
12 FORMAT ('O USING VLASOV SHELL THEORY')	SS8L065
WRITE (6,4)	SS8L066
4 FORMAT ('OTHE AL INTEGRALS FOLLOW')	SS8L067
DO 990 I=1,2	SS8L068
DO 990 I1=1,3	SS8L069
DO 900 J1=1,3	SS8L070
IF (I .EQ. 2) GO TO 7	SS8L071
IF (I1 .EQ. 1) M1L = NTUX	SS8L072
IF (I1 .EQ. 2) M1L = NTVX	SS8L073
IF (I1 .EQ. 3) M1L = NTWX	SS8L074
IF (J1 .EQ. 1) M2L = NTUX	SS8L075
IF (J1 .EQ. 2) M2L = NTVX	SS8L076
IF (J1 .EQ. 3) M2L = NTWX	SS8L077
GO TO 8	SS8L078
7 IF (I1 .EQ. 1) M1L = NTUY	SS8L079
IF (I1 .EQ. 2) M1L = NTVY	SS8L080
IF (I1 .EQ. 3) M1L = NTWY	SS8L081
IF (J1 .EQ. 1) M2L = NTUY	SS8L082
IF (J1 .EQ. 2) M2L = NTVY	SS8L083
IF (J1 .EQ. 3) M2L = NTWY	SS8L084
8 CONTINUE	SS8L085
DO 3 K1=1,6	SS8L086
WRITE (6,1) I,K1,I1,J1	SS8L087
1 FORMAT ('O',4I2)	SS8L088
DO 3 M1=1,M1L	SS8L089
WRITE (6,2) (AL(I,K1,I1,M1,J1,M2), M2=1,M2L)	SS8L090
2 FORMAT (' ',1P10E12.5)	SS8L091
3 CONTINUE	SS8L092
930 CONTINUE	SS8L093
DO 930 ID1=1,4	SS8L094
WRITE (6,931) ID1,I,I1	SS8L095
931 FORMAT ('OEVAL ',3I2)	SS8L096
DO 930 LL=1,25	SS8L097
930 WRITE (6,2) (EVAL(ID1,I,I1,M1,LL), M1=1,M1L)	SS8L098
IF (I.EQ.1) MAXP = MAXO (NPNX,NQTX,1)	SS8L099
IF (I.EQ.2) MAXP = MAXO (NPNY,NQTY,1)	SS8L100
DO 940 IP=1,MAXP	SS8L101
DO 940 K2=1,3	SS8L102
WRITE(6,941) IP,I,K2,I1	SS8L103
941 FORMAT ('OP INTEGRALS ',4I2)	SS8L104
940 WRITE (6,2) (P(IP,I,K2,I1,M1), M1=1,M1L)	SS8L105
990 CONTINUE	SS8L106
WRITE (6,901)	SS8L107
901 FORMAT ('OTHE W**2 INTEGRALS FOLLOW')	SS8L108
DO 920 I=1,2	SS8L109
IF (I.EQ.2) GO TO 902	SS8L110
MAXP = MAXO (NPNX,NQTX,1)	SS8L111

M3L = NTWX	SS8L112
L3L = NTWX	SS8L113
GO TO 903	SS8L114
902 MAXP = MAXO (NPNY,NQTY,1)	SS8L115
M3L = NTWX	SS8L116
L3L = NTWX	SS8L117
903 DO 920 IP=1,MAXP	SS8L118
DO 920 K2=1,3	SS8L119
WRITE (6,1) IP,I,K2	SS8L120
DO 920 L3=1,L3L	SS8L121
920 WRITE (6,2) (\$W(IP,I,K2,L3,M3),M3=1,M3L)	SS8L122
1001 CONTINUE	SS8L123
DO 5 I=1,50	SS8L124
X(I)=0.	SS8L125
5 Y(I)=0.	SS8L126
DO 6 I=1,MWSIZ	SS8L127
DO 6 J=1,MWSIZ	SS8L128
6 U(I,J) = 0.	SS8L129
DO 10 I = 1,MATSIZ	SS8L130
Q(I) = 0.	SS8L131
S(I) = 0.	SS8L132
DO 10 J = 1,MATSIZ	SS8L133
V(I,J) = 0.	SS8L134
TT(I,J) = 0.	SS8L135
10 CONTINUE	SS8L136
L = 1	SS8L137
K = 1	SS8L138
A1 = 1./AA	SS8L139
B1 = 1./BB	SS8L140
R1 = 1./RR	SS8L141
A1B = A1*BB	SS8L142
AB1 = AA*B1	SS8L143
A1BR1 = A1B*R1	SS8L144
AB1R1 = AB1*R1	SS8L145
BR1 = BB*R1	SS8L146
AR1 = AA*R1	SS8L147
A2B = A1B*A1	SS8L148
AB2 = AB1*B1	SS8L149
B1R2 = B1*R1*R1	SS8L150
R2 = R1*R1	SS8L151
BR2 = BR1*R1	SS8L152
AR2 = AR1*R1	SS8L153
A1R1 = A1*R1	SS8L154
A2BR1 = A2B*R1	SS8L155
AB2R1 = AB2*R1	SS8L156
B1R1 = B1*R1	SS8L157
TBR2 = 2.*BR2	SS8L158
ABR2 = AA*BR2	SS8L159
A3B = A2B/AA	SS8L160
A1B1 = A1*B1	SS8L161
A2 = A1*A1	SS8L162
AB3 = AB2/BB	SS8L163
B2 = B1*B1	SS8L164
B3 = B2*B1	SS8L165
AB = AA*BB	SS8L166
A1B1R1 = A1*B1R1	SS8L167

A1B2 = A1B1*B1	SS8L168
A2B1 = A1*A1B1	SS8L169
A3 = A1*A2	SS8L170
AB1R2 = AB1*R2	SS8L171
A1BR2 = A1B*R2	SS8L172
A2BR2 = A2B*R2	SS8L173
ABR1 = AA*BR1	SS8L174
AR3 = AR2 * R1	SS8L175
BR3 = BR2 * R1	SS8L176
ABR3 = ABR2 * R1	SS8L177
ABR4 = ABR3 * R1	SS8L178
CALL STATUS (ITIME)	SS8L179
TIME(5) = .01*ITIME(8)	SS8L180
DO 1000 IP = 1,3	SS8L181
DO 1000 IQ = 1,3	SS8L182
IF (IP .EQ. 1) NTLI = NTUX	SS8L183
IF (IP .EQ. 1) NTLJ = NTUY	SS8L184
IF (IP .EQ. 2) NTLI = NTVX	SS8L185
IF (IP .EQ. 2) NTLJ = NTVY	SS8L186
IF (IP .EQ. 3) NTLI = NTWX	SS8L187
IF (IP .EQ. 3) NTLJ = NTWY	SS8L188
IF (IQ .EQ. 1) NTLM = NTUX	SS8L189
IF (IQ .EQ. 1) NTLN = NTUY	SS8L190
IF (IQ .EQ. 2) NTLM = NTVX	SS8L191
IF (IQ .EQ. 2) NTLN = NTVY	SS8L192
IF (IQ .EQ. 3) NTLM = NTWX	SS8L193
IF (IQ .EQ. 3) NTLN = NTWY	SS8L194
DO 1000 I = 1,NTLI	SS8L195
DO 1000 J = 1,NTLJ	SS8L196
DO 1000 M = 1,NTLM	SS8L197
DO 1000 N = 1,NTLN	SS8L198
IF (IP .EQ. 1) II = (I-1)*NTUY + J	SS8L199
IF (IP .EQ. 2) II = NTUX*NTUY + (I-1)*NTVY + J	SS8L200
IF (IP .EQ. 3) II = NTUX*NTUY + NTVX*NTVY + (I-1)*NTWY + J	SS8L201
IF (IQ .EQ. 1) JJ = (M-1)*NTUY + N	SS8L202
IF (IQ .EQ. 2) JJ = NTUX*NTUY + (M-1)*NTVY + N	SS8L203
IF (IQ .EQ. 3) JJ = NTUX*NTUY + NTVX*NTVY + (M-1)*NTWY + N	SS8L204
KK = II -MUVSIZ	SS8L205
LL = JJ -MUVSIZ	SS8L206
IF (IP .GT. IQ) GO TO 580	SS8L207
IF (IP .EQ. 1 .AND. IQ .EQ. 1) GO TO 20	SS8L208
IF (IP .EQ. 1 .AND. IQ .EQ. 2) GO TO 100	SS8L209
IF (IP .EQ. 1 .AND. IQ .EQ. 3) GO TO 160	SS8L210
IF (IP .EQ. 2 .AND. IQ .EQ. 2) GO TO 220	SS8L211
IF (IP .EQ. 2 .AND. IQ .EQ. 3) GO TO 310	SS8L212
IF (IP .EQ. 3 .AND. IQ .EQ. 3) GO TO 370	SS8L213
20 X(1) = AL(1,2,1,I,1,M) * AL(2,1,1,J,1,N)	SS8L214
X(2) = AL(1,4,1,I,1,M) * AL(2,4,1,N,1,J)	SS8L215
X(3) = AL(1,4,1,M,1,I) * AL(2,4,1,J,1,N)	SS8L216
X(4) = AL(1,1,1,I,1,M) * AL(2,2,1,J,1,N)	SS8L217
Y(1) = A(1,1) * A1B * X(1) + A(1,3) * (X(2) + X(3))	SS8L218
1 + A(3,3) * AB1 * X(4)	SS8L219
V(II,JJ) = V(II,JJ) + Y(1)	SS8L220
IF (ITHERY .EQ. 2) V(II,JJ) = V(II,JJ) - B(1,3) * R1 * (X(2)	SS8L221
1 + X(3)) - 2.* B(3,3) * AB1R1 * X(4) + D(3,3) * AB1R2 * X(4)	SS8L222
IF (NSTRNG .EQ. 0) GO TO 30	SS8L223

DO 30 L=1,NSTRNG	SS8L224
V(II,JJ) = V(II,JJ) + A1 * ES(L) * AS(L) * AL(1,2,1,I,1,M)	SS8L225
1 * ESW(J,L) * ESW(N,L)	SS8L226
30 CONTINUE	SS8L227
IF (NRING .EQ. 0) GO TO 40	SS8L228
DO 40 K=1,NRING	SS8L229
V(II,JJ) = V(II,JJ) + B3 * ER(K) * XIZZR(K) * AL(2,3,1,J,1,N)	SS8L230
1 * ERU(I,K) * ERU(M,K)	SS8L231
40 CONTINUE	SS8L232
IF (IFLAGD .EQ. 0) GO TO 70	SS8L233
TT(II,JJ) = RHAB * AL(1,1,1,I,1,M) * AL(2,1,1,J,1,N)	SS8L234
IF (NSTRNG .EQ. 0) GO TO 50	SS8L235
DO 50 L=1,NSTRNG	SS8L236
TT(II,JJ) = TT(II,JJ) + RHOS(L) * AS(L) * AL(1,1,1,I,1,M) * AA	SS8L237
1 * ESW(J,L) * ESW(N,L)	SS8L238
50 CONTINUE	SS8L239
IF (NRING .EQ. 0) GO TO 60	SS8L240
DO 60 K=1,NRING	SS8L241
TT(II,JJ) = TT(II,JJ) + RHOR(K) * (BB * AR(K) * AL(2,1,1,J,1,N)	SS8L242
1 + XIZZR(K) * B1 * AL(2,2,1,J,1,N))	SS8L243
2 * ERU(I,K) * ERU(M,K)	SS8L244
60 CONTINUE	SS8L245
IF (NLMASS .EQ. 0) GO TO 70	SS8L246
DO 70 L=1,NLMASS	SS8L247
TT(II,JJ) = TT(II,JJ) + PMASS(L) * EVAL(1,1,1,I,IPWW(L)) *	SS8L248
1EVAL(1,2,1,J,IPWY(L))*EVAL(1,1,1,M,IPWW(L))*EVAL(1,2,1,N,IPWY(L))	SS8L249
70 CONTINUE	SS8L250
IF (IFLAGW .EQ. 0) GO TO 1000	SS8L251
IF (JJ .GT. 1) GO TO 1000	SS8L252
IF (IEDGE .EQ. 0) GO TO 75	SS8L253
IF (NSTRNG .EQ. 0) GO TO 72	SS8L254
DO 72 L=1,NSTRNG	SS8L255
S(II) = S(II) - PAXS(L) * P(1,1,2,1,I) * ESW(J,L)	SS8L256
72 CONTINUE	SS8L257
IF (NRING .EQ. 0) GO TO 73	SS8L258
DO 73 K=1,NRING	SS8L259
S(II) = S(II) - PAXR(K) * XBARR(K) * P(1,2,3,1,J) * ERU(I,K)	SS8L260
73 CONTINUE	SS8L261
DO 74 K=1,NPNX	SS8L262
DO 74 L=1,NPNY	SS8L263
74 S(II) = S(II) - BB * PX (K,L) * P(K,1,2,1,I) * P(L,2,1,1,J)	SS8L264
1 - AA * PXY(K,L) * P(K,1,1,1,I) * P(L,2,2,1,J)	SS8L265
75 IF (NPTMOM .EQ. 0) GO TO 80	SS8L266
DO 80 L=1,NPTMOM	SS8L267
IF (ITAGCM(L) .EQ. 1) GO TO 80	SS8L268
Q(II) = Q(II) - R1 * FC(L) * EVAL(1,1,1,I,IFXX(L))	SS8L269
1 * EVAL(1,2,1,J,IFYY(L))	SS8L270
80 CONTINUE	SS8L271
IF (NLNMOM .EQ. 0) GO TO 1000	SS8L272
DO 90 L=1,NLNMOM	SS8L273
IF (ITAGLM(L) .EQ. 1) GO TO 90	SS8L274
Q(II) = Q(II) - BR1 * PLMOM(L) * EVAL(1,1,1,I,IDISLM(L))	SS8L275
1 * P(1,2,1,1,J)	SS8L276
90 CONTINUE	SS8L277
GO TO 1000	SS8L278
100 X(5) = AL(1,4,1,I,2,M) * AL(2,4,2,N,1,J)	SS8L279

X(6) =	AL(1,2,1,I,2,M) * AL(2,1,1,J,2,N)	SS8L280
X(7) =	AL(1,1,1,I,2,M) * AL(2,2,1,J,2,N)	SS8L281
X(8) =	AL(1,4,2,M,1,I) * AL(2,4,1,J,2,N)	SS8L282
Y(2) = A(1,2) * X(5) + A(1,3) * A1B * X(6)		SS8L283
1 + A(2,3) * AB1 * X(7) + A(3,3) * X(8)		SS8L284
IF (ITHERY .NE. 1) GO TO 105		SS8L285
Y(3) = B(1,2) * R1 * X(5) + 2. * B(1,3) * A1BR1 * X(6)		SS8L286
1 + B(2,3) * AB1R1 * X(7) + 2. * B(3,3) * R1 * X(8)		SS8L287
GO TO 110		SS8L288
105 Y(3) = B(1,3) * A1BR1 * X(6) - B(2,3) * AB1R1 * X(7)		SS8L289
1 - D(3,3) * R2 * X(8)		SS8L290
110 V(II,JJ) = V(II,JJ) + Y(2) + Y(3)		SS8L291
IF (NSTRNG .EQ. 0) GO TO 120		SS8L292
DO 120 L=1,NSTRNG		SS8L293
V(II,JJ) = V(II,JJ) - A2 * ES(L) * AS(L) * YBARS(L)		SS8L294
1 * AL(1,6,2,M,1,I) * ESW(J,L) * ESV(N,L)		SS8L295
120 CONTINUE		SS8L296
IF (NRING .EQ. 0) GO TO 130		SS8L297
DO 130 K=1,NRING		SS8L298
V(II,JJ) = V(II,JJ) - B2 * ER(K) * AR(K) * XBARR(K)		SS8L299
2 * AL(2,6,1,J,2,N) * ERU(I,K) * ERW(M,K)		SS8L300
130 CONTINUE		SS8L301
IF (IFLAGD .EQ. 0) GO TO 1000		SS8L302
IF (NSTRNG .EQ. 0) GO TO 140		SS8L303
DO 140 L=1,NSTRNG		SS8L304
TT(II,JJ) = TT(II,JJ) - RHOS(L) * AS(L) * YBARS(L)		SS8L305
1 * AL(1,4,2,M,1,I) * ESW(J,L) * ESV(N,L)		SS8L306
140 CONTINUE		SS8L307
IF (NRING .EQ. 0) GO TO 1000		SS8L308
DO 150 K=1,NRING		SS8L309
TT(II,JJ) = TT(II,JJ) - RHOR(K) * AR(K) * XBARR(K)		SS8L310
2 * AL(2,4,1,J,2,N) * ERU(I,K) * ERW(M,K)		SS8L311
150 CONTINUE		SS8L312
GO TO 1000		SS8L313
160 X(9) =	AL(1,4,1,I,3,M) * AL(2,1,1,J,3,N)	SS8L314
X(10) =	AL(1,1,1,I,3,M) * AL(2,4,1,J,3,N)	SS8L315
X(11) =	AL(1,6,3,M,1,I) * AL(2,1,1,J,3,N)	SS8L316
X(12) =	AL(1,4,1,I,3,M) * AL(2,5,3,N,1,J)	SS8L317
X(13) =	AL(1,2,1,I,3,M) * AL(2,4,3,N,1,J)	SS8L318
X(14) =	AL(1,5,3,M,1,I) * AL(2,4,1,J,3,N)	SS8L319
X(15) =	AL(1,1,1,I,3,M) * AL(2,6,3,N,1,J)	SS8L320
X(16) =	AL(1,4,3,M,1,I) * AL(2,2,1,J,3,N)	SS8L321
Y(4) = A(1,2) * BR1 * X(9) + A(2,3) * AR1 * X(10)		SS8L322
IF (ITHERY .NE. 1) GO TO 165		SS8L323
Y(5) = -B(1,1) * A2B * X(11) - B(1,2) * B1 * X(12)		SS8L324
1 - B(1,3) * A1 * (2. * X(13) + X(14))		SS8L325
2 - B(2,3) * AB2 * X(15) - 2. * B(3,3) * B1 * X(16)		SS8L326
GO TO 170		SS8L327
165 Y(5) = - B(1,1) * A2B * X(11) - B(1,2) * (BR2 * X(9) + B1 * X(12))		SS8L328
1 - B(1,3) * A1 * (2. * X(13) + X(14)) - B(2,3) * (2. * AR2		SS8L329
2 * X(10) + AB2 * X(15)) - 2. * B(3,3) * B1 * X(16)		SS8L330
3 + D(1,3) * A1R1 * X(14) + D(2,3) * (AR3 * X(10)		SS8L331
4 + AB2R1 * X(15)) + 2. * D(3,3) * B1R1 * X(16)		SS8L332
170 V(II,JJ) = V(II,JJ) + Y(4) + Y(5)		SS8L333
IF (NSTRNG .EQ. 0) GO TO 180		SS8L334
DO 180 L=1,NSTRNG		SS8L335

V(II,JJ) = V(II,JJ) - ES(L) * AS(L) * ZBARS(L) * A2	SS8L336
1 * AL(1,6,3,M,1,I) * ESW(J,L) * ESW(N,L)	SS8L337
180 CONTINUE	SS8L338
IF (NRING .EQ. 0) GO TO 190	SS8L339
DO 190 K=1,NRING	SS8L340
V(II,JJ) = V(II,JJ) + ERU(I,K) * ER(K) * (ERW(M,K) * (XIXZR(K)	SS8L341
1 * B3 * AL(2,3,1,J,3,N) - AR(K) * XBARR(K) * B1R1	SS8L342
2 * AL(2,5,1,J,3,N)) - XIZZR(K) * A1B1R1 * ERDW(M,K)	SS8L343
3 * AL(2,5,1,J,3,N))	SS8L344
190 CONTINUE	SS8L345
IF (IFLAGD .EQ. 0) GO TO 1000	SS8L346
IF (NSTRNG .EQ. 0) GO TO 200	SS8L347
DO 200 L=1,NSTRNG	SS8L348
TT(II,JJ) = TT(II,JJ) - RHOS(L) * AS(L) * ZBARS(L)	SS8L349
1 * AL(1,4,3,M,1,I) * ESW(J,L) * ESW(N,L)	SS8L350
200 CONTINUE	SS8L351
IF (NRING .EQ. 0) GO TO 1000	SS8L352
DO 210 K=1,NRING	SS8L353
TT(II,JJ) = TT(II,JJ) + RHOR(K) * ERU(I,K) * (-ZBARR(K) * A1B	SS8L354
1 * AR(K) * ERDW(M,K) * AL(2,1,1,J,3,N) + B1 * XIXZR(K)	SS8L355
2 * AL(2,2,1,J,3,N) * ERW(M,K))	SS8L356
210 CONTINUE	SS8L357
GO TO 1000	SS8L358
220 X(17) = AL(1,1,2,I,2,M) * AL(2,2,2,J,2,N)	SS8L359
X(18) = AL(1,4,2,I,2,M) * AL(2,4,2,N,2,J)	SS8L360
X(19) = AL(1,4,2,M,2,I) * AL(2,4,2,J,2,N)	SS8L361
X(20) = AL(1,2,2,I,2,M) * AL(2,1,2,J,2,N)	SS8L362
Y(6) = A(2,2) * AB1 * X(17) + A(2,3) * (X(18) + X(19))	SS8L363
1 + A(3,3) * A1B * X(20)	SS8L364
IF (ITHERY .NE. 1) GO TO 225	SS8L365
Y(7) = 2. * B(2,2) * AB1R1 * X(17) + 3. * B(2,3) * R1 * (X(18)	SS8L366
1 + X(19)) + 4. * B(3,3) * A1BR1 * X(20)	SS8L367
Y(8) = D(2,2) * AB1R2 * X(17) + 2. * D(2,3) * R2 * (X(18)+X(19)	SS8L368
1 + 4. * D(3,3) * A1BR2 * X(20)	SS8L369
GO TO 230	SS8L370
225 Y(7) = B(2,3) * R1 * (X(18) + X(19)) + 2. * B(3,3)*A1BR1*X(20)	SS8L371
Y(8) = D(3,3) * A1BR2 * X(20)	SS8L372
230 V(II,JJ) = V(II,JJ) + Y(6) + Y(7) + Y(8)	SS8L373
IF (NSTRNG .EQ. 0) GO TO 240	SS8L374
DO 240 L=1,NSTRNG	SS8L375
V(II,JJ) = V(II,JJ) + ES(L) * XIZZS(L) * A3 * AL(1,3,2,I,2,M)	SS8L376
1 * ESV(J,L) * ESV(N,L)	SS8L377
240 CONTINUE	SS8L378
IF (NRING .EQ. 0) GO TO 250	SS8L379
DO 250 K=1,NRING	SS8L380
V(II,JJ) = V(II,JJ) + ER(K) * AR(K) * B1 * AL(2,2,2,J,2,N)	SS8L381
1 * ERW(I,K) * ERW(M,K)	SS8L382
250 CONTINUE	SS8L383
IF (IFLAGD .EQ. 0) GO TO 280	SS8L384
TT(II,JJ) = TT(II,JJ) + RHAB * AL(1,1,2,I,2,M) * AL(2,1,2,J,2,N)	SS8L385
IF (NSTRNG .EQ. 0) GO TO 260	SS8L386
DO 260 L=1,NSTRNG	SS8L387
TT(II,JJ) = TT(II,JJ) + RHOS(L) * ESV(J,L)*ESV(N,L)*(AA*AS(L)	SS8L388
2 * AL(1,1,2,I,2,M) + A1 * XIZZS(L) * AL(1,2,2,I,2,M))	SS8L389
260 CONTINUE	SS8L390
IF (NRING .EQ. 0) GO TO 270	SS8L391

DO 270 K=1,NRING	SS8L392	
TT(II,JJ) = TT(II,JJ) + RHOR(K) * AR(K) * BB * AL(2,1,2,J,2,N)	SS8L393	
1 * ERW(I,K) * ERW(M,K)	SS8L394	
270 CONTINUE	SS8L395	
IF (NLMASS .EQ. 0) GO TO 280	SS8L396	
DO 280 K=1,NLMASS	SS8L397	
TT(II,JJ) = TT(II,JJ) + PMASS(K) * EVAL(1,1,2,I,IPWW(K)) *	SS8L398	
1EVAL(1,2,2,J,IPWY(K))*EVAL(1,1,2,M,IPWW(K))*EVAL(1,2,2,N,IPWY(K))	SS8L399	
280 CONTINUE	SS8L400	
IF (IFLAGW .EQ. 0) GO TO 1000	SS8L401	
IF (JJ .GT. NTUX*NTUY + 1) GO TO 1000	SS8L402	
IF (IEDGE .EQ. 0) GO TO 285	SS8L403	
IF (NSTRNG .EQ. 0) GO TO 282	SS8L404	
DO 282 L=1,NSTRNG	SS8L405	
S(II) = S(II) + PAXS(L) * A1 * YBARS(L) * P(1,1,3,2,I)*ESV(J,L)	SS8L406	
282 CONTINUE	SS8L407	
IF (NRING .EQ. 0) GO TO 283	SS8L408	
DO 283 K=1,NRING	SS8L409	
S(II) = S(II) - PAXR(K) * P(1,2,2,2,J) * ERW(I,K)	SS8L410	
283 CONTINUE	SS8L411	
DO 284 K=1,NPNX	SS8L412	
DO 284 L=1,NPNY	SS8L413	
284 S(II) = S(II) - AA * PY (K,L) * P(K,1,1,2,I) * P(L,2,2,2,J)	SS8L414	
1 - BB * PXY(K,L) * P(K,1,2,2,I) * P(L,2,1,2,J)	SS8L415	
285 IF (NPTMOM .EQ. 0) GO TO 290	SS8L416	
DO 290 K=1,NPTMOM	SS8L417	
IF (ITAGCM(K) .EQ. 2) GO TO 290	SS8L418	
Q(II) = Q(II) - R1 * FC(K) * EVAL(1,1,2,I,IFXX(K))	SS8L419	
1 * EVAL(1,2,2,J,IFY(Y(K))	SS8L420	
290 CONTINUE	SS8L421	
IF (NLNMOM .EQ. 0) GO TO 1000	SS8L422	
DO 300 K=1,NLNMOM	SS8L423	
IF (ITAGLM(K) .EQ. 2) GO TO 300	SS8L424	
Q(II) = Q(II) - AR1 * PLMOM(K) * EVAL(1,2,2,J,IDISLM(K))	SS8L425	
1 * P(1,1,1,2,I)	SS8L426	
300 CONTINUE	SS8L427	
GO TO 1000	SS8L428	
310 X(21) =	AL(1,1,2,I,3,M) * AL(2,4,2,J,3,N)	SS8L429
X(22) =	AL(1,4,2,I,3,M) * AL(2,1,2,J,3,N)	SS8L430
X(23) =	AL(1,5,3,M,2,I) * AL(2,4,2,J,3,N)	SS8L431
X(24) =	AL(1,6,3,M,2,I) * AL(2,1,2,J,3,N)	SS8L432
X(25) =	AL(1,4,3,M,2,I) * AL(2,2,2,J,3,N)	SS8L433
X(26) =	AL(1,4,2,I,3,M) * AL(2,5,3,N,2,J)	SS8L434
X(27) =	AL(1,2,2,I,3,M) * AL(2,4,3,N,2,J)	SS8L435
X(28) =	AL(1,1,2,I,3,M) * AL(2,6,3,N,2,J)	SS8L436
Y(9) = A(2,2) * AR1 * X(21) + A(2,3) * BR1 * X(22)	SS8L437	
IF (ITHERY .NE. 1) GO TO 315	SS8L438	
Y(10) = - B(1,2) * A1 * X(23) - B(1,3) * A2B * X(24)	SS8L439	
1 + B(2,2) * (AR2 * X(21) - AB2 * X(28))	SS8L440	
2 + B(2,3) * (TBR2 * X(22) - 2. * B1 * X(25) - B1 * X(26))	SS8L441	
3 - B(3,3) * 2. * A1 * X(27)	SS8L442	
Y(11) = - D(1,2) * A1R1 * X(23) - 2. * D(1,3) * A2BR1 * X(24)	SS8L443	
1 - D(2,2) * AB2R1 * X(28) - 2. * D(2,3) * B1R1 * (X(26)	SS8L444	
2 + X(25)) - 4. * D(3,3) * A1R1 * X(27)	SS8L445	
GO TO 320	SS8L446	
315 Y(10) = - B(1,2) *A1 * X(23) - B(1,3) * A2B * X(24)	SS8L447	

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1      - B(2,2) * ( AR2 * X(21) + AB2 * X(28) )      SS8L448
2      - B(2,3) * B1 * ( 2.*X(25) + X(26) )          SS8L449
3      - 2.*B(3,3) * A1 * X(27)                      SS8L450
Y(11) = - D(1,3) * A2BR1 * X(24) - D(2,3) * ( B1R1 * X(26)
1      + BR3 * X(22) ) - 2.*D(3,3) * A1R1 * X(27)    SS8L451
320 V(II,JJ) = V(II,JJ) + Y(9) + Y(10) + Y(11)      SS8L452
      IF ( NSTRNG .EQ. 0 ) GO TO 330                  SS8L453
      DO 330 L=1,NSTRNG                               SS8L454
      V(II,JJ) = V(II,JJ) + ES(L) * XIYZS(L) * A3 * AL(1,3,2,I,3,M)
1      * ESV(J,L) * ESW(N,L)                          SS8L455
330 CONTINUE                                           SS8L456
      IF ( NRING .EQ. 0 ) GO TO 340                   SS8L457
      DO 340 K=1,NRING                                SS8L458
      V(II,JJ) = V(II,JJ) + ER(K) * AR(K) * ERW(I,K)  SS8L459
1      * ( ERW(M,K) * (-ZBARR(K) * B2                SS8L460
2      * AL(2,6,3,N,2,J) + R1 * AL(2,4,2,J,3,N) ) + XBARR(K)
3      * A1R1 * ERDW(M,K) * AL(2,4,2,J,3,N) )         SS8L461
340 CONTINUE                                           SS8L462
      IF ( IFLAGD .EQ. 0 ) GO TO 1000                 SS8L463
      IF ( NSTRNG .EQ. 0 ) GO TO 350                 SS8L464
      DO 350 L=1,NSTRNG                               SS8L465
      TT(II,JJ) = TT(II,JJ) + RHDS(L) * ESV(J,L)      SS8L466
1      * ( - AB1 * ZBARS(L) * AS(L) * AL(1,1,2,I,3,M) SS8L467
2      * ESDW(N,L) + A1 * XIYYS(L)                   SS8L468
3      * AL(1,2,2,I,3,M) * ESW(N,L) )                 SS8L469
350 CONTINUE                                           SS8L470
      IF ( NRING .EQ. 0 ) GO TO 1000                 SS8L471
      DO 360 K=1,NRING                                SS8L472
      TT(II,JJ) = TT(II,JJ) - RHOR(K) * AR(K) * ZBARR(K)
2      * AL(2,4,3,N,2,J) * ERW(I,K) * ERW(M,K)       SS8L473
360 CONTINUE                                           SS8L474
      GO TO 1000                                       SS8L475
370 X(29) = AL(1,1,3,I,3,M) * AL(2,1,3,J,3,N)        SS8L476
      X(30) = AL(1,5,3,I,3,M) * AL(2,1,3,J,3,N)      SS8L477
      X(31) = AL(1,5,3,M,3,I) * AL(2,1,3,J,3,N)      SS8L478
      X(32) = AL(1,1,3,I,3,M) * AL(2,5,3,N,3,J)      SS8L479
      X(33) = AL(1,1,3,I,3,M) * AL(2,5,3,J,3,N)      SS8L480
      X(34) = AL(1,4,3,M,3,I) * AL(2,4,3,N,3,J)      SS8L481
      X(35) = AL(1,4,3,I,3,M) * AL(2,4,3,J,3,N)      SS8L482
      X(36) = AL(1,3,3,I,3,M) * AL(2,1,3,J,3,N)      SS8L483
      X(37) = AL(1,5,3,M,3,I) * AL(2,5,3,J,3,N)      SS8L484
      X(38) = AL(1,5,3,I,3,M) * AL(2,5,3,N,3,J)      SS8L485
      X(39) = AL(1,6,3,M,3,I) * AL(2,4,3,J,3,N)      SS8L486
      X(40) = AL(1,6,3,I,3,M) * AL(2,4,3,N,3,J)      SS8L487
      X(41) = AL(1,1,3,I,3,M) * AL(2,3,3,J,3,N)      SS8L488
      X(42) = AL(1,4,3,M,3,I) * AL(2,6,3,J,3,N)      SS8L489
      X(43) = AL(1,4,3,I,3,M) * AL(2,6,3,N,3,J)      SS8L490
      X(44) = AL(1,2,3,I,3,M) * AL(2,2,3,J,3,N)      SS8L491
      Y(12) = A(2,2) * ABR2 * X(29)                  SS8L492
      IF ( ITHRY .NE. 1 ) GO TO 375                  SS8L493
      Y(13) = -B(1,2) * A1BR1 * ( X(30) + X(31) )    SS8L494
1      - B(2,2) * AB1R1 * ( X(32) + X(33) )          SS8L495
2      - B(2,3) * 2.*R1 * ( X(34) + X(35) )          SS8L496
      Y(14) = D(1,1) * A3B * X(36) + D(1,2) * A1B1 * ( X(37)+X(38) )
1      + D(1,3) * 2.*A2 * ( X(39)+X(40) ) + D(2,2) * AB3 * X(41)
2      + D(2,3) * 2.*B2 * ( X(42)+X(43) ) + D(3,3) * 4.*A1B1 * X(44)

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GO TO 379
375 Y(13) = - B(1,2) * A1BR1 * ( X(30) + X(31) ) - B(2,2) * AB1R1 *
1      ( X(32) + X(33) ) - 2.*B(2,2) * ABR3 * X(29)
2      - 2.*B(2,3)* R1 * ( X(34) + X(35) )
Y(14) = D(1,1) * A3B * X(36) + D(1,2) * A1B1 * ( X(37) + X(38) )
1      + D(1,2) * A1BR2 * ( X(30) + X(31) ) + 2.*D(1,3) * A2 *
2      ( X(39) + X(40) ) + D(2,2) * (AB3 * X(41) + ABR4 * X(29)
3      + AB1R2 * ( X(32) + X(33) ) ) + 2.*D(2,3) * ( B2 * ( X(42)
4      + X(43) ) + R2 * ( X(34) + X(35) ) ) + 4.*D(3,3)*A1B1*X(44)
379 V(II,JJ) = V(II,JJ) + Y(12) + Y(13) + Y(14)
IF ( NSTRNG .EQ. 0 ) GO TO 380
DO 380 L=1,NSTRNG
V(II,JJ) = V(II,JJ) + ES(L) * XIYYS(L) * A3 * AL(1,3,3,I,3,M)
1      * ESW(J,L) * ESW(N,L)
2      + GJS(L) * A1B2 * AL(1,2,3,I,3,M)
3      * ESDW(J,L) * ESDW(N,L)
380 CONTINUE
IF ( NRING .EQ. 0 ) GO TO 390
DO 390 K=1,NRING
V(II,JJ) = V(II,JJ) + ER(K) * XIXXR(K) * B3 * AL(2,3,3,J,3,N)
1      * ERW(I,K) * ERW(M,K)
2      + GJR(K) * A2B1 * AL(2,2,3,J,3,N)
3      * ERDW(I,K) * ERDW(M,K)
390 CONTINUE
IF ( IELAST .EQ. 1 ) GO TO 400
V(II,JJ) = V(II,JJ) + A3B * D(1,1) * AL(2,1,3,J,3,N) *
1      ( ALFAX * EVAL(2,1,3,I,1) * EVAL(2,1,3,M,1)
2      + BETAX * EVAL(2,1,3,I,25) * EVAL(2,1,3,M,25) )
3      + AB3 * D(2,2) * AL(1,1,3,I,3,M) *
4      ( ALFAY * EVAL(2,2,3,J,1) * EVAL(2,2,3,N,1)
5      + BETAY * EVAL(2,2,3,J,25) * EVAL(2,2,3,N,25) )
400 CONTINUE
IF ( NPTSUP .EQ. 0 ) GO TO 410
DO 410 L=1,NPTSUP
V(II,JJ) = V(II,JJ) + PKC(L)
1      * EVAL(1,1,3,I,IGSPRX(L)) * EVAL(1,1,3,M,IGSPRX(L))
2      * EVAL(1,2,3,J,IGSPRY(L)) * EVAL(1,2,3,N,IGSPRY(L))
410 CONTINUE
IF ( NLNSPR .EQ. 0 ) GO TO 430
DO 430 L=1,NLNSPR
IF ( ITAGLS(L) .EQ. 2 ) GO TO 420
V(II,JJ) = V(II,JJ) + PLIN(L) * AA * AL(1,1,3,I,3,M)
1      * EVAL(1,2,3,J,IDISLS(L)) * EVAL(1,2,3,N,IDISLS(L))
GO TO 430
420 V(II,JJ) = V(II,JJ) + PLIN(L) * BB * AL(2,1,3,J,3,N)
1      * EVAL(1,1,3,I,IDISLS(L)) * EVAL(1,1,3,M,IDISLS(L))
430 CONTINUE
IF ( NRING .EQ. 0 ) GO TO 450
DO 450 K=1,NRING
V(II,JJ) = V(II,JJ) + ER(K) * ( ERW(I,K) * ( AR(K)
1      * ERW(M,K) * ( BR2 * AL(2,1,3,J,3,N)
2      - ZBARR(K) * B1R1 * ( AL(2,5,3,J,3,N) + AL(2,5,3,N,3,J) ) )
3      + ERDW(M,K) * ( - XIXZR(K) * A1B1R1*AL(2,5,3,J,3,N)
4      + AR(K) * XBARR(K) * A1BR2 * AL(2,1,3,J,3,N) ) )
5      + ERDW(I,K) * ( ERW(M,K) * ( - XIXZR(K)
6      * A1B1R1 * AL(2,5,3,N,3,J) + AR(K) * XBARR(K) * A1BR2

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7          * AL(2,1,3,J,3,N) ) + ERDW(M,K)          * XIZZR(K)          SS8L560
8          * A2BR2 * AL(2,1,3,J,3,N) ) )          SS8L561
450 CONTINUE          SS8L562
    IF ( IFLAGD .EQ. 0 ) GO TO 480          SS8L563
    TT(II,JJ) = TT(II,JJ) + RHAB * AL(1,1,3,I,3,M) * AL(2,1,3,J,3,N)          SS8L564
    IF ( NSTRNG .EQ. 0 ) GO TO 460          SS8L565
    DO 460 L=1,NSTRNG          SS8L566
    TT(II,JJ) = TT(II,JJ) + ( AL(1,1,3,I,3,M) * ( AA * AS(L)          SS8L567
1          * ESW(J,L) * ESW(N,L) + AB1 * YBARS(L) * AS(L) * (          SS8L568
2          ESW(J,L) * ESDW(N,L) + ESDW(J,L) * ESW(N,L) ) + AB2 * (          SS8L569
3          XIZZS(L) + XIYYS(L) ) * ESDW(J,L) * ESDW(N,L) ) + A1 *          SS8L570
4          XIYYS(L) * AL(1,2,3,I,3,M) * ESW(J,L) * ESW(N,L) ) * RHOS(L)          SS8L571
460 CONTINUE          SS8L572
    IF ( NRING .EQ. 0 ) GO TO 470          SS8L573
    DO 470 K=1,NRING          SS8L574
    TT(II,JJ) = TT(II,JJ) + RHOR(K) * ( AL(2,1,3,J,3,N) * ( BB * AR(K)          SS8L575
1          * ERW(I,K) * ERW(M,K) + XBARR(K) * A1B * AR(K) * (          SS8L576
2          ERW(I,K) * ERDW(M,K) + ERDW(I,K) * ERW(M,K) )          SS8L577
2          + A2B * ( XIXXR(K) + XIZZR(K) ) *          SS8L578
3          ERDW(I,K) * ERDW(M,K) ) + B1 * AL(2,2,3,J,3,N) * XIXXR(K)          SS8L579
4          * ERW(I,K) * ERW(M,K) )          SS8L580
470 CONTINUE          SS8L581
    IF ( NLMASS .EQ. 0 ) GO TO 480          SS8L582
    DO 480 L=1,NLMASS          SS8L583
    TT(II,JJ) = TT(II,JJ) + PMASS(L) * EVAL(1,1,3,I,IPWW(L)) *          SS8L584
1EVAL(1,2,3,J,IPWY(L)) * EVAL(1,1,3,M,IPWW(L)) * EVAL(1,2,3,N,IPWY(L))          SS8L585
480 CONTINUE          SS8L586
    IF ( IEDGE .EQ. 0 ) GO TO 510          SS8L587
    X(45) = 0.          SS8L588
    DO 490 L=1,NPNX          SS8L589
    DO 490 K=1,NPNY          SS8L590
    X(45) = X(45) - PX(L,K) * $W(L,1,2,I,M) * $W(K,2,1,J,N) * A1B          SS8L591
1          - PY(L,K) * $W(L,1,1,I,M) * $W(K,2,2,J,N) * AB1          SS8L592
2          - PXY(L,K) * ($W(L,1,3,I,M) * $W(K,2,3,N,J)          SS8L593
3          + $W(L,1,3,M,I) * $W(K,2,3,J,N) )          SS8L594
490 CONTINUE          SS8L595
    U(KK,LL) = X(45)          SS8L596
    IF ( NSTRNG .EQ. 0 ) GO TO 500          SS8L597
    DO 500 L=1,NSTRNG          SS8L598
    U(KK,LL) = U(KK,LL) - PAXS(L) * AL(1,2,3,I,3,M) * A1          SS8L599
1          * ESW(J,L) * ESW(N,L)          SS8L600
500 CONTINUE          SS8L601
    IF ( NRING .EQ. 0 ) GO TO 510          SS8L602
    DO 510 K=1,NRING          SS8L603
    U(KK,LL) = U(KK,LL) - PAXR(K) * B1 * AL(2,2,3,J,3,N)          SS8L604
1          * ERW(I,K) * ERW(M,K)          SS8L605
510 CONTINUE          SS8L606
    IF ( IFLAGW .EQ. 0 ) GO TO 1000          SS8L607
    IF ( JJ .GT. NTUX*NTUY + NTVX*NTVY + 1 ) GO TO 1000          SS8L608
    IF ( IFLAGW .EQ. 2 ) GO TO 521          SS8L609
    X(46) = 0.          SS8L610
    DO 520 K=1,NQTX          SS8L611
    DO 520 L=1,NQTY          SS8L612
520 X(46) = X(46) + QQ(K,L) * AB * P(K,1,1,3,I) * P(L,2,1,3,J)          SS8L613
    Q(II) = X(46)          SS8L614
521 CONTINUE          SS8L615

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IF (IEDGE .EQ. 0) GO TO 525	SS8L616
IF (NSTRNG .EQ. 0) GO TO 522	SS8L617
DO 522 L=1,NSTRNG	SS8L618
S(II) = S(II) + PAXS(L) * A1 * ZBARS(L) * P(1,1,3,3,I) * ESW(J,L)	SS8L619
522 CONTINUE	SS8L620
IF (NRING .EQ. 0) GO TO 523	SS8L621
DO 523 K=1,NRING	SS8L622
S(II) = S(II) - PAXR(K) * (- ZBARR(K) * P(1,2,3,3,J)	SS8L623
1 * ERW(I,K) + P(1,2,1,3,J) * (BR1	SS8L624
2 * ERW(I,K) + BR1 * XBARR(K) * ERDW(I,K))	SS8L625
523 CONTINUE	SS8L626
DO 524 K=1,NPNX	SS8L627
DO 524 L=1,NPNY	SS8L628
524 S(II) = S(II) - ABR1 * PY(K,L) * P(K,1,1,3,I) * P(L,2,1,3,J)	SS8L629
525 IF (NPTLDS .EQ. 0) GO TO 530	SS8L630
DO 530 L=1,NPTLDS	SS8L631
Q(II) = Q(II) + PC(L) * EVAL(1,1,3,I,IPXX(L))	SS8L632
1 * EVAL(1,2,3,J,IPYY(L))	SS8L633
530 CONTINUE	SS8L634
IF (NPTMOM .EQ. 0) GO TO 550	SS8L635
DO 550 L=1,NPTMOM	SS8L636
IF (ITAGCM(L) .EQ. 1) GO TO 540	SS8L637
C TAG = 1 FOR MY , = 2 FOR MX	SS8L638
Q(II) = Q(II) - A1 * FC(L)	SS8L639
1 * EVAL(2,1,3,I,IFXX(L)) * EVAL(1,2,3,J,IFYY(L))	SS8L640
GO TO 550	SS8L641
540 Q(II) = Q(II) - B1 * FC(L)	SS8L642
1 * EVAL(1,1,3,I,IFXX(L)) * EVAL(2,2,3,J,IFYY(L))	SS8L643
550 CONTINUE	SS8L644
IF (NLNMOM .EQ. 0) GO TO 1000	SS8L645
DO 570 L=1,NLNMOM	SS8L646
IF (ITAGLM(L) .EQ. 1) GO TO 560	SS8L647
Q(II) = Q(II) - A1B * PLMOM(L) * P(1,2,1,3,J)	SS8L648
1 * EVAL(2,1,3,I,IDISLM(L))	SS8L649
GO TO 570	SS8L650
560 Q(II) = Q(II) - AB1 * PLMOM(L) * P(1,1,1,3,I)	SS8L651
1 * EVAL(2,2,3,J,IDISLM(L))	SS8L652
570 CONTINUE	SS8L653
GO TO 1000	SS8L654
580 V(II,JJ) = V(JJ,II)	SS8L655
IF (IFLAGD .EQ. 0) GO TO 1000	SS8L656
TT(II,JJ) = TT(JJ,II)	SS8L657
1000 CONTINUE	SS8L658
CALL STATUS (ITIME)	SS8L659
TIME(6) = .01*ITIME(8)	SS8L660
ET = TIME(6) - TIME(5)	SS8L661
C ** CHANGE SIGN ON Q	SS8L662
DO 1584 I=1,MATSIZ	SS8L663
1584 Q(I) = -Q(I)	SS8L664
DO 2584 I=1,MWSIZ	SS8L665
DO 2584 J=1,MWSIZ	SS8L666
2584 U(I,J) = -U(I,J)	SS8L667
DO 585 I=1,MATSIZ	SS8L668
QHOLD(I) = Q(I)	SS8L669
SHOLD(I) = S(I)	SS8L670
DO 585 J=1,MATSIZ	SS8L671

585	VHOLD(I,J) = V(I,J)	SS8L672
C		SS8L673
	IF (INTprt .NE. 1) GO TO 670	SS8L674
	WRITE (6,590) ET	SS8L675
590	FORMAT ('OTIME REQUIRED TO ASSEMBLE MATRICES = ',F7.3,' SEC.')	SS8L676
	WRITE (6,610) NAMEV	SS8L677
610	FORMAT ('MATRIX ',A4)	SS8L678
	DO 630 I=1,MATSIZ	SS8L679
	WRITE (6,620)	SS8L680
620	FORMAT ('O')	SS8L681
630	WRITE (6,640) (V(I,J), J=1,MATSIZ)	SS8L682
640	FORMAT (' ',10E12.4)	SS8L683
	IF (IFLAGD .EQ. 0) GO TO 651	SS8L684
	WRITE (6,610) NAMETT	SS8L685
	DO 650 I=1,MATSIZ	SS8L686
	WRITE (6,620)	SS8L687
650	WRITE (6,640) (TT(I,J), J=1,MATSIZ)	SS8L688
651	CONTINUE	SS8L689
	IF (IEDGE .EQ. 0) GO TO 661	SS8L690
	WRITE (6,610) NAMEU	SS8L691
	DO 660 I=1,MWSIZ	SS8L692
	WRITE (6,620)	SS8L693
660	WRITE (6,640) (U(I,J), J=1,MWSIZ)	SS8L694
661	CONTINUE	SS8L695
	IF (IFLAGW .EQ. 0) GO TO 670	SS8L696
	WRITE (6,610) NAMES	SS8L697
	WRITE (6,640) (S(J), J=1,MATSIZ)	SS8L698
	WRITE (6,610) NAMEQ	SS8L699
	WRITE (6,640) (Q(J), J=1,MATSIZ)	SS8L700
670	CONTINUE	SS8L701
	RETURN	SS8L702
	END	SS8L703

CC = 00704

	SUBROUTINE SOLVE	SS8M000
C		SS8M001
	DIMENSION V(150,150), T(150,150), Z(150,150)	SS8M002
	DIMENSION VV(22500), TV(22500), ZV(22500)	SS8M003
	DIMENSION Z1(100,100), Z2(100,50), Z3(50,100), Z4(50,50)	SS8M004
	DIMENSION U(50,50), Q(150)	SS8M005
	DIMENSION WORK1(150), WORK2(150)	SS8M006
	DIMENSION S(150)	SS8M007
	DIMENSION ITIME(12), TIME(50)	SS8M008
	DIMENSION INDEX(150)	SS8M009
C		SS8M010
	COMMON U	SS8M011
	COMMON / BLOCK / T	SS8M012
	COMMON / ARRAYS / V	SS8M013
	COMMON / CNTROL / IFLAGD, IFLAGB, IFLAGW, IBCX, IBCY, I\$, IEDGE,	SS8M014
	1 JS(2), KEY, KS(2), INTprt, IKDF, IFLEX	SS8M015
	COMMON / NUMBER / ND2(6), NTWY, NMODES, ND3(12), NUVW, NUV, NW	SS8M016
	COMMON / NUMBER / ITX, ITY	SS8M017
	COMMON / ZWORK / Z	SS8M018
	COMMON / PARAM / Q, S, WORK1, WORK2	SS8M019
	COMMON / \$TIME / TIME, ITIME	SS8M020
	COMMON / MODES / MM(50), NN(50)	SS8M021
C		SS8M022
	EQUIVALENCE (Z1(1), Z(1)), (Z2(1), Z(10001))	SS8M023
	EQUIVALENCE (Z3(1), Z(15001)), (Z4(1), Z(20001))	SS8M024
	EQUIVALENCE (V(1), VV(1)), (T(1), TV(1)), (Z(1), ZV(1))	SS8M025
C		SS8M026
	CALL STATUS (ITIME)	SS8M027
	TIME(10) = .01*ITIME(8) - TIME(1)	SS8M028
	IF (INTprt .EQ. 1) WRITE (6,10) TIME(10)	SS8M029
	10 FORMAT ('OELAPSED TIME AT BEGINNING OF ',7H'SOLVE', ' = ',F7.2)	SS8M030
C		SS8M031
	IF (IFLAGW .NE. 0) GO TO 20	SS8M032
	IF (IFLAGD .NE. 0) GO TO 90	SS8M033
	IF (IFLAGB .NE. 0) GO TO 170	SS8M034
C		SS8M035
C **	STATIC DEFLECTION	SS8M036
C		SS8M037
	20 CONTINUE	SS8M038
	IF (IEDGE .EQ. 1) GO TO 40	SS8M039
	DO 30 I=1,NUVW	SS8M040
	DO 30 J=1,NUVW	SS8M041
	30 T(I,J) = V(I,J)	SS8M042
	GO TO 65	SS8M043
	40 DO 60 I=1,NUVW	SS8M044
	DO 60 J=1,NUVW	SS8M045
	IF (I.GT.NUV .AND. J.GT.NUV) GO TO 50	SS8M046
	T(I,J) = V(I,J)	SS8M047
	GO TO 60	SS8M048
	50 K = I-NUV	SS8M049
	L = J-NUV	SS8M050
	T(I,J) = V(I,J) + U(K,L)	SS8M051
	60 CONTINUE	SS8M052
	65 CONTINUE	SS8M053
C		SS8M054
	IF (IFLEX.EQ. 0) GO TO 70	SS8M055

CALL REDUCE (1,V,Z1,Z2,Z3,Z4,WORK1,WORK2,NUV,NW)	SS8M056
CALL FLEX	SS8M057
70 CONTINUE	SS8M058
C DO 80 I=1,NUVW	SS8M059
80 WORK1(I) = -S(I) - Q(I)	SS8M060
C	SS8M061
CALL SWITCH (T, NUVW, 150, 0., 1.)	SS8M062
CALL SIMEQ (T,WORK1,NUVW,1,150,150,0.,IER)	SS8M063
KEY = 1	SS8M064
GO TO 1000	SS8M065
C	SS8M066
C ** VIBRATION	SS8M067
C	SS8M068
90 CONTINUE	SS8M069
CALL STATUS (ITIME)	SS8M070
TIME(11) = .01*ITIME(8) - TIME(1)	SS8M071
DO 100 I=1,NUVW	SS8M072
DO 100 J=1,NUVW	SS8M073
100 Z(I,J) = V(I,J)	SS8M074
CALL SWITCH (T, NUVW, 150, 0., 1.)	SS8M075
C	SS8M076
CALL ARRAY (2,NUVW,NUVW,150,150,VV,V)	SS8M077
CALL ARRAY (2,NUVW,NUVW,150,150,ZV,Z)	SS8M078
CALL ARRAY (2,NUVW,NUVW,150,150,TV,T)	SS8M079
CALL NROOT (NUVW,ZV,TV,WORK1,VV)	SS8M080
CALL ARRAY (1,NUVW,NUVW,150,150,VV,V)	SS8M081
DO 120 J=1,NUVW	SS8M082
WORK2(J) = 1.E+40	SS8M083
DO 110 I=1,NUVW	SS8M084
IF (WORK1(I).GE.WORK2(J)) GO TO 110	SS8M085
WORK2(J) = WORK1(I)	SS8M086
INDEX(J) = I	SS8M087
110 CONTINUE	SS8M088
120 WORK1(INDEX(J)) = 1.E+40	SS8M089
DO 130 J=1,NUVW	SS8M090
WORK1(J) = WORK2(J)	SS8M091
DO 130 K=1,NUVW	SS8M092
130 T(J,K) = V(K,INDEX(J))	SS8M093
CALL STATUS (ITIME)	SS8M094
TIME(12) = .01*ITIME(8) - TIME(1)	SS8M095
ET = TIME(12) - TIME(11)	SS8M096
IF (INTPT .EQ. 1) WRITE (6,140) ET	SS8M097
140 FORMAT ('OTIME TO SOLVE FOR EIGENVALUES AND EIGENVECTORS = ',F7.2)	SS8M098
DO 55 I=1,NUVW	SS8M099
BIG = ABS(T(I,NUV+1))	SS8M100
NSAVE = 1	SS8M101
DO 59 J=2,NW	SS8M102
IF (ABS (T(I,J+NUV)).LE.BIG) GO TO 59	SS8M103
BIG = ABS (T(I,J+NUV))	SS8M104
NSAVE = J	SS8M105
59 CONTINUE	SS8M106
M = ITX	SS8M107
N = ITY	SS8M108
IF (NSAVE .EQ. 1) GO TO 3	SS8M109
DO 2 J=2,NSAVE	SS8M110
	SS8M111

IF (N+1-ITY .GE. NTWY) GO TO 1	SS8M112
N = N+1	SS8M113
GO TO 2	SS8M114
1 N = ITY	SS8M115
M = M+1	SS8M116
2 CONTINUE	SS8M117
3 CONTINUE	SS8M118
MM(I) = M	SS8M119
NN(I) = N	SS8M120
IF (WORK1(I) .GT. 0.) WORK1(I)=SQRT(WORK1(I))/6.2831853	SS8M121
55 CONTINUE	SS8M122
WRITE (6,160) (WORK1(I), MM(I), NN(I) , I=1,NUVW)	SS8M123
160 FORMAT ('1 FREQUENCY',7X,'M',5X,'N'/'0',E13.5,4X,I2,4X,I2)	SS8M124
KEY = 2	SS8M125
GO TO 1000	SS8M126
C	SS8M127
C ** BUCKLING	SS8M128
C	SS8M129
170 CONTINUE	SS8M130
DO 180 I=1,NW	SS8M131
DO 180 J=1,NW	SS8M132
180 U(I,J) = - U(I,J)	SS8M133
C	SS8M134
IF (IFLEX .EQ. 0) GO TO 190	SS8M135
CALL REDUCE (1,V,Z1,Z2,Z3,Z4,WORK1,WORK2,NUV,NW)	SS8M136
CALL FLEX	SS8M137
190 CONTINUE	SS8M138
IF (IKDF .NE. 0) CALL KDF (BUCKNX)	SS8M139
C	SS8M140
IF (IFLEX .EQ. 0) GO TO 200	SS8M141
CALL YOSFEM (2,Z,NW,NW,150,U,NW,50,V,WORK1)	SS8M142
GO TO 210	SS8M143
200 CALL REDUCE (2,V,Z1,Z2,Z3,Z4,WORK1,WORK2,NUV,NW)	SS8M144
CALL YOSFEM (2,V,NW,NW,150,U,NW,50,Z,WORK1)	SS8M145
210 CONTINUE	SS8M146
IF (IFLAGB .EQ. 1) CALL EIGONE (U,WORK1,NW,50)	SS8M147
IF (IFLAGB .EQ. 2) CALL EIGALL (U,WORK1,NW,50,1,2)	SS8M148
KEY = 3	SS8M149
1000 CONTINUE	SS8M150
RETURN	SS8M151
END	SS8M152
SUBROUTINE SWITCH (DIAG, N, NMAX, FROM, TO)	SS8M153
C CHANGES A DIAGONAL TERM FROM 0 TO 1 OR FROM 1 TO 0 .	SS8M154
DIMENSION DIAG(NMAX,N)	SS8M155
DO 10 I=1,N	SS8M156
IF (DIAG(I,I) .EQ. FROM) DIAG(I,I) = TO	SS8M157
10 CONTINUE	SS8M158
RETURN	SS8M159
END	SS8M160

CC = 00161

C	SUBROUTINE YOSFEM (NOPT, A,NRA,NCA,MRA,B,NCB,MRB,C,WORK)	SS8N000
C	** YOSFEM = YE OLDE SUBROUTINE FOR EFFICIENT MULTIPLICATION.	SS8N001
C	** NOPT = 1, 2, OR 3	SS8N002
C	** = 1 , COMPUTES A = A * B	SS8N003
C	** = 2 , COMPUTES B = A * B	SS8N004
C	** = 3 , COMPUTES C = A * B	SS8N005
C	** A = AN NRA BY NCA MATRIX	SS8N006
C	** NRA = NUMBER OF ROWS IN A	SS8N007
C	** NCA = NUMBER OF COLUMNS IN A	SS8N008
C	** MRA = MAXIMUM NUMBER OF ROWS IN A	SS8N009
C	** B = AN NCA BY NCB MATRIX	SS8N010
C	** NCB = NUMBER OF COLUMNS IN B	SS8N011
C	** MRB = MAXIMUM NUMBER OF ROWS IN B	SS8N012
C	** C = AN NRA BY NCB MATRIX	SS8N013
C	** WORK = A WORK VECTOR OF LENGTH NRA	SS8N014
C		SS8N015
C	DIMENSION A(MRA,NCA), B(MRB,NCB), C(MRA,NCB), WORK(NRA)	SS8N016
C		SS8N017
	IF (NOPT .NE. 1) GO TO 40	SS8N018
	DO 30 I=1,NRA	SS8N019
	DO 20 M=1,NCA	SS8N020
20	WORK(M) = A(I,M)	SS8N021
	DO 30 J=1,NCB	SS8N022
	A(I,J) = 0.	SS8N023
	DO 30 K=1,NCA	SS8N024
30	A(I,J) = A(I,J) + WORK(K) * B(K,J)	SS8N025
	GO TO 100	SS8N026
40	IF (NOPT .NE. 2) GO TO 70	SS8N027
	DO 60 J=1,NCB	SS8N028
	DO 50 M=1,NCA	SS8N029
50	WORK(M) = B(M,J)	SS8N030
	DO 60 I=1,NRA	SS8N031
	B(I,J) = 0.	SS8N032
	DO 60 K=1,NCA	SS8N033
60	B(I,J) = B(I,J) + A(I,K) * WORK(K)	SS8N034
	GO TO 100	SS8N035
70	DO 80 I=1,NRA	SS8N036
	DO 80 J=1,NCB	SS8N037
	C(I,J) = 0.	SS8N038
	DO 80 K=1,NCA	SS8N039
80	C(I,J) = C(I,J) + A(I,K) * B(K,J)	SS8N040
100	RETURN	SS8N041
	END	SS8N042
		SS8N043

CC = 00044

	SUBROUTINE EIGONE (A, X, N, NRA)	SS8N045
C		SS8N046
C	THIS SUBROUTINE COMPUTES THE INVERSE OF THE LARGEST EIGEN VALUE	SS8N047
C	OF AN N BY N MATRIX, AND THE CORRESPONDING MODE SHAPE, BY SIMPLE	SS8N048
C	ITERATION.	SS8N049
C	CAST PROBLEM IN THE FORM $A \cdot X = X / OLAMB$	SS8N050
C		SS8N051
	DIMENSION A(NRA,N), X(N)	SS8N052
	DIMENSION B(150,150), ITIME(12), TIME(50)	SS8N053
	DIMENSION USED(150), XA(150), XX(150)	SS8N054
	DIMENSION XXX(150), XY(150), MPN(150)	SS8N055
C		SS8N056
	COMMON / ZWORK / B	SS8N057
	COMMON / PARAM / XA, XX, USED, XXX, XY, MPN	SS8N058
	COMMON / \$TIME / TIME, ITIME	SS8N059
	COMMON / CNTROL / I\$(12), INTPT	SS8N060
C		SS8N061
	CALL STATUS (ITIME)	SS8N062
	TIME(20) = .01*ITIME(8) - TIME(1)	SS8N063
	PDIDLE=.00001	SS8N064
	MAD= 72	SS8N065
	IKEP=1	SS8N066
	OLAMB = 0.	SS8N067
	DO 1 I=1,N	SS8N068
	1 X(I)=.1	SS8N069
	M=1	SS8N070
	6 XMIN=0	SS8N071
	OLAMBO=OLAMB	SS8N072
C	A NEW MODE SHAPE IS COMPUTED AS A TIMES X, AND THE LARGEST ELEMENT	SS8N073
C	OF THE NEW X IS STORED IN XMIN.	SS8N074
	DO 44 I=1,N	SS8N075
	44 XA(I)=X(I)	SS8N076
	DO 42 K=1,6	SS8N077
	DO 3 I=1,N	SS8N078
	XX(I)=0.	SS8N079
	DO 3 J=1,N	SS8N080
	3 XX(I)=XX(I)+ A(I,J)*X(J)	SS8N081
	XPQ=X(N)/XX(N)	SS8N082
	XPR=XPQ/ABS(XPQ)	SS8N083
	DO 41 I=1,N	SS8N084
	XXX(I)=X(I)	SS8N085
	41 X(I)=XX(I)	SS8N086
	42 CONTINUE	SS8N087
	DO 2 I=1,N	SS8N088
	IF(ABS(XMIN)-ABS(XX(I)))7,2,2	SS8N089
	7 XMIN = XX(I)	SS8N090
	JJ= I	SS8N091
	MPN(IKEP)=I	SS8N092
	2 CONTINUE	SS8N093
C	THE NEW VECTOR IS NORMALIZED WITH RESPECT TO XMIN.	SS8N094
	DO 4 I=1,N	SS8N095
	4 XX(I)= XX(I)/ XMIN	SS8N096
C	THE LATEST APPROXIMATION TO 1 DIVIDED BY THE LARGEST EIGEN VALUE	SS8N097
C	IS COMPUTED.	SS8N098
	OLAMB=XA(JJ)/XMIN	SS8N099
	OLAMB= ((ABS(OLAMB))**.1666667)*XPR	SS8N100

C	THE NEW VECTOR IS STORED FOR A NEW ITERATION.	SS8N101
	DO 9 I =1,N	SS8N102
9	X(I) = XX(I)	SS8N103
C	THE RELATIVE CHANGE IN OLAMB IS THE BASIS FOR CONVERGENCE.	SS8N104
	IF(ABS((OLAMB - OLAMBO) /OLAMB) .LT.PDIDLE)GO TO 5	SS8N105
	M=M+1	SS8N106
	IF(M.GT.15)PDIDLE =.0005	SS8N107
	IF (M.LT.50) GO TO 6	SS8N108
	WRITE(6,8)OLAMBO,OLAMB	SS8N109
8	FORMAT('ONO CONVERGENCE'2E15.7)	SS8N110
	XY(IKEP)=OLAMB	SS8N111
	DO 60 IJ=1,N	SS8N112
60	B(IKEP,IJ) =X(IJ)	SS8N113
	GO TO 39	SS8N114
5	IF(M.GT.15)GO TO 20	SS8N115
	M=M+1	SS8N116
	GO TO 6	SS8N117
20	IF (INTPT .EQ. 1) WRITE (6,12) M	SS8N118
12	FORMAT('0'I4,' ITERATIONS')	SS8N119
	DO 43 I=1,N	SS8N120
43	X(I)=(X(I)+XXX(I)/OLAMB/XMIN)/2.	SS8N121
	DO 55 I=1,N	SS8N122
55	B(IKEP,I)=X(I)	SS8N123
	XY(IKEP)=OLAMB	SS8N124
39	CONTINUE	SS8N125
500	DO 38 J=1,IKEP	SS8N126
	X(J)=XY(J)	SS8N127
	DO 38 I=1,N	SS8N128
38	A(J,I)=B(J,I)	SS8N129
40	CONTINUE	SS8N130
	CALL STATUS (ITIME)	SS8N131
	TIME(21) = .01*ITIME(8) - TIME(1)	SS8N132
	ET = TIME(21) - TIME(20)	SS8N133
	IF (INTPT .EQ. 1) WRITE (6,600) ET	SS8N134
600	FORMAT ('OTIME REQUIRED TO FIND ONE EIGENVALUE AND EIGENVECTOR = '	SS8N135
1	,F7.2)	SS8N136
	RETURN	SS8N137
	END	SS8N138

CC = 00094

	SUBROUTINE EIGALL (A, X, N, NRA, ITAG, MODES)	SS8P000
C		SS8P001
C **	THIS SUBROUTINE FINDS ALL THE EIGENVALUES OF THE NRA BY N	SS8P002
C **	MATRIX A. IT ALSO FINDS THE EIGENVECTORS CORRESPONDING TO	SS8P003
C **	THE FIRST 'MODES' EIGENVALUES.	SS8P004
C **	THE MATRIX EQUATION IS IN THE FORM $A*X = X/EGNVAL$	SS8P005
C		SS8P006
	DIMENSION A(NRA,N), X(N)	SS8P007
	DIMENSION USED(150), XX(150), WORK(3000)	SS8P008
	DIMENSION Z(150,150), XY(150), NDUM1(150), NDUM2(150)	SS8P009
	DIMENSION VEC(150), ITIME(12), TIME(50)	SS8P010
C		SS8P011
	COMMON / ZWORK / Z	SS8P012
	COMMON / PARAM / XX, XY, USED, VEC, NDUM1, NDUM2	SS8P013
	COMMON / EIGWRK / WORK	SS8P014
	COMMON / CNTROL / IFLAGD, I\$(11), INTPR	SS8P015
	COMMON / COMMON / DUMCOM(150)	SS8P016
	COMMON / \$TIME / TIME, ITIME	SS8P017
C		SS8P018
	DO 10 J=1,N	SS8P019
10	X(J) = 0.	SS8P020
	DO 20 I=1,N	SS8P021
	DO 20 J=1,N	SS8P022
20	Z(I,J) = A(I,J)	SS8P023
	IPRNT = INTPR	SS8P024
	CALL STATUS (ITIME)	SS8P025
	TIME(17) = .01*ITIME(8) - TIME(1)	SS8P026
	CALL HESSEN (Z, N, 150)	SS8P027
	CALL QREIG (Z, N, XY, XX, IPRNT, 150)	SS8P028
	CALL STATUS (ITIME)	SS8P029
	TIME(18) = .01*ITIME(8) - TIME(1)	SS8P030
	ET = TIME(18) - TIME(17)	SS8P031
	IF (INTPR .EQ. 1) WRITE (6,21) ET	SS8P032
21	FORMAT ('OTIME REQUIRED TO FIND ALL EIGENVALUES = ',F7.2)	SS8P033
	IF (ITAG .EQ. 3) GO TO 70	SS8P034
	GREAT= 0.	SS8P035
	DO 71 I=1,N	SS8P036
	IF(XX(I).NE.0.)GO TO 71	SS8P037
	IF (XY(I) .EQ. 0.) GO TO 71	SS8P038
	IF(ABS(GREAT).GT.ABS(XY(I)))GO TO 71	SS8P039
	GREAT = XY(I)	SS8P040
71	CONTINUE	SS8P041
	GREAT2 = -0.	SS8P042
	DO 72 I=1,N	SS8P043
	IF(XX(I).NE.0.)GO TO 72	SS8P044
	IF (XY(I) .EQ. 0.) GO TO 72	SS8P045
	IF(GREAT*XY(I).GT.0..OR.ABS(GREAT2).GT.ABS(XY(I))) GO TO 72	SS8P046
	GREAT2 = XY(I)	SS8P047
72	CONTINUE	SS8P048
	MODES = 2	SS8P049
	XY(1)= GREAT	SS8P050
	XY(2)= GREAT2	SS8P051
	X(1)= 1./GREAT	SS8P052
	IF(ABS(GREAT2).LT.1.E-40)GO TO 80	SS8P053
	X(2)= 1./GREAT2	SS8P054
	GO TO 73	SS8P055

80 X(2)=0.	SS8P056
MODES = 1	SS8P057
GO TO 73	SS8P058
70 CONTINUE	SS8P059
DO 50 J=1,N	SS8P060
IF (XY(J) .NE. 0.) XY(J) = 1./XY(J)	SS8P061
50 CONTINUE	SS8P062
DO 74 J=1,N	SS8P063
IF(XX(J).NE.0.)XY(J)= 0.	SS8P064
DO 75 I=J,N	SS8P065
IF(XX(I).NE.0.)GO TO 75	SS8P066
IF (XY(I) .EQ. 0.) GO TO 75	SS8P067
IF(XY(I).LT.XY(J))GO TO 75	SS8P068
GREAT= XY(J)	SS8P069
XY(J)= XY(I)	SS8P070
XY(I)= GREAT	SS8P071
GREAT= XX(J)	SS8P072
XX(J)= XX(I)	SS8P073
XX(I)= GREAT	SS8P074
75 CONTINUE	SS8P075
IF (XY(J) .NE. 0.) X(J) = 1./XY(J)	SS8P076
74 CONTINUE	SS8P077
73 CONTINUE	SS8P078
DO 77 I=1,MODES	SS8P079
DO 78 J=1,N	SS8P080
DO 78 K=1,N	SS8P081
78 Z(J,K) = A(J,K)	SS8P082
EGNVAL = X(I)	SS8P083
IF (ITAG .NE. 3) EGNVAL = 1./X(I)	SS8P084
CALL EGNVCT (Z, XX, EGNVAL, VEC, NDUM1, NDUM2, N, 150, IPRNT)	SS8P085
JO = (I-1)*N	SS8P086
DO 79 J=1,N	SS8P087
K = JO + J	SS8P088
79 WORK(K) = VEC(J)	SS8P089
77 CONTINUE	SS8P090
DO 90 I=1,MODES	SS8P091
J = (I-1)*N	SS8P092
DO 90 K=1,N	SS8P093
L = J + K	SS8P094
90 A(I,K) = WORK(L)	SS8P095
CALL STATUS (ITIME)	SS8P096
TIME(19) = .01*ITIME(8) - TIME(1)	SS8P097
ET = TIME(19) - TIME(18)	SS8P098
IF (INTPT .EQ. 1) WRITE (6,91) ET	SS8P099
91 FORMAT ('OTIME REQUIRED TO FIND EIGENVECTORS = ',F7.2)	SS8P100
RETURN	SS8P101
END	SS8P102

CC = 00103

	SUBROUTINE EGNVCT (C1, C2, EIGEN, C3, N1, N2, N, NROWS, NTIME)	SS8Q000
C		SS8Q001
C	SUBROUTINE TO OBTAIN EIGENVECTOR FROM REAL NON-SYMMETRIC	SS8Q002
C	MATRICES FOR WHICH THE EIGENVALUE IS KNOWN. THE METHOD	SS8Q003
C	USED IS THE DIRECT METHOD OUTLINED IN ERR-FW- BY DR.	SS8Q004
C	A. M. CUNNINGHAM. ALL ARITHMETIC IS IN DOUBLE PRECISION.	SS8Q005
C		SS8Q006
	DIMENSION C1(NROWS,NROWS), C2(NROWS), C3(NROWS), N1(NROWS),	SS8Q007
1	N2(NROWS)	SS8Q008
C		SS8Q009
	II3 = N	SS8Q010
	II2 = N - 1	SS8Q011
	IF (NTIME .NE. 0) CALL STATUS (N1)	SS8Q012
	IT1 = N1(8)	SS8Q013
	D1 = 0.0 D0	SS8Q014
	DO 20 J=1,N	SS8Q015
	N1(J) = J	SS8Q016
	N2(J) = J	SS8Q017
	C1(J,J) = C1(J,J) - EIGEN	SS8Q018
	DO 10 I=1,N	SS8Q019
	D2 = ABS(C1(I,J))	SS8Q020
	IF (D1-D2) 5,10,10	SS8Q021
5	D1 = D2	SS8Q022
	I1 = I	SS8Q023
	J1 = J	SS8Q024
10	CONTINUE	SS8Q025
20	CONTINUE	SS8Q026
	DO 150 K6=2,N	SS8Q027
	IF (C1(I1,J1)) 50,30,50	SS8Q028
30	K5 = K6 - 1	SS8Q029
35	WRITE (6,40) K5	SS8Q030
40	FORMAT (1H1, 4X,57H THE REDUCED MATRIX WAS FOUND TO BE SINGULAR ON	SS8Q031
	1 ITERATION, I4)	SS8Q032
	N1(1) = 1	SS8Q033
	GO TO 1000	SS8Q034
C		SS8Q035
50	D1 = 1.0/C1(I1,J1)	SS8Q036
	D2 = C1(I1,II3)	SS8Q037
	D3 = C1(II3,J1)	SS8Q038
	D4 = C1(II3,II3)	SS8Q039
	DO 60 I=1,II2	SS8Q040
	C3(I) = C1(I,J1)	SS8Q041
	C1(I,J1) = C1(I,II3)	SS8Q042
	C1(I,II3) = -C3(I)*D1	SS8Q043
	D5 = -C1(I1,I)*D1	SS8Q044
	C1(I1,I) = C1(II3,I)	SS8Q045
	C1(II3,I) = D5	SS8Q046
60	CONTINUE	SS8Q047
	C3(I1) = D3	SS8Q048
	C1(I1,J1) = D4	SS8Q049
	C1(II3,J1) = -D2*D1	SS8Q050
	C1(I1,II3) = -D3*D1	SS8Q051
	C1(II3,II3) = D1	SS8Q052
	IF (II3 .EQ. N) GO TO 80	SS8Q053
	II4 = II3 + 1	SS8Q054
	DO 70 I=II4,N	SS8Q055

D6 = C1(I1,I)	SS8Q056
C1(I1,I) = C1(I13,I)	SS8Q057
C1(I13,I) = D6	SS8Q058
C3(I) = C1(I,J1)	SS8Q059
C1(I,J1) = C1(I,I13)	SS8Q060
70 C1(I,I13) = C3(I)	SS8Q061
80 I = N1(J1)	SS8Q062
N1(J1) = N1(I13)	SS8Q063
N1(I13) = I	SS8Q064
I = N2(I1)	SS8Q065
N2(I1) = N2(I13)	SS8Q066
N2(I13) = I	SS8Q067
D7 = 0.0 D0	SS8Q068
DO 140 J=1,I12	SS8Q069
D8 = C1(I13,J)	SS8Q070
DO 130 I=1,I12	SS8Q071
C1(I,J) = C1(I,J) + C3(I)*D8	SS8Q072
D9 = ABS(C1(I,J))	SS8Q073
IF (D7-D9) 120,130,130	SS8Q074
120 D7 = D9	SS8Q075
I1 = I	SS8Q076
J1 = J	SS8Q077
130 CONTINUE	SS8Q078
140 CONTINUE	SS8Q079
I13 = I13 - 1	SS8Q080
I12 = I12 - 1	SS8Q081
150 CONTINUE	SS8Q082
C	SS8Q083
C	SS8Q084
160 C3(2) = C1(2,1)	SS8Q085
C3(1) = 1.0	SS8Q086
DO 180 J=3,N	SS8Q087
C3(J) = 0.0 D0	SS8Q088
J1 = J-1	SS8Q089
DO 170 I=1,J1	SS8Q090
C3(J) = C3(J) + C3(I)*C1(J,I)	SS8Q091
170 CONTINUE	SS8Q092
180 CONTINUE	SS8Q093
IF (ABS(C1(1,1)) .LT. 1.0 E-20) GO TO 202	SS8Q094
DO 201 K6=1,2	SS8Q095
C	SS8Q096
DO 184 J=1,N	SS8Q097
I1 = N2(J)	SS8Q098
DO 182 I=1,N	SS8Q099
IF (I1 .EQ. N1(I)) GO TO 184	SS8Q100
182 CONTINUE	SS8Q101
184 C2(J) = C3(I)	SS8Q102
C	SS8Q103
DO 190 J=2,N	SS8Q104
I1 = N - J + 1	SS8Q105
J1 = I1 + 1	SS8Q106
DO 185 I=1,I1	SS8Q107
C2(I) = C2(I) + C1(I,J1)*C2(J1)	SS8Q108
185 CONTINUE	SS8Q109
190 CONTINUE	SS8Q110
D1 = C1(1,1)/C2(1)	SS8Q111

C3(I) = 1.0 DO	SS8Q112
DO 200 J=2,N	SS8Q113
I1 = J - 1	SS8Q114
C3(J) = C2(J)*C1(J,J)*D1	SS8Q115
DO 195 I=1,I1	SS8Q116
C3(J) = C3(J) + C1(J,I)*C3(I)	SS8Q117
195 CONTINUE	SS8Q118
200 CONTINUE	SS8Q119
201 CONTINUE	SS8Q120
C	SS8Q121
C C3(I) NOW CONTAINS THE EIGENVECTOR WHICH MUST BE RE-ARRANGED	SS8Q122
C ACCORDING TO THE ORDER DICTATED BY N1(I) BACK TO THE ORIGINAL	SS8Q123
C ORDER.	SS8Q124
C	SS8Q125
202 DO 230 I=1,N	SS8Q126
I1 = N1(I)	SS8Q127
N1(I) = I	SS8Q128
205 IF (I1-I) 210,230,210	SS8Q129
210 D1 = C3(I1)	SS8Q130
C3(I1) = C3(I)	SS8Q131
C3(I) = D1	SS8Q132
K = N1(I1)	SS8Q133
N1(I1) = I1	SS8Q134
I1 = K	SS8Q135
GO TO 205	SS8Q136
230 CONTINUE	SS8Q137
C	SS8Q138
IF (NTIME) 240,260,240	SS8Q139
240 CALL STATUS (N1)	SS8Q140
A1 = (N1(8) - IT1)*0.01	SS8Q141
WRITE (6,250) N,A1	SS8Q142
250 FORMAT (1H0,////,42H THE TOTAL TIME FOR OBTAINING THE	SS8Q143
1 ,//, 25H EIGENVECTOR OF ORDER ,I3,6H IS ,E12.5,	SS8Q144
2 9H SECONDS.)	SS8Q145
260 N1(I) = 2	SS8Q146
C	SS8Q147
1000 RETURN	SS8Q148
END	SS8Q149

CC = 00150

	SUBROUTINE DISPLA (C, ITAG)	SS8R000
C		SS8R001
C **	THIS SUBROUTINE CALCULATES AND PRINTS DEFLECTIONS, CURVATURES,	SS8R002
C **	MOMENTS, SHEARS AND EDGE REACTIONS	SS8R003
C		SS8R004
	DIMENSION F(15,25,25), FMAX(15), \$(3,4,4), C(150)	SS8R005
	DIMENSION RA(2,25), RB(2,25), RLN(25)	SS8R006
	DIMENSION A(3,3), B(3,3), D(3,3)	SS8R007
	DIMENSION PKC(50), IGSPRX(50), IGSPRY(50)	SS8R008
	DIMENSION PLINE(50), IDISLS(50), ITAGLS(50)	SS8R009
	DIMENSION E(4,2,3,10,25)	SS8R010
C		SS8R011
	COMMON / ARRAYS / F, FMAX	SS8R012
	COMMON / VALUES / E	SS8R013
	COMMON / PARAM / H(2250), PKC, IGSPRX, IGSPRY,	SS8R014
1	PLINE, IDISLS, ITAGLS	SS8R015
	COMMON / ABD / A, B, D	SS8R016
	COMMON / GEOM / AA, BB, RR	SS8R017
	COMMON / CNTROL / NCNT(7), IREACT, IOUT	SS8R018
	COMMON / NUMBER / NPLY, NTUX, NTVX, NTWX, NTUY,	SS8R019
1	NTVY, NTWY, NMODES, NNUM(10), NPTSUP,	SS8R020
2	NLNSPR, NUVW, NUV, NW	SS8R021
C		SS8R022
	EQUIVALENCE (H(1),RA(1)),(H(51),RB(1)),(H(101),RLN(1))	SS8R023
	EQUIVALENCE (H(126),\$(1))	SS8R024
	DATA NMW / 'W' /, NMU / 'U' /, NMV / 'V' /	SS8R025
C		SS8R026
	ITHERY = 1	SS8R027
40	DO 100 K=1,25	SS8R028
	DO 100 L=1,25	SS8R029
	DO 41 K1=1,3	SS8R030
	DO 41 K2=1,4	SS8R031
	DO 41 K3=1,4	SS8R032
41	\$(K1,K2,K3) = 0.	SS8R033
	M = 1	SS8R034
	IF (ITAG .EQ. 3) M = 3	SS8R035
	IF (IOUT .EQ. 1 .AND. IREACT .EQ. 0) M=3	SS8R036
42	DO 80 N=M,3	SS8R037
	DO 80 I=1,NTWX	SS8R038
	DO 80 J=1,NTWY	SS8R039
	IF (N.EQ.1) II = (I-1)*NTUY + J	SS8R040
	IF (N.EQ.2) II = NTUX*NTUY + (I-1)*NTVY + J	SS8R041
	IF (N.EQ.3) II = NUV + (I-1)*NTWY + J	SS8R042
	IF (N.EQ.3 .AND. ITAG.EQ.3) II = II - NUV	SS8R043
	IF (N.EQ.1) GO TO 50	SS8R044
	IF (N.EQ.2) GO TO 60	SS8R045
	IF (N.EQ.3) GO TO 70	SS8R046
50	\$(N,2,1) = \$(N,2,1) + E(2,1,N,I,K)*E(1,2,N,J,L)*C(II) /AA	SS8R047
	\$(N,3,1) = \$(N,3,1) + E(3,1,N,I,K)*E(1,2,N,J,L)*C(II) /AA/AA	SS8R048
	\$(N,2,2) = \$(N,2,2) + E(2,1,N,I,K)*E(2,2,N,J,L)*C(II) /AA/BB	SS8R049
	\$(N,1,3) = \$(N,1,3) + E(1,1,N,I,K)*E(3,2,N,J,L)*C(II) /BB/BB	SS8R050
	\$(N,1,2) = \$(N,1,2) + E(1,1,N,I,K)*E(2,2,N,J,L)*C(II) /BB	SS8R051
	\$(N,1,1) = \$(N,1,1) + E(1,1,N,I,K)*E(1,2,N,J,L)*C(II)	SS8R052
	GO TO 80	SS8R053
60	\$(N,2,1) = \$(N,2,1) + E(2,1,N,I,K)*E(1,2,N,J,L)*C(II) /AA	SS8R054
	\$(N,3,1) = \$(N,3,1) + E(3,1,N,I,K)*E(1,2,N,J,L)*C(II) /AA/AA	SS8R055

	$\$(N,2,2) = \$(N,2,2) + E(2,1,N,I,K)*E(2,2,N,J,L)*C(II)$	/AA/BB	SS8R056
	$\$(N,1,3) = \$(N,1,3) + E(1,1,N,I,K)*E(3,2,N,J,L)*C(II)$	/BB/BB	SS8R057
	$\$(N,1,2) = \$(N,1,2) + E(1,1,N,I,K)*E(2,2,N,J,L)*C(II)$	/BB	SS8R058
	$\$(N,1,1) = \$(N,1,1) + E(1,1,N,I,K)*E(1,2,N,J,L)*C(II)$		SS8R059
	GO TO 80		SS8R060
70	$\$(N,1,1) = \$(N,1,1) + E(1,1,N,I,K)*E(1,2,N,J,L)*C(II)$		SS8R061
	IF (IOUT .EQ. 1 .AND. IREACT .EQ. 0) GO TO 80		SS8R062
	$\$(N,2,1) = \$(N,2,1) + E(2,1,N,I,K)*E(1,2,N,J,L)*C(II)$	/AA	SS8R063
	$\$(N,3,1) = \$(N,3,1) + E(3,1,N,I,K)*E(1,2,N,J,L)*C(II)$	/AA/AA	SS8R064
	$\$(N,4,1) = \$(N,4,1) + E(4,1,N,I,K)*E(1,2,N,J,L)*C(II)$	/AA/AA/AA	SS8R065
	$\$(N,3,2) = \$(N,3,2) + E(3,1,N,I,K)*E(2,2,N,J,L)*C(II)$	/AA/AA/BB	SS8R066
	$\$(N,2,2) = \$(N,2,2) + E(2,1,N,I,K)*E(2,2,N,J,L)*C(II)$	/AA/BB	SS8R067
	$\$(N,2,3) = \$(N,2,3) + E(2,1,N,I,K)*E(3,2,N,J,L)*C(II)$	/AA/BB/BB	SS8R068
	$\$(N,1,4) = \$(N,1,4) + E(1,1,N,I,K)*E(4,2,N,J,L)*C(II)$	/BB/BB/BB	SS8R069
	$\$(N,1,3) = \$(N,1,3) + E(1,1,N,I,K)*E(3,2,N,J,L)*C(II)$	/BB/BB	SS8R070
	$\$(N,1,2) = \$(N,1,2) + E(1,1,N,I,K)*E(2,2,N,J,L)*C(II)$	/BB	SS8R071
80	CONTINUE		SS8R072
	$F(1,K,L) = \$(3,1,1)$		SS8R073
	IF (IOUT .EQ. 1 .AND. IREACT .EQ. 0) GO TO 100		SS8R074
	$F(2,K,L) = \$(1,1,1)$		SS8R075
	$F(3,K,L) = \$(2,1,1)$		SS8R076
	IF (IOUT .EQ. 2 .AND. IREACT .EQ. 0) GO TO 100		SS8R077
	$EX = \$(1,2,1)$		SS8R078
	$EY = \$(2,1,2) + \$(3,1,1)/RR$		SS8R079
	$EXY = \$(1,1,2) + \$(2,2,1)$		SS8R080
	$XK = -\$(3,3,1)$		SS8R081
	IF (ITHERY .NE. 1) GO TO 85		SS8R082
	$YK = \$(2,1,2)/RR - \$(3,1,3)$		SS8R083
	$XYK = 2.*(\$(2,2,1)/RR - \$(3,2,2))$		SS8R084
	GO TO 86		SS8R085
85	$YK = -\$(3,1,3) - \$(3,1,1)/RR/RR$		SS8R086
	$XYK = -2.*\$(3,2,2) - \$(1,1,2)/RR + \$(2,2,1)/RR$		SS8R087
86	CONTINUE		SS8R088
	$F(4,K,L) = EX$		SS8R089
	$F(5,K,L) = EY$		SS8R090
	$F(6,K,L) = EXY$		SS8R091
	$F(7,K,L) = XK$		SS8R092
	$F(8,K,L) = YK$		SS8R093
	$F(9,K,L) = XYK$		SS8R094
	IF (IOUT .EQ. 3 .AND. IREACT .EQ. 0) GO TO 100		SS8R095
90	$F(10,K,L) = B(1,1)*EX + B(1,2)*EY + B(1,3)*EXY + D(1,1)*XK + D(1,2)*YK$		SS8R096
1	$+ D(1,3)*XYK$		SS8R097
	$F(11,K,L) = B(1,2)*EX + B(2,2)*EY + B(2,3)*EXY + D(1,2)*XK + D(2,2)*YK$		SS8R098
1	$+ D(2,3)*XYK$		SS8R099
	$F(12,K,L) = B(1,3)*EX + B(2,3)*EY + B(3,3)*EXY + D(1,3)*XK + D(2,3)*YK$		SS8R100
1	$+ D(3,3)*XYK$		SS8R101
C **	LET $\$(1,4,4) = MX, X$		SS8R102
C **	$\$(2,4,4) = MY, Y$		SS8R103
C **	$\$(3,4,4) = MXY, X$		SS8R104
C **	$\$(3,4,3) = MXY, Y$		SS8R105
	$\$(1,4,4) = B(1,1)*\$(1,3,1) + B(1,2)*(\$(2,2,2) + \$(3,2,1)/RR)$		SS8R106
1	$+ B(1,3)*(\$(1,2,2) + \$(2,3,1)) - D(1,1)*\$(3,4,1)$		SS8R107
2	$+ D(1,2)*(\$(2,2,2)/RR - \$(3,2,3)) + D(1,3)*2.*\$(2,3,1)/RR$		SS8R108
3	$- \$(3,3,2))$		SS8R109
	$\$(2,4,4) = B(1,2)*\$(1,2,2) + B(2,2)*(\$(2,1,3) + \$(3,1,2)/RR)$		SS8R110
1	$+ B(2,3)*(\$(1,1,3) + \$(2,2,2)) - D(1,2)*\$(3,3,2)$		SS8R111

2	+ D(2,2)*(\$ (2,1,3)/RR-\$ (3,1,4))	SS8R112
3	+ D(2,3)*2.*(\$ (2,2,2)/RR - \$ (3,2,3))	SS8R113
	\$ (3,4,4) = B(1,3)*\$ (1,3,1) + B(2,3)*(\$ (2,2,2)+\$ (3,2,1)/RR)	SS8R114
1	+ B(3,3)*(\$ (1,2,2)+\$ (2,3,1)) - D(1,3)*\$ (3,4,1)	SS8R115
2	+ D(2,3)*(\$ (2,2,2)/RR-\$ (3,2,3))	SS8R116
3	+ D(3,3)*2.*(\$ (2,3,1)/RR-\$ (3,3,2))	SS8R117
	\$ (3,4,3) = B(1,3)*\$ (1,2,2) + B(2,3)*(\$ (2,1,3)+\$ (3,1,2)/RR)	SS8R118
1	+ B(3,3)*(\$ (1,1,3)+\$ (2,2,2)) - D(1,3)*\$ (3,3,2)	SS8R119
2	+ D(2,3)*(\$ (2,1,3)/RR-\$ (3,1,4))	SS8R120
3	+ D(3,3)*2.*(\$ (2,2,2)/RR-\$ (3,2,3))	SS8R121
C		SS8R122
C	F(13,K,L) = QX = MX,X + MXY,Y	SS8R123
C	F(14,K,L) = QY = MY,Y + MXY,X	SS8R124
C		SS8R125
	F(13,K,L) = \$ (1,4,4) + \$ (3,4,3)	SS8R126
	F(14,K,L) = \$ (2,4,4) + \$ (3,4,4)	SS8R127
C		SS8R128
C	RA = QX + MXY,Y	SS8R129
C	RB = QY + MXY,X	SS8R130
C		SS8R131
	IF(K.EQ.1) RA(1,L) = - (F(13,K,L)+ \$ (3,4,3))	SS8R132
	IF(K.EQ.25) RA(2,L) = F(13,K,L)+ \$ (3,4,3)	SS8R133
	IF(L.EQ.1) RB(1,K) = - (F(14,K,L)+ \$ (3,4,4))	SS8R134
	IF(L.EQ.25) RB(2,K) = F(14,K,L)+ \$ (3,4,4)	SS8R135
100	CONTINUE	SS8R136
C		SS8R137
C	TO NORMALIZE	SS8R138
C		SS8R139
	KMAX = 14	SS8R140
	IF (IREACT .NE. 0) GO TO 101	SS8R141
	IF (IOUT .EQ. 1) KMAX = 1	SS8R142
	IF (IOUT .EQ. 2) KMAX = 3	SS8R143
	IF (IOUT .EQ. 3) KMAX = 9	SS8R144
101	CONTINUE	SS8R145
	CALL NRMLIZ (1, KMAX)	SS8R146
	WRITE (6,600) NMW, FMAX(1)	SS8R147
600	FORMAT ('1THE ',A1,' DEFLECTIONS DIVIDED BY ',E15.6,'/10000 FOLLOW	SS8R148
	1')	SS8R149
	CALL OUT (1)	SS8R150
	I=IOUT	SS8R151
	IF(I.EQ.1.OR.I.EQ.6.OR.I.EQ.7.OR.I.EQ.8) GO TO 150	SS8R152
	WRITE (6,600) NMU, FMAX(2)	SS8R153
	CALL OUT (2)	SS8R154
	WRITE (6,600) NMV, FMAX(3)	SS8R155
	CALL OUT (3)	SS8R156
	IF (IOUT .EQ. 2 .OR. IOUT .EQ. 3) GO TO 150	SS8R157
220	WRITE (6,680) FMAX(10)	SS8R158
680	FORMAT ('1MX DIVIDED BY ',E15.6,'/10000 FOLLOWS')	SS8R159
	CALL OUT (10)	SS8R160
	WRITE (6,690) FMAX(11)	SS8R161
690	FORMAT ('1MY DIVIDED BY ',E15.6,'/10000 FOLLOWS')	SS8R162
	CALL OUT (11)	SS8R163
	WRITE (6,700) FMAX(12)	SS8R164
700	FORMAT ('1MXY DIVIDED BY ',E15.6,'/10000 FOLLOWS')	SS8R165
	CALL OUT (12)	SS8R166
	WRITE (6,710) FMAX(13)	SS8R167

710	FORMAT ('1QX DIVIDED BY ',E15.6,'/10000 FOLLOWS')	SS8R168
	CALL OUT (13)	SS8R169
	WRITE (6,720) FMAX(14)	SS8R170
720	FORMAT ('1QY DIVIDED BY ',E15.6,'/10000 FOLLOWS')	SS8R171
	CALL OUT (14)	SS8R172
150	IF (IREACT .EQ. 0) GO TO 900	SS8R173
C **	POINT SPRING REACTIONS	SS8R174
	IF (NPTSUP .EQ. 0) GO TO 170	SS8R175
	DO 160 J=1,NPTSUP	SS8R176
	K = IGSPRX(J)	SS8R177
	L = IGSPRY(J)	SS8R178
	FD = - F(1,K,L) * PKC(J) * FMAX(1)	SS8R179
160	WRITE (6,650) K,L,FD	SS8R180
650	FORMAT ('OTHE REACTION AT GRID POINT 'I3,', 'I3,' IS ',E15.7)	SS8R181
170	CONTINUE	SS8R182
	IF (NLNSPR .EQ. 0) GO TO 725	SS8R183
	DO 210 J=1,NLNSPR	SS8R184
	IF (ITAGLS(J) .EQ. 2) GO TO 190	SS8R185
	L = IDISLS(J)	SS8R186
	DO 180 K=1,25	SS8R187
180	RLN(K) = - F(1,K,L) * PLINE(J) * FMAX(1)	SS8R188
	WRITE (6,660) L, (RLN(K), K=1,25)	SS8R189
660	FORMAT ('OTHE REACTION OF THE LINE SPRING ALONG GRID LINE 'I3,	SS8R190
1	' PARALLEL TO THE X AXIS FOLLOWS'/(5E15.7))	SS8R191
	GO TO 210	SS8R192
190	K = IDISLS(J)	SS8R193
	DO 200 L=1,25	SS8R194
200	RLN(L) = - F(1,K,L) * PLINE(J) * FMAX(1)	SS8R195
	WRITE (6,670) K, (RLN(L), L=1,25)	SS8R196
670	FORMAT ('OTHE REACTION OF THE LINE SPRING ALONG GRID LINE 'I3,	SS8R197
1	' PARALLEL TO THE Y AXIS FOLLOWS'/(5E15.7))	SS8R198
210	CONTINUE	SS8R199
C **	CORNER REACTIONS	SS8R200
725	F(12,1,1) = -2. * F(12,1,1) * FMAX(12)	SS8R201
	F(12,1,25) = 2. * F(12,1,25) * FMAX(12)	SS8R202
	F(12,25,1) = 2. * F(12,25,1) * FMAX(12)	SS8R203
	F(12,25,25) = -2. * F(12,25,25) * FMAX(12)	SS8R204
	WRITE (6,730) (RA(1,L), L=1,25)	SS8R205
730	FORMAT(1H1'THE REACTIONS ALONG X=0 FOLLOW'/(1H07E16.7))	SS8R206
	WRITE (6,740) (RA(2,L), L=1,25)	SS8R207
740	FORMAT(1H0/' THE REACTIONS ALONG X=A FOLLOW'/(1H07E16.7))	SS8R208
	WRITE (6,750) (RB(1,K), K=1,25)	SS8R209
750	FORMAT(1H0/' THE REACTIONS ALONG Y=0 FOLLOW'/(1H07E16.7))	SS8R210
	WRITE (6,760) (RB(2,K), K=1,25)	SS8R211
760	FORMAT(1H0/' THE REACTIONS ALONG Y=B FOLLOW'/(1H07E16.7))	SS8R212
	WRITE (6,770) F(12,1,1)	SS8R213
770	FORMAT(1H0/' THE CORNER REACTION AT 0,0 IS' E16.7)	SS8R214
	WRITE (6,780) F(12,25,1)	SS8R215
780	FORMAT(1H /' THE CORNER REACTION AT A,0 IS' E16.7)	SS8R216
	WRITE (6,790) F(12,1,25)	SS8R217
790	FORMAT(1H /' THE CORNER REACTION AT 0,B IS' E16.7)	SS8R218
	WRITE (6,800) F(12,25,25)	SS8R219
800	FORMAT(1H /' THE CORNER REACTION AT A,B IS' E16.7)	SS8R220
900	IF (IOUT .GE. 3) CALL STRESS	SS8R221
999	RETURN	SS8R222
	END	SS8R223

	SUBROUTINE PRINT	SS8S000
C **		SS8S001
C **	THIS SUBROUTINE CONTROLS THE PRINTING OF GRID POINT OUTPUT.	SS8S002
C **		SS8S003
	DIMENSION T(150,150)	SS8S004
	DIMENSION U(50,50), Q(150), S(150)	SS8S005
	DIMENSION WORK1(150), WORK2(150), ITIME(12), TIME(50)	SS8S006
	DOUBLE PRECISION T	SS8S007
C		SS8S008
	COMMON U	SS8S009
	COMMON / BLOCK / T	SS8S010
	COMMON / CNTROL / ID, IFLAGB, I\$(7), KEY	SS8S011
	COMMON / NUMBER / N\$(6), NTWY, NMODES, M\$(12), NUVW, NUV, NW, ITX, ITY	SS8S012
	COMMON / \$TIME / TIME, ITIME	SS8S013
	COMMON / PARAM / Q, S, WORK1, WORK2	SS8S014
	COMMON / MODES / MM(50), NN(50)	SS8S015
C		SS8S016
	IF (KEY .EQ. 1) GO TO 10	SS8S017
	IF (KEY .EQ. 2) GO TO 20	SS8S018
	IF (KEY .EQ. 3) GO TO 30	SS8S019
C **	STATIC DEFLECTION	SS8S020
10	CONTINUE	SS8S021
	WRITE (6,48) (WORK1(I), I=1,NUVW)	SS8S022
48	FORMAT ('!THE CONTRIBUTIONS OF THE SERIES TERMS TO DEFLECTION FOLL	SS8S023
	OW'/(1X,10E12.4))	SS8S024
	CALL DISPLA (WORK1, 1)	SS8S025
	GO TO 1000	SS8S026
C **	FREE VIBRATION	SS8S027
20	CONTINUE	SS8S028
	DO 9990 I=1,NUVW	SS8S029
	IF (WORK1(I) .LE. .5) GO TO 9990	SS8S030
	ISTART = I	SS8S031
	GO TO 9991	SS8S032
9990	CONTINUE	SS8S033
9991	IFIN = ISTART + NMODES - 1	SS8S034
	DO 90 I=ISTART,IFIN	SS8S035
	WRITE (6,60) WORK1(I), MM(I), NN(I), (T(I,J), J=1,NUVW)	SS8S036
60	FORMAT ('!THE FREQUENCY IS ',E16.7,' CPS. FOR M = ',I2,', N = ',	SS8S037
	1 I2,',.'/!THE CONTRIBUTIONS OF THE SERIES TERMS FOLLOW!/'	SS8S038
	2 (1X,10E12.4))	SS8S039
	DO 70 J=1,NUVW	SS8S040
70	WORK2(J) = T(I,J)	SS8S041
	CALL DISPLA (WORK2, 2)	SS8S042
90	CONTINUE	SS8S043
	GO TO 1000	SS8S044
C **	BUCKLING	SS8S045
30	CONTINUE	SS8S046
	DO 200 I=1,IFLAGB	SS8S047
	BIG = 0.1	SS8S048
	NSAVE = 0	SS8S049
	DO 180 J=1,NW	SS8S050
	IF (ABS (U(I,J)) .LE. BIG) GO TO 180	SS8S051
	BIG = ABS (U(I,J))	SS8S052
	NSAVE = J	SS8S053
180	WORK2(J) = U(I,J)	SS8S054
	M = ITX	SS8S055

N = ITY	SS8S056
IF (NSAVE .EQ. 1) GO TO 6	SS8S057
DO 5 J=2,NSAVE	SS8S058
IF (N+1-ITY .GE. NTWY) GO TO 4	SS8S059
N = N+1	SS8S060
GO TO 5	SS8S061
4 N = ITY	SS8S062
M = M+1	SS8S063
5 CONTINUE	SS8S064
6 CONTINUE	SS8S065
WRITE (6,190) WORK1(I), M, N, (WORK2(J), J=1,NW)	SS8S066
190 FORMAT ('OTHE BUCKLING EIGENVALUE IS' E16.7,' FOR M ='I3,', N ='	SS8S067
1 I3,','/'OTHE CONTRIBUTIONS OF THE SERIES TERMS FOR W FOLL	SS8S068
20W'/(1X,10E12.4))	SS8S069
CALL DISPLA (WORK2, 3)	SS8S070
200 CONTINUE	SS8S071
1000 CONTINUE	SS8S072
CALL STATUS (ITIME)	SS8S073
ET = .01*ITIME(8) - TIME(1)	SS8S074
MINUTE = INT (ET/60.)	SS8S075
SEC = AMOD (ET , 60.)	SS8S076
ISEC = SEC	SS8S077
WRITE (6,66) MINUTE, ISEC	SS8S078
66 FORMAT ('OTHE EXECUTION TIME FOR THIS PROBLEM WAS ',I3,' MINUTES,	SS8S079
1',I2,' SECONDS.')	SS8S080
RETURN	SS8S081
END	SS8S082

CC = 00083

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SUBROUTINE STRESS
C **
C ** THIS SUBROUTINE CALCULATES STRESSES AND STRAINS.
C **
    DIMENSION F(15,25,25), FMAX(5)
    DIMENSION A(3,3), B(3,3), D(3,3), Z(41)
    DIMENSION THETA(40), THICK(40), C11(40), C22(40)
    DIMENSION C12(40), C66(40), ANGCK(3,10), MCHK(3)
    DIMENSION EC(3,40), ET(3,40), SIG(5)
    DIMENSION SIGS(5), SMAR(5), EPSN(5), EPSS(5)

    COMMON / ARRAYS / F, FMAX
    COMMON / ABD / A, B, D, RHAB, THETA, THICK, C11, C22,
1      C66, C12, EC, ET, ANGCK, MCHK, Z
    COMMON / CNTROL / I$(5), IMATL, J$(2), IOUT
    COMMON / NUMBER / NPLYS

    DATA X/'X'/, Y/'Y'/, YO/'LOW'/, UP/'UPP'/
    DATA $X/'X-'/, $Y/'Y-'/, $Z /'XY'/, $1/'1-'/, $2/'2-'/, $3 /'12'/
    DATA SIG(1)/'NORM'/, SIG(2)/'AL S'/, SIG(3)/'TRES'/
    DATA SIG(4)/'SES '/, SIG(5)/' '/
    DATA SIGS(1)/'SHEA'/, SIGS(2)/'R S'/, SIGS(3)/'TRES'/
    DATA SIGS(4)/'SES '/, SIGS(5)/' '/
    DATA SMAR(1)/'MARG'/, SMAR(2)/'INS '/, SMAR(3)/'OF S'/
    DATA SMAR(4)/'AFET'/, SMAR(5)/'Y'/
    DATA EPSN(1)/'NORM'/, EPSN(2)/'AL S'/, EPSN(3)/'TRAI'/
    DATA EPSN(4)/'NS '/, EPSN(5)/' '/
    DATA EPSS(1)/'SHEA'/, EPSS(2)/'R S'/, EPSS(3)/'TRAI'/
    DATA EPSS(4)/'NS '/, EPSS(5)/' '/

    FMIN = 100.
    VAL = 1.
10  FORMAT ('0',25F5.2)
    I = IOUT
    IF(I.EQ.4.OR.I.EQ.6.OR.I.EQ.7.OR.I.EQ.8) GO TO 51
    WRITE (6,20) X, FMAX(4)
    CALL OUT ( 4)
20  FORMAT ('1THE MIDDLE SURFACE STRAIN IN THE ',A1,' DIRECTION DIVIDE
1D BY ',E15.6,'/10000 FOLLOWS')
    WRITE (6,20) Y, FMAX(5)
    CALL OUT ( 5)
    WRITE (6,30) FMAX(6)
    CALL OUT ( 6)
30  FORMAT ('1THE MIDDLE SURFACE SHEAR STRAIN DIVIDED BY ',E15.6,
1      '/10000 FOLLOWS')
    WRITE (6,40) X, FMAX(7)
    CALL OUT ( 7)
40  FORMAT ('1THE CURVATURE IN THE ',A1,' DIRECTION DIVIDED BY ',
1      E15.6,'/10000 FOLLOWS')
    WRITE (6,40) Y, FMAX(8)
    CALL OUT ( 8)
    WRITE (6,50) FMAX(9)
    CALL OUT ( 9)
50  FORMAT ('1THE TWIST CURVATURE DIVIDED BY ',E15.6,'/10000 FOLLOWS')
    IF ( IOUT .EQ. 3 ) GO TO 999
51  IF ( IMATL .EQ. 1 .OR. IMATL .EQ. 4 ) GO TO 150

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C ** SOLID LAMINATE	SS8T056
IF (IOUT .LT. 7) GO TO 999	SS8T057
NP = NPLYS + 1	SS8T058
DO 100 N=1,NP	SS8T059
ITEST = 0	SS8T060
J = N	SS8T061
IF (Z(N) .GE. 0) J = N - 1	SS8T062
IF (C11(J) .LE. 10.) GO TO 100	SS8T063
DO 60 JJ=1,3	SS8T064
J3 = JJ+3	SS8T065
J6 = JJ+6	SS8T066
DO 60 K=1,25	SS8T067
DO 60 L=1,25	SS8T068
60 F(JJ,K,L) = FMAX(J3)*F(J3,K,L) + Z(N)*FMAX(J6)*F(J6,K,L)	SS8T069
70 IF (ITEST .NE. 0) J = N	SS8T070
ANG = THETA(J)	SS8T071
CALL ROTATE (10, 1, ANG)	SS8T072
CALL NRMLIZ (10, 12)	SS8T073
CALL MARGIN (10, 13, J)	SS8T074
WRITE(6,80)J,THETA(J),EPSN,\$1,FMAX(10)	SS8T075
CALL OUT (10)	SS8T076
WRITE(6,80)J,THETA(J),EPSN,\$2,FMAX(11)	SS8T077
CALL OUT (11)	SS8T078
WRITE(6,80)J,THETA(J),EPSS,\$3,FMAX(12)	SS8T079
CALL OUT (12)	SS8T080
WRITE(6,80)J,THETA(J),SMAR,\$1,VAL	SS8T081
CALL OUT (13)	SS8T082
WRITE(6,80)J,THETA(J),SMAR,\$2,VAL	SS8T083
CALL OUT (14)	SS8T084
WRITE(6,80)J,THETA(J),SMAR,\$3,VAL	SS8T085
CALL OUT (15)	SS8T086
80 FORMAT ('1FOR LAYER ',I2,' (THETA = ',F6.2,'), THE ',4A4,A1, ' IN THE ',A2,' DIRECTION DIVIDED BY ',E15.6,'/10000 FOLLOW')	ISS8T087
CALL SEARCH (J,1,13,15,MH,KH,LH,IH,NH,FMIN)	SS8T088
IF (ABS(Z(N)) .GT. 1.E-4) GO TO 100	SS8T089
IF (ABS(THETA(N) - THETA(N-1)) .LT. .01) GO TO 100	SS8T090
IF (ITEST .EQ. 1) GO TO 100	SS8T091
ITEST = 1	SS8T092
GO TO 70	SS8T093
100 CONTINUE	SS8T094
IF (MH .EQ. 13) \$=\$1	SS8T095
IF (MH .EQ. 14) \$=\$2	SS8T096
IF (MH .EQ. 15) \$=\$3	SS8T097
WRITE (6,110) \$, IH, KH, LH, FMIN	SS8T098
110 FORMAT ('1THE MINIMUM MARGIN OF SAFETY OCCURS FOR A STRAIN IN THE ',A2,' DIRECTION IN LAYER ',I2,' AT X = ',I2,' Y = ',I2,' ITS VALUE IS ',F5.2)	SS8T099
2 GO TO 999	SS8T100
C ** ISOTROPIC OR SANDWICH	SS8T101
150 CONTINUE	SS8T102
DO 600 N=1,2	SS8T103
SUR = YO	SS8T104
IF (N.EQ.2) SUR = UP	SS8T105
IF (IMATL .EQ. 4) GO TO 160	SS8T106
I = 1	SS8T107
J = N	SS8T108
	SS8T109
	SS8T110
	SS8T111

GO TO 170	SS8T112
160 I=1	SS8T113
J=1	SS8T114
IF (N.EQ.1) GO TO 170	SS8T115
I = 3	SS8T116
J = 4	SS8T117
170 CONTINUE	SS8T118
C ** CALCULATE COMBINED STRAINS IN PANEL AXES.	SS8T119
DO 180 JJ=1,3	SS8T120
J3 = JJ+3	SS8T121
J6 = JJ+6	SS8T122
DO 180 K=1,25	SS8T123
DO 180 L=1,25	SS8T124
180 F(JJ,K,L) = FMAX(J3)*F(J3,K,L) + Z(J) * FMAX(J6)*F(J6,K,L)	SS8T125
IF (IOUT .LT. 4 .OR. IOUT .EQ. 7) GO TO 240	SS8T126
C ** CALCULATE COMBINED STRESSES IN PANEL AXES.	SS8T127
DO 190 K=1,25	SS8T128
DO 190 L=1,25	SS8T129
F(10,K,L) = C11(I) * F(1,K,L) + C12(I) * F(2,K,L)	SS8T130
F(11,K,L) = C12(I) * F(1,K,L) + C22(I) * F(2,K,L)	SS8T131
190 F(12,K,L) = C66(I) * F(3,K,L)	SS8T132
CALL NRMLIZ (10, 12)	SS8T133
WRITE(6,200) SIG ,SUR,\$X,FMAX(10)	SS8T134
CALL OUT (10)	SS8T135
WRITE(6,200) SIG ,SUR,\$Y,FMAX(11)	SS8T136
CALL OUT (11)	SS8T137
WRITE(6,200) SIGS,SUR,\$Z,FMAX(12)	SS8T138
CALL OUT (12)	SS8T139
200 FORMAT ('1THE ',4A4,A1,' ON THE ',A3,'ER SURFACE IN THE ',A2,	SS8T140
1 ' DIRECTION DIVIDED BY ',E15.6,'/10000 FOLLOW')	SS8T141
240 CONTINUE	SS8T142
IF (IOUT .LT. 7) GO TO 600	SS8T143
IF (IMATL .EQ. 4) GO TO 400	SS8T144
C ** ISOTROPIC	SS8T145
CALL NRMLIZ (1, 3)	SS8T146
CALL MARGIN (1, 10, I)	SS8T147
WRITE(6,200) EPSN,SUR,\$X,FMAX(1)	SS8T148
CALL OUT (1)	SS8T149
WRITE(6,200) EPSN,SUR,\$Y,FMAX(2)	SS8T150
CALL OUT (2)	SS8T151
WRITE(6,200) EPSS,SUR,\$Z,FMAX(3)	SS8T152
CALL OUT (3)	SS8T153
WRITE(6,200) SMAR,SUR,\$X,VAL	SS8T154
CALL OUT (10)	SS8T155
WRITE(6,200) SMAR,SUR,\$Y,VAL	SS8T156
CALL OUT (11)	SS8T157
WRITE(6,200) SMAR,SUR,\$Z,VAL	SS8T158
CALL OUT (12)	SS8T159
CALL SEARCH (I,N,10,12,MH,KH,LH,IH,NH,FMIN)	SS8T160
GO TO 600	SS8T161
C ** SANDWICH	SS8T162
400 NCHK = MCHK(I)	SS8T163
DO 500 NN=1,NCHK	SS8T164
ANG = ANGCK(I,NN)	SS8T165
CALL ROTATE (10, 1, ANG)	SS8T166
CALL NRMLIZ (10, 12)	SS8T167

CALL MARGIN (10, 13, I)	SS8T168
CALL SEARCH (I, NN, 13, 15, MH, KH, LH, IH, NH, FMIN)	SS8T169
WRITE(6,410) ANG, EPSN, SUR, \$1, FMAX(10)	SS8T170
CALL OUT (10)	SS8T171
WRITE(6,410) ANG, EPSN, SUR, \$2, FMAX(11)	SS8T172
CALL OUT (11)	SS8T173
WRITE(6,410) ANG, EPSS, SUR, \$3, FMAX(12)	SS8T174
CALL OUT (12)	SS8T175
WRITE(6,410) ANG, SMAR, SUR, \$1, VAL	SS8T176
CALL OUT (13)	SS8T177
WRITE(6,410) ANG, SMAR, SUR, \$2, VAL	SS8T178
CALL OUT (14)	SS8T179
WRITE(6,410) ANG, SMAR, SUR, \$3, VAL	SS8T180
CALL OUT (15)	SS8T181
410 FORMAT ('1FOR THETA = ', F6.2, ', THE ', 4A4, A1, ' ON THE ', A3,	SS8T182
1'ER SURFACE IN THE ', A2, ' DIRECTION DIVIDED BY ',	SS8T183
2 E15.6, '/10000 FOLLOW')	SS8T184
500 CONTINUE	SS8T185
600 CONTINUE	SS8T186
IF (IOUT .LT. 7) GO TO 999	SS8T187
IF (IMATL .EQ. 4) GO TO 620	SS8T188
IF (MH .EQ. 10) \$=\$1	SS8T189
IF (MH .EQ. 11) \$=\$2	SS8T190
IF (MH .EQ. 12) \$=\$3	SS8T191
IF (NH .EQ. 1) SUR = YO	SS8T192
IF (NH .EQ. 2) SUR = UP	SS8T193
WRITE (6,610) \$, SUR, KH, LH, FMIN	SS8T194
610 FORMAT ('1THE MINIMUM MARGIN OF SAFETY OCCURS FOR A STRAIN IN THE	SS8T195
1', A2, ' DIRECTION ON THE ', A3, 'ER SURFACE AT X = ', I2, ', Y = ', I2,	SS8T196
2 ' ', '/ ' ITS VALUE IS ', F6.2)	SS8T197
GO TO 999	SS8T198
620 ANG = ANGCK(IH, NH)	SS8T199
IF (MH .EQ. 13) \$=\$1	SS8T200
IF (MH .EQ. 14) \$=\$2	SS8T201
IF (MH .EQ. 15) \$=\$3	SS8T202
WRITE (6,630) \$, ANG, IH, KH, LH, FMIN	SS8T203
630 FORMAT ('1THE MINIMUM MARGIN OF SAFETY OCCURS FOR A STRAIN IN THE	SS8T204
1', A2, ' DIRECTION AT AN ANGLE THETA OF ', F6.2, ' DEGREES IN LAYER '	SS8T205
2 ', I2, ' ', '/ ' IT IS LOCATED AT X = ', I2, ', Y = ', I2, ', AND HAS A VAL	SS8T206
3UE OF ', F6.2)	SS8T207
999 RETURN	SS8T208
END	SS8T209

CC = 00210

	SUBROUTINE ROTATE (M, MX, ANG)	SS8U000
C **		SS8U001
C **	THIS SUBROUTINE PERFORMS A TRANSFORMATION OF COORDINATES	SS8U002
C **	FROM THETA = 0. TO THETA = ANG .	SS8U003
C **		SS8U004
	DIMENSION F(15,25,25)	SS8U005
C		SS8U006
	COMMON / ARRAYS / F	SS8U007
C		SS8U008
	M1 = M+1	SS8U009
	M2 = M+2	SS8U010
	MX1 = MX+1	SS8U011
	MX2 = MX+2	SS8U012
	A = ANG * .0174533	SS8U013
	C = COS(A)	SS8U014
	S = SIN(A)	SS8U015
	C2 = C*C	SS8U016
	S2 = S*S	SS8U017
	SC = S*C	SS8U018
	DO 10 K=1,25	SS8U019
	DO 10 L=1,25	SS8U020
	F(M,K,L) = F(MX,K,L)*C2 + F(MX1,K,L)*S2 + F(MX2,K,L)*SC	SS8U021
	F(M1,K,L) = F(MX,K,L)*S2 + F(MX1,K,L)*C2 + F(MX2,K,L)*SC	SS8U022
10	F(M2,K,L) = -2.*SC*(F(MX,K,L) - F(MX1,K,L)) + F(MX2,K,L)*(C2-S2)	SS8U023
	RETURN	SS8U024
	END	SS8U025

CC = 00026

	SUBROUTINE NRMLIZ (M1, M2)	SS8V000
C **		SS8V001
C **	THE INPUT ARRAYS ARE NORMALIZED BY THEIR LARGEST VALUES.	SS8V002
C **		SS8V003
	DIMENSION F(15,25,25), FMAX(15)	SS8V004
C		SS8V005
	COMMON / ARRAYS / F, FMAX	SS8V006
C		SS8V007
	DO 30 M=M1,M2	SS8V008
	FMAX(M) = F(M,1,1)	SS8V009
	DO 10 K=1,25	SS8V010
	DO 10 L=1,25	SS8V011
	FD = ABS (F(M,K,L))	SS8V012
	IF (FD .GT. FMAX(M)) FMAX(M) = FD	SS8V013
10	CONTINUE	SS8V014
	IF (ABS (FMAX(M)) .LT. 1.E-10) FMAX(M) = 1.	SS8V015
	DO 20 K=1,25	SS8V016
	DO 20 L=1,25	SS8V017
20	F(M,K,L) = F(M,K,L) / FMAX(M)	SS8V018
30	CONTINUE	SS8V019
	RETURN	SS8V020
	END	SS8V021

CC = 00022

	SUBROUTINE MARGIN (MSTRN, MMAR, LAY)	SS8W000
C **		SS8W001
C **	THIS SUBROUTINE CALCULATES MARGINS OF SAFETY ACCORDING	SS8W002
C **	TO THE MAXIMUM STRAIN THEORY.	SS8W003
C **		SS8W004
	DIMENSION F(15,25,25), FMAX(15), EA(3), ET(3,40), EC(3,40)	SS8W005
C		SS8W006
	COMMON / ARRAYS / F, FMAX	SS8W007
	COMMON / ABD / DUM(268), EC, ET	SS8W008
C		SS8W009
	DO 10 M=1,3	SS8W010
	I= M+MSTRN -1	SS8W011
	J= M+MMAR -1	SS8W012
	DO 10 K=1,25	SS8W013
	DO 10 L=1,25	SS8W014
	EA(M) = ET(M,LAY)	SS8W015
	IF (F(I,K,L) .LE. 0.) EA(M) = EC(M,LAY)	SS8W016
	F(J,K,L) = 9.0	SS8W017
	IF (F(I,K,L) .NE. 0.) F(J,K,L) = EA(M)/F(I,K,L)/FMAX(I) - 1.	SS8W018
	IF (F(J,K,L) .GE. 9.99) F(J,K,L) = 9.98	SS8W019
	IF (F(J,K,L) .LE.-9.99) F(J,K,L) =-9.98	SS8W020
10	CONTINUE	SS8W021
	RETURN	SS8W022
	END	SS8W023

CC = 00024

	SUBROUTINE REDUCE (NOPT,V,Z1,Z2,Z3,Z4,WORK1,WORK2,NUV,NW)	SS8W025
	DIMENSION V(150,150), Z1(100,100), Z2(100,50), Z3(50,100),	SS8W026
	1 Z4(50,50), WORK1(150), WORK2(150)	SS8W027
C		SS8W028
	DO 10 I=1,NUV	SS8W029
	DO 10 J=1,NUV	SS8W030
10	Z1(I,J) = V(I,J)	SS8W031
	DO 20 I=1,NUV	SS8W032
	DO 20 J=1,NW	SS8W033
20	Z2(I,J) = V(I,J+NUV)	SS8W034
	DO 30 I=1,NW	SS8W035
	DO 30 J=1,NUV	SS8W036
30	Z3(I,J) = V(I+NUV,J)	SS8W037
	CALL GJINV (Z1,NUV,0,IER,WORK1,WORK2,100)	SS8W038
	CALL SWITCH (Z1, NUV, 50, 1., 0.)	SS8W039
	CALL YOSFEM (2,Z1,NUV,NUV,50,Z2,NW,50,V,WORK1)	SS8W040
	CALL YOSFEM (3,Z3,NW,NUV,25,Z2,NW,50,Z4,WORK1)	SS8W041
	DO 40 I=1,NW	SS8W042
	DO 40 J=1,NW	SS8W043
40	Z4(I,J) = V(I+NUV,J+NUV) - Z4(I,J)	SS8W044
50	DO 60 I=1,NW	SS8W045
	DO 60 J=1,NW	SS8W046
60	V(I,J) = Z4(I,J)	SS8W047
999	RETURN	SS8W048
	END	SS8W049

CC = 00025

	SUBROUTINE FLEX	SS8Y000
C	THIS SUBROUTINE CALCULATES THE FLEXIBILITY MATRIX AT THE	SS8Y001
C	DESIRED POINTS.	SS8Y002
	COMMON / FLEXBL / XP(50), YP(50)	SS8Y003
	COMMON / ZWORK / W(50,50), EM(50,50), FL(50,50),	SS8Y004
1	W1(50), W2(50)	SS8Y005
	COMMON / VALUES / E(4,2,3,10,25)	SS8Y006
	COMMON / NUMBER / NPLYS, NTX, N\$(2), NTY, M\$(15), MAT, NUV, NW	SS8Y007
	COMMON / CNTROL / I\$(14), IFLEX	SS8Y008
	COMMON / ARRAYS / V(150,150)	SS8Y009
	DO 10 I=1,NW	SS8Y010
	DO 10 J=1,NW	SS8Y011
10	W(I,J) = V(I,J)	SS8Y012
	CALL GJINV (W, NW, 0, IER, W1, W2, 50)	SS8Y013
	DO 20 II=1,IFLEX	SS8Y014
	I = XP(II)*24 + 1	SS8Y015
	J = YP(II)*24 + 1	SS8Y016
	IF (I.LT.1) I=1	SS8Y017
	IF (J.LT.1) J=1	SS8Y018
	IF (I.GT.24) I=24	SS8Y019
	IF (J.GT.24) J=24	SS8Y020
	IP1 = I + 1	SS8Y021
	JP1 = J + 1	SS8Y022
	DELX = XP(II)*24. - (I-1)	SS8Y023
	DELY = YP(II)*24. - (J-1)	SS8Y024
	DO 20 L = 1,NTX	SS8Y025
	DO 20 K = 1,NTY	SS8Y026
	JJ = NTY*(L-1) + K	SS8Y027
	EVX = E(1,1,3,L,I)*(1.-DELX) + E(1,1,3,L,IP1)*DELX	SS8Y028
	EVY = E(1,2,3,K,J)*(1.-DELY) + E(1,2,3,K,JP1)*DELY	SS8Y029
	EM(II,JJ) = EVX * EVY	SS8Y030
20	CONTINUE	SS8Y031
	DO 60 II=1,IFLEX	SS8Y032
	DO 40 JJ=1,NW	SS8Y033
	W1(JJ) = 0.	SS8Y034
	DO 30 KK=1,NW	SS8Y035
30	W1(JJ) = W1(JJ) + W(JJ,KK) * EM(II,KK)	SS8Y036
40	CONTINUE	SS8Y037
	DO 50 LL=1,IFLEX	SS8Y038
	FL(II,LL) = 0.	SS8Y039
	DO 50 KK=1,NW	SS8Y040
50	FL(II,LL) = FL(II,LL) + EM(LL,KK) * W1(KK)	SS8Y041
60	CONTINUE	SS8Y042
	WRITE (6,70)	SS8Y043
70	FORMAT ('IFLEXIBILITY MATRIX')	SS8Y044
	DO 90 I=1,IFLEX	SS8Y045
	WRITE (6,80) I, (FL(I,J), J=1,IFLEX)	SS8Y046
80	FORMAT ('OROW',I3//('1P6E16.6'))	SS8Y047
90	CONTINUE	SS8Y048
	RETURN	SS8Y049
	END	SS8Y050

CC = 00051

	SUBROUTINE KDF (BUCKNX)	SS8Z000
C		SS8Z001
C	COMPUTES AXIAL BUCKLING NX FOR IMPERFECT ANISOTROPIC CYLINDERS	SS8Z002
C		SS8Z003
	DIMENSION AS(3,3), BS(3,3), DS(3,3), W1(3), W2(3)	SS8Z004
	COMMON / ABD / A(3,3), B(3,3), D(3,3)	SS8Z005
	COMMON / GEOM / AA, BB, RR, S\$(4), MU	SS8Z006
	COMMON / CUBE / P1, P2, P3, P4, ROOT	SS8Z007
	DIMENSION ITIME(12)	SS8Z008
	DIMENSION ATAU(20), AMDA(20)	SS8Z009
	REAL MU	SS8Z010
C		SS8Z011
	FAC = 100	SS8Z012
	RHO = .707	SS8Z013
	DO 10 I=1,3	SS8Z014
	DO 10 J=1,3	SS8Z015
	10 AS(I,J) = A(I,J)	SS8Z016
	CALL GJINV (AS, 3, 0, IER, W1, W2, 3)	SS8Z017
C **	AS = A**-1	SS8Z018
	DO 20 I=1,3	SS8Z019
	DO 20 J=1,3	SS8Z020
	20 BS(I,J) = - B(I,J)	SS8Z021
	CALL YOSFEM (2, AS, 3, 3, 3, BS, 3, 3, D, W1)	SS8Z022
C	BS = - A**-1 * B	SS8Z023
	CALL YOSFEM (3, B, 3, 3, 3, BS, 3, 3, DS, W1)	SS8Z024
	DO 30 I=1,3	SS8Z025
	DO 30 J=1,3	SS8Z026
	30 DS(I,J) = D(I,J) + DS(I,J)	SS8Z027
C	DS = D - B * A**-1 * B	SS8Z028
	GAM = 1./SQRT(AS(2,2)*DS(1,1))	SS8Z029
	ALP = DS(1,1)*GAM	SS8Z030
	BET = BS(2,1)*GAM	SS8Z031
	IMAX = 10	SS8Z032
	TAUO = 0.	SS8Z033
	FTAU = 10.	SS8Z034
	40 DO 100 I=1,IMAX	SS8Z035
	ATAU(I) = TAUO + I/FTAU	SS8Z036
	TAU = ATAU(I)	SS8Z037
	D12 = DS(1,1)*RHO**4 + (2.*DS(1,2) + 4.*DS(3,3)) *RHO**2*TAU**2	SS8Z038
1	+ DS(2,2)*TAU**4	SS8Z039
	A11 = AS(2,2)*RHO**4 + (2.*AS(1,2) + AS(3,3)) *RHO**2*TAU**2	SS8Z040
1	+ AS(1,1)*TAU**4	SS8Z041
	A13 = AS(2,2)*81.*RHO**4 + (2.*AS(1,2) + AS(3,3)) *9.*RHO**2	SS8Z042
1	* TAU**2 + AS(1,1)*TAU**4	SS8Z043
	A21 = -2.*AS(2,3)*RHO**3*TAU - 2.*AS(1,3)*RHO*TAU**3	SS8Z044
	A22 = -A21	SS8Z045
	A23 = 2.*AS(2,3)*27.*RHO**3*TAU + 2.*AS(1,3)*3.*RHO*TAU**3	SS8Z046
	B11 = BS(2,1)*RHO**4 + (BS(1,1) + BS(2,2) - 2.*BS(3,3)) *RHO**2	SS8Z047
1	* TAU**2 + BS(1,2)*TAU**4	SS8Z048
	B11P = B11 - 2.*RHO*RHO/GAM	SS8Z049
	B22 = (BS(3,1) - 2.*BS(2,3)) * RHO**3*TAU + (BS(3,2)	SS8Z050
1	- 2.*BS(1,3)) * RHO*TAU**3	SS8Z051
	C1 = RHO*RHO + (1.-2.*RHO*RHO*BET)**2/4./RHO/RHO	SS8Z052
	D1 = A11*A11 - A21*A21	SS8Z053
	D3 = A13*A13 - A23*A23	SS8Z054
	A1 = D12 + ((A11*B11P - A22*B22) * B11P + (A11*B22 - A22*B11P)	SS8Z055

1	* B22) / D1	SS8Z056
	A2 = 4.*ALP*RHO*RHO/GAM	SS8Z057
	A3 = 4.*MU*RHO*RHO*TAU*TAU* (A11*B11P - A22*B22) *C1/D1	SS8Z058
	A4 = MU*ALP* (1. - 2.*RHO*RHO*BET) *TAU*TAU	SS8Z059
	A5 = 4.*MU*MU*RHO**4*TAU**4*C1*C1* (A11/D1 + A13/D3)	SS8Z060
	P1 = A2	SS8Z061
	P2 = - (A1 + 2.*A2*C1 + A4)	SS8Z062
	P3 = 2.*A1*C1 + A2*C1*C1 + A4*C1 + A3	SS8Z063
	P4 = - (A1*C1*C1 + A3*C1 + A5)	SS8Z064
	CALL CUBIC	SS8Z065
	AMDA(I) = ROOT	SS8Z066
100	CONTINUE	SS8Z067
	CALL MIN (AMDA, IMAX, IMIN)	SS8Z068
	IF (IMAX .EQ. 20) GO TO 200	SS8Z069
	TAUO = ATAU(IMIN) - .1	SS8Z070
	IMAX = 20	SS8Z071
	FTAU = 100	SS8Z072
	GO TO 40	SS8Z073
200	CONTINUE	SS8Z074
	FAC = AMDA(IMIN)	SS8Z075
	TAU = ATAU(IMIN)	SS8Z076
50	BUCKNX = 2.*ALP*FAC/RR	SS8Z077
	PBUCK = 2.*RR*BUCKNX*3.14159	SS8Z078
	WRITE (6,600) RHO, TAU, FAC, BUCKNX, PBUCK	SS8Z079
600	FORMAT ('OIMPERFECTION SENSITIVITY ANALYSIS FOR FULL CYLINDER --	SS8Z080
1	RHO, TAU, LAMBDA-CR, NX-CR, P-CR'/' ' ',5E20.6)	SS8Z081
	RETURN	SS8Z082
	END	SS8Z083

CC = 00084

	SUBROUTINE CUBIC	SS8\$000
C	SOLVES A CUBIC POLYNOMIAL FOR THE REAL ROOT BY NEWTON-RAPHSON	SS8\$001
	COMMON / CUBE / P1, P2, P3, P4, Y	SS8\$002
	X = 1	SS8\$003
	I = 0	SS8\$004
1	F = P1*X*X*X + P2*X*X + P3*X + P4	SS8\$005
	I = I + 1	SS8\$006
	FP = 3.*P1*X*X + 2.*P2*X + P3	SS8\$007
	Y = X - F/FP	SS8\$008
	IF (ABS(1-Y/X).LE. .001) GO TO 10	SS8\$009
	X = Y	SS8\$010
	IF (I .LT. 10) GO TO 1	SS8\$011
10	CONTINUE	SS8\$012
	A = P1	SS8\$013
	B = P1*Y + P2	SS8\$014
	C = P1*Y*Y + P2*Y + P3	SS8\$015
	DISC = B*B - 4.*A*C	SS8\$016
	IF (DISC) 20,30,30	SS8\$017
20	WRITE (6,70)	SS8\$018
70	FORMAT ('OOTHER TWO ROOTS ARE COMPLEX')	SS8\$019
	GO TO 100	SS8\$020
30	X1 = (-B + SQRT(DISC)) /2./A	SS8\$021
	X2 = (-B - SQRT(DISC)) /2./A	SS8\$022
	Y = AMIN1 (Y,X1,X2)	SS8\$023
100	CONTINUE	SS8\$024
	RETURN	SS8\$025
	END	SS8\$026

CC = 00027

	SUBROUTINE OUT (N)	SS8/000
C **		SS8/001
C **	THIS SUBROUTINE PUTS THE ARRAYS OF OUTPUT IN A FORM FOR	SS8/002
C **	EFFICIENT WRITING.	SS8/003
C **		SS8/004
	COMMON / ARRAYS / F(15,25,25), FMAX(15), LIST(625)	SS8/005
C		SS8/006
	DO 10 K=1,25	SS8/007
	DO 10 L=1,25	SS8/008
	J = (K-1) * 25 + L	SS8/009
10	LIST(J) = F(N,K,L) * 10000	SS8/010
	WRITE (6,20) LIST	SS8/011
20	FORMAT ('0',25I5)	SS8/012
	RETURN	SS8/013
	END	SS8/014

CC = 00015

SUBROUTINE MIN (VEC, N, IMIN)	SS8 000
DIMENSION VEC(N)	SS8 001
SMALL = 10.	SS8 002
DO 10 I=1,N	SS8 003
IF (SMALL .LT. VEC(I)) GO TO 10	SS8 004
SMALL = VEC(I)	SS8 005
IMIN = I	SS8 006
10 CONTINUE	SS8 007
RETURN	SS8 008
END	SS8 009

CC = 00010