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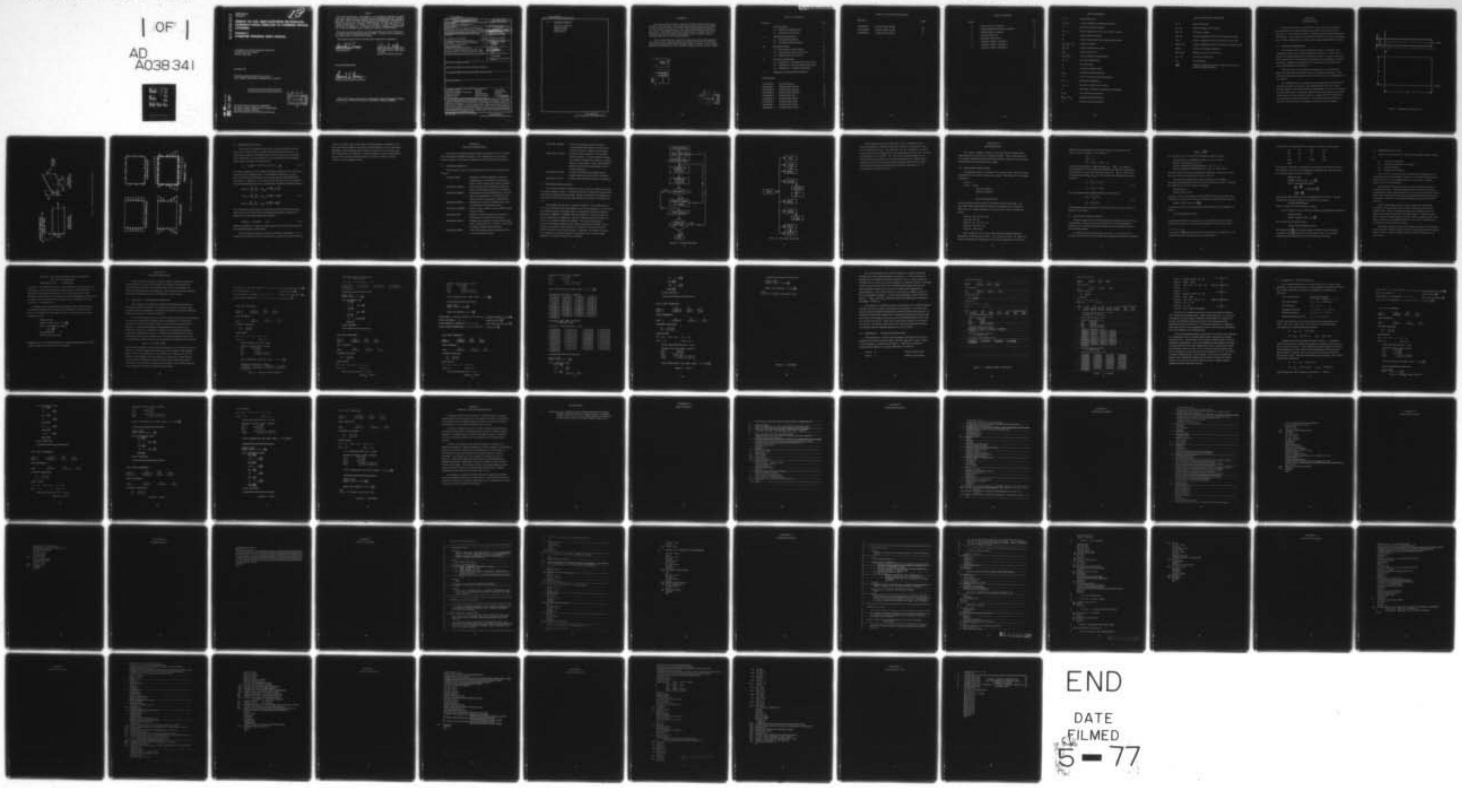

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Volume II

STABILITY OF FLAT, SIMPLY-SUPPORTED RECTANGULAR SANDWICH PANELS SUBJECTED TO COMBINED INPLANE LOADINGS

Volume II
COMPUTER PROGRAM USER'S MANUAL

UNIVERSITY OF DAYTON RESEARCH INSTITUTE
300 COLLEGE PARK AVENUE
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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A computer program which implements the stability analysis of flat, simply supported sandwich composite panels is presented. The program is operable either in an interactive or batch mode, and provides for multiple problem runs and selective editing of current problem data. Instructions for data input are given, and a number of example problems are shown. The numerical analysis which is applicable to three-layer sandwich constructions having isotropic thin face sheets and orthotropic cores, is based upon a Ritz-method discretization of the linearized potential energy.

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FOREWORD

The work reported herein was performed by the Aerospace Mechanics Division of the University of Dayton Research Institute, Dayton, Ohio, under Air Force Contract F33615-75-C-3009, "Structural Sandwich Composites," for the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. This effort was directed under Task 02 of Project 1368, with Technical direction and support being provided by Mr. Harold C. Croop (AFFDL/FBS) as Air Force Project Engineer.

The work described was conducted during the period between November 1974 and June 1975, under the general supervision of Mr. Dale H. Whitford, Supervisor, Aerospace Mechanics Division, and Mr. George J. Roth, Leader, Structural Analysis Group. The principal investigator was Dr. Fred K. Bogner.

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LIST OF SYMBOLS

a, b	panel dimensions
E_1, E_2	Young's Moduli of sandwich face sheets
G	geometric stiffness matrix
G_x, G_y	shear moduli of the core in x-z and y-z planes
K	elastic stiffness matrix
N	range of summation in the displacement series
N_x, N_{xy}, N_y	stress resultants
$\overline{N}_x, \overline{N}_y$	critical compressive loads
$\overline{N}_{xy}$	critical shear load
$\overline{N}_{xb}, \overline{N}_{yb}$	critical edgewise bending loads
t_1, t_2	face sheet thicknesses
t_c	core thickness
w	transverse displacement
w_{mn}	assumed-mode parameters
W	vector of assumed-mode parameters
x, y, z	Cartesian coordinates
ν_1, ν_2	Poisson's ratios of face sheets
λ	eigenvalue, related to the intensity of loading
ϕ, ψ	core rotation parameters
Φ_{mn}, Ψ_{mn}	assumed-mode parameters
π_p	potential energy functional

LIST OF PROGRAM VARIABLES

A, B	panel dimensions
E1, E2	Young's Moduli of face sheets
GX, GY	core shear moduli
NX, NY	relative magnitude factors for compressive loads
NXY	relative magnitude factor for edgewise shear load
NXB, NYB	relative magnitude factors for edgewise bending loads
NRUN	counter for multiple solutions
NU1, NU2	Poisson's ratios of face sheets
T1, T2	face sheet thicknesses
TC	core thickness
CR	indicates depression of the carriage return key on a remote terminal keyboard

SECTION I
INTRODUCTION

The problem of general instability of a flat, rectangular sandwich panel subjected to combined inplane edge loads has been considered in Reference 1. This report describes a computer program which implements that analysis. The program is suitable for interactive or batch processing, and is readily adapted for use in interactive design/optimization programs.

1.1 PROBLEM DESCRIPTION

The sandwich panel under consideration is flat, rectangular and composed of three layers of uniform thickness (Figure 1). Each edge of the panel is simply supported, as indicated in Figure 2, and the transverse shear strains of the core parallel to the boundary are assumed to vanish on each edge. Edgewise loads applied to the panel consist of compression, shear and bending forces (Figure 3).

Each face sheet of the sandwich is idealized as an isotropic thin plate which deforms according to the Love-Kirchhoff assumptions. The thickness and material properties of the two face sheets are independent of one another.

The sandwich core is assumed to be incompressible in the direction normal to the plane of the panel, and rigidly bonded to the face sheets. Since the inplane extensional and flexural stiffnesses of most core materials are generally small in comparison with the extensional stiffness of the face sheets, the core strain energy is taken to consist solely of contributions due to transverse shear deformation. The elastic properties of the core therefore consist of the two independent transverse shear rigidities.

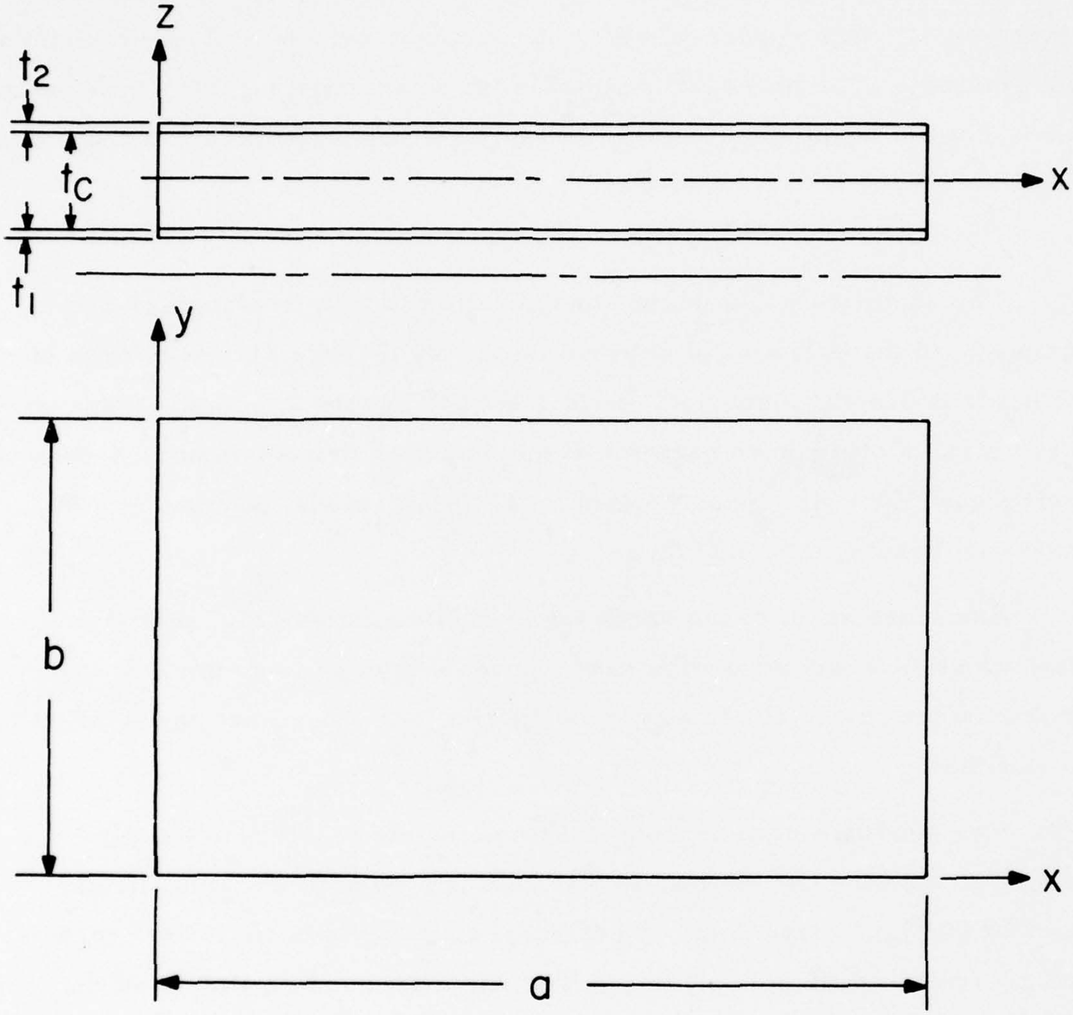

Figure 1. Sandwich Panel Geometry.

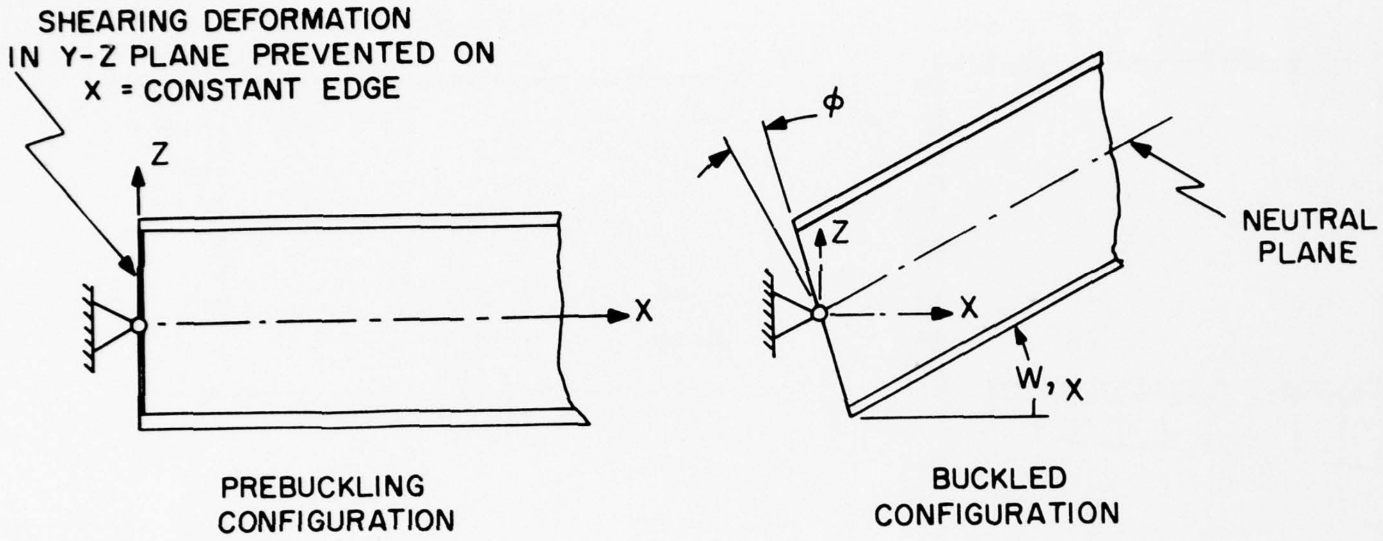

Figure 2. Simply Supported Boundary Condition.

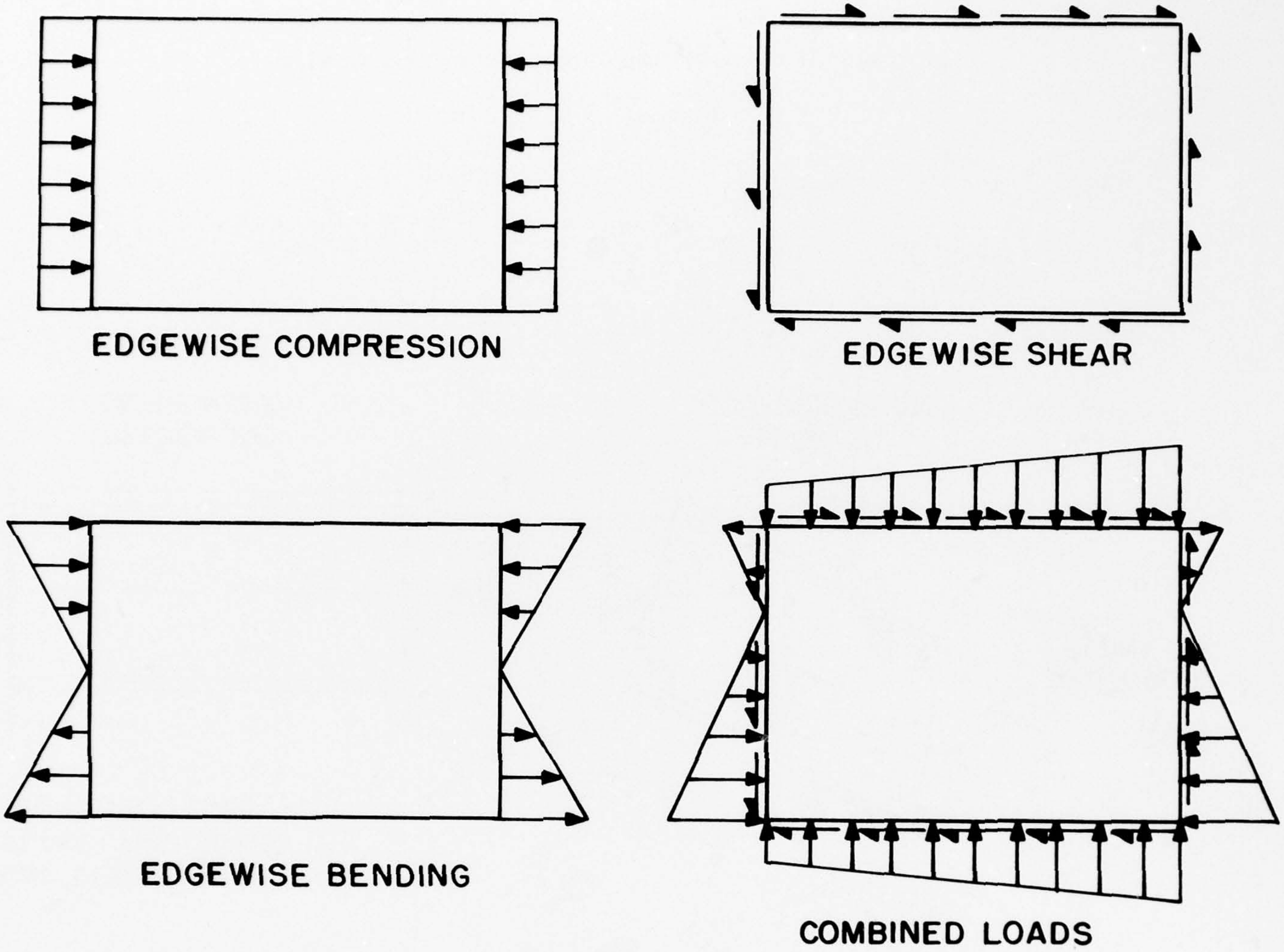

Figure 3. Applied Inplane Loadings.

1.2 METHOD OF SOLUTION

The analysis contained in the subject computer program is based upon a discrete form of the principle of minimum potential energy. By relating the components of displacement in the face sheets to the displacements within the core, the potential energy associated with the buckling deformation of the panel is expressed as:

$$\pi_p = \pi_p \left[\phi(x,y),\ \psi(x,y),\ w(x,y),\ e_x,\ e_y \right] \tag{1.1}$$

Here $\phi(x,y)$ and $\psi(x,y)$ are related to rotations within the core, and $w(x,y)$ is the transverse displacement. Two additional parameters e_x and e_y describe the effects of unbalanced face sheets upon the buckling displacement pattern. Equation 1.1 is cast into a discrete form by the introduction of assumed displacement modes satisfying the conditions of simple support:

$$\begin{aligned}
\phi(x,y) &= \sum_{m=1}^{N} \sum_{n=1}^{N} \Phi_{mn} \cos\frac{m\pi x}{a} \sin\frac{n\pi y}{b} \\
\psi(x,y) &= \sum_{m=1}^{N} \sum_{n=1}^{N} \Psi_{mn} \sin\frac{m\pi x}{a} \cos\frac{n\pi y}{b} \\
w(x,y) &= \sum_{m=1}^{N} \sum_{n=1}^{N} W_{mn} \sin\frac{m\pi x}{a} \sin\frac{n\pi y}{b}
\end{aligned} \tag{1.2}$$

The requirement that the discrete potential energy function be minimized with respect to the undetermined coefficients appearing in Equation 1.2 results in the generalized eigenvalue problem:

$$[K]\{W\} + \lambda[G]\{W\} = \{o\} \tag{1.3}$$

Solution of Equation 1.3 yields an approximation to the critical load and the corresponding buckled mode shapes.

In the computer program, at least two solutions of Equation 1.3 are performed per problem in order to assess the convergence of the numerical result. An initial value of the limit N of summations (see Equation 1. 2) is first selected, according to the types of loading which are to be considered. Solutions are then obtained using N and (N + 1) terms in each series, and the critical loads are compared. Further solutions are performed until the change in the calculated buckling loads is less than 0. 250%, or until N reaches a preset maximum value.

SECTION II

PROGRAM DESCRIPTION

The subject computer program (listed in Appendices A-L) is coded in CDC FORTRAN-EXTENDED language. The organization of the program and the functions of individual subprograms are described in this section.

2.1 PROGRAM SEGMENTS

The functions of each of the individual sections of the program are as follows:

Program MAIN - initializes control parameters, calls the subprograms, and computes the execution times of major steps in the problem solution.

Subroutine INDATA - reads problem data, initializes sizing parameters and defines all geometric constants.

Subroutine ASSMBL - assembles the elastic stiffness [K] , and computes the contributions of compression and shear loads to the geometric stiffness [G].

Subroutine BEND1 - computes the geometric stiffness terms due to nonuniform (edge bending) loads.

Subroutine CRAMER - solves a linear system of four equations using Cramer's Rule.

Subroutine DET - performs a literal expansion to obtain the determinant of a matrix of order four.

Subroutine NROOT - manages the solution of the generalized eigenvalue problem $[A]\{X\} = \lambda [B]\{X\}$, where [B] is positive definite and symmetric.

Subroutine EIGEN - extracts the eigenvalues and eigenvectors of a real, symmetric matrix.

Subroutine CHECK - locates a minimum eigenvalue and the corresponding mode shape, and determines whether or not the solution has converged.

Subroutine OUTPUT - prints the final solution for critical loads and mode shapes. During batch processing, intermediate solutions and segment execution times are also printed. Entry point ECHO is called to reprint the problem data for verification purposes.

Subroutine ALTER - accepts corrections and modifications to problem data during interactive execution.

Subroutine TITLE - prints a title heading at the start of execution.

2.2 PROGRAM ORGANIZATION

The general structure and flow of control within the computer program is shown in Figures 4 and 5. Execution proceeds in exactly the same way for both batch and interactive processing, with the exceptions of a multiple-run provision in the batch mode and a data modification sequence for interactive use.

The solution procedure is arranged as follows. The problem data is read, and an initial range on the displacement series (Equation 1.2) is chosen, according to the types of loading which are specified (subroutine INDATA). Subroutines ASSMBL, CRAMER, DET and BEND1 are entered to form the elastic and geometric stiffnesses, and the resulting eigenvalue problem is solved in subroutines NROOT and EIGEN. The lowest eigenvalue is located and compared with previous solutions (subroutine CHECK). If the required convergence test is passed, the solution is printed (subroutine OUTPUT), and a new problem is begun. Otherwise, the number of terms in the displacement approximation is increased by one, and subroutine ASSMBL is recalled to begin the next solution.

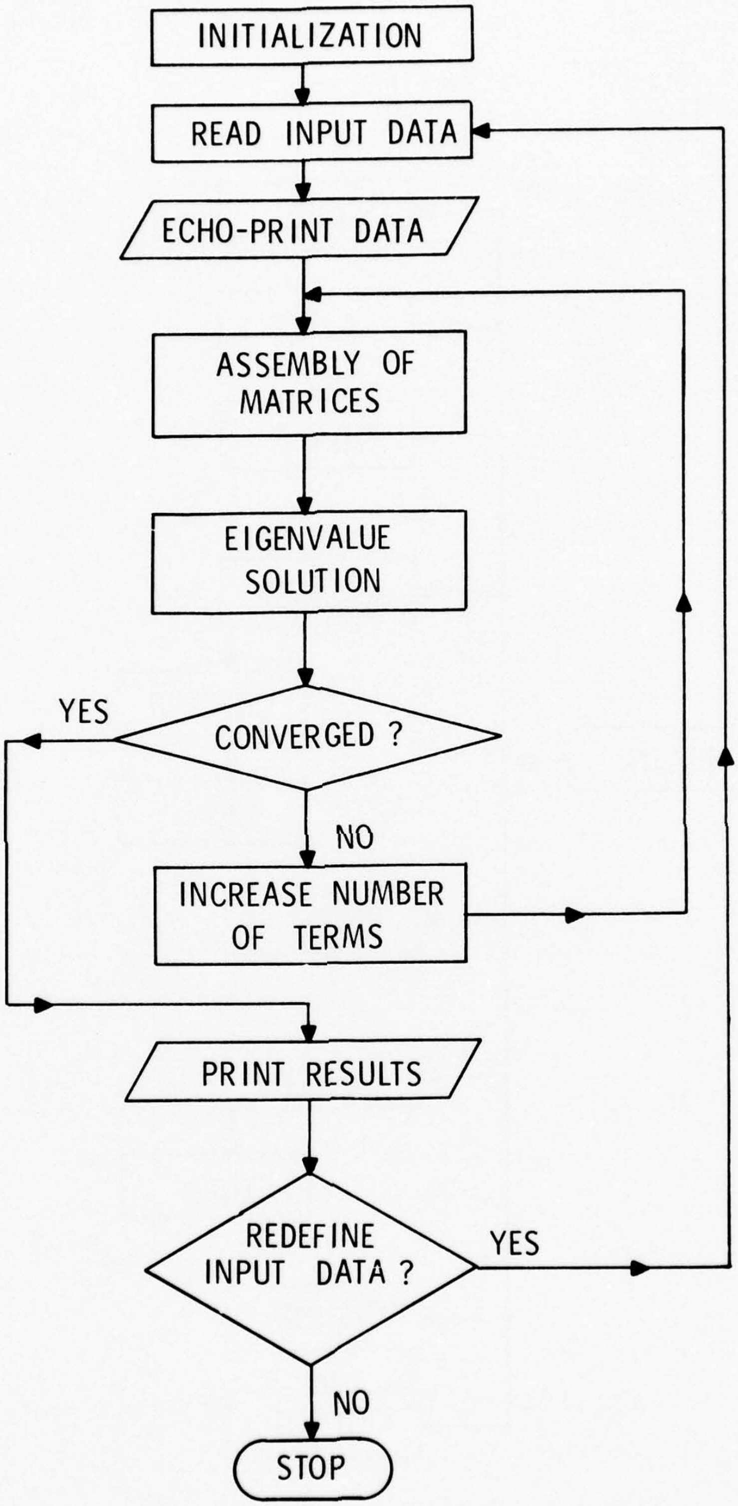

Figure 4. Program Structure.

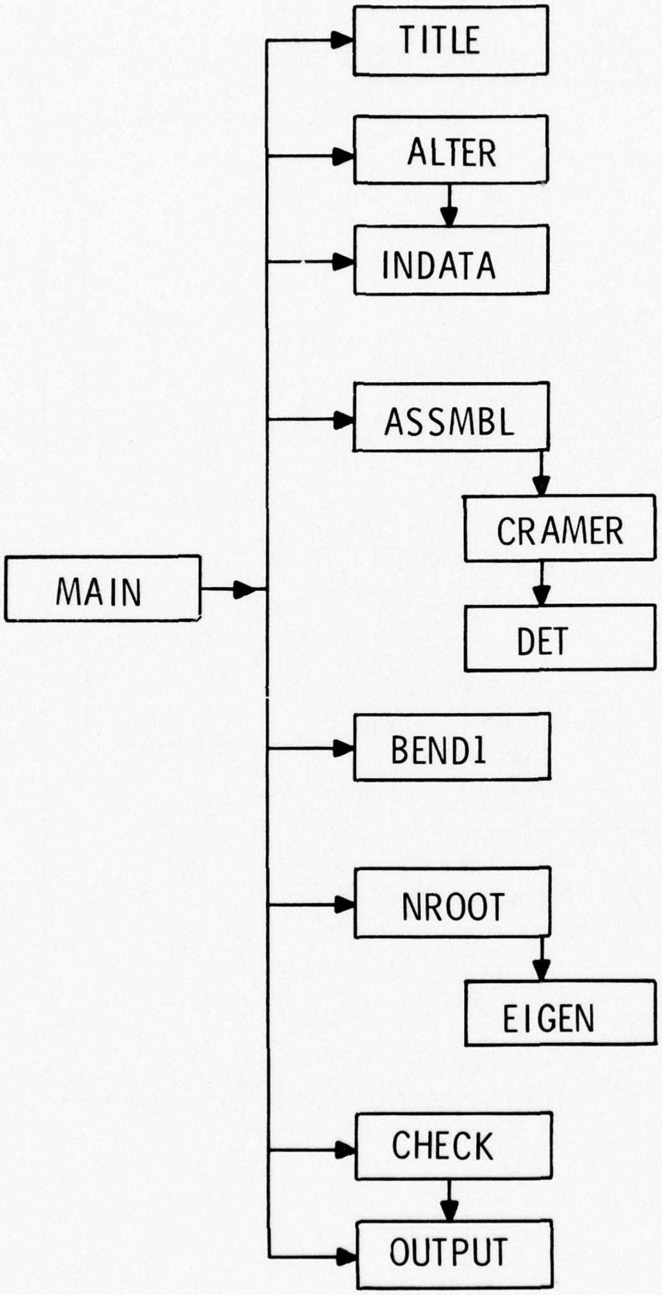

Figure 5. Subroutine Interaction.

The maximum number of terms which can be considered in the numerical analysis is limited by high-speed storage requirements, since no scratch files are used. For interactive use, the program is restricted to seven terms in the displacement series (Equation 1.2), since the resulting eigenproblem is of order $N^2 = 49$. The order of approximation can be increased when the program is executed noninteractively, although this is usually not necessary for panels having reasonably small aspect ratios. Array dimensioning for the listing of the program (Appendices A - L) corresponds to a maximum of $N = 7$.

SECTION III

PROGRAM USAGE

The subject computer program is operable from card input (batch processing) or interactively at a teletype console. This section describes the required input data for both modes of operation, and gives the necessary information for interpretation of the output.

3.1 DATA INPUT FROM CARDS

Punched-card input is arranged in free format, with each item of data separated from the next by a space or a comma. The data deck is arranged as follows:

Card 1 : 0
Card 2 : NRUN
Data for problem 1
Data for problem 2
⋮ ⋮
Data for problem NRUN

A zero entered on the first data card indicates batch processing. The parameter NRUN determines the number of problems to be considered. Data items for a single problem are entered on five cards, as indicated below:

Card (a): E1 E2 NU1 NU2
Card (b): GX GY
Card (c): T1 T2 TC A B
Card (d): NX NXY NY
Card (e): NXB NYB

Some comments are in order concerning the loading parameters specified on cards (d) and (e) above. The values NX, NXY, NY, NXB, and NYB are understood to specify only the relative magnitudes of each of the applied edgewise loadings; the intensity of loading is determined by the eigenvalues of the problem. For example, if

NX = 1.
NXY = 2.
NY = NXB = NYB = 0.,

a critical load intensity is sought such that $N_{xy} = 2N_x$. The values of NXB and NYB refer to the maximum magnitude of an edgewise bending load, measured at the corners of the panel (see Figure 3). That is, values of the corresponding loads $\overline{N}_{xb}$, $\overline{N}_{yb}$ are to be interpreted as defining the edgewise resultants

$$
\begin{aligned}
N_x &= \overline{N}_{xb} (1 - 2y/b) \\
N_y &= \overline{N}_{yb} (1 - 2x/a).
\end{aligned}
\tag{3.1}
$$

The corresponding total bending moments are then given by

$$
\begin{aligned}
M_x &= \overline{N}_{xb}\, b^2/6 \\
M_y &= \overline{N}_{yb}\, a^2/6.
\end{aligned}
\tag{3.2}
$$

The loading parameters specified on cards (d) and (e) may be given either as integer or real values.

3.2 DATA INPUT FROM TELETYPE

The data required for interactive processing is similar to the card input outlined above. However, the counter NRUN is not used, and additional options may be exercised for making modifications to the problem data and for selection of output.

To initiate requests for input data, the value "1" is entered (in free format) as the first item of data following the command to execute; for example,

```
LGO. 1 (CR) *
```

The program then responds with the following requests for input:

```
ENTER MODULI & POISSONS RATIOS, E1  E2  NU1  NU2     :
ENTER CORE MODULI,  GX  GY                           :
ENTER GEOMETRIC PARAMETERS, T1  T2  TC  A  B         :
ENTER LOADING PROPORTIONS, NX  NXY  NY  NXB  NYB     :
```

After each ENTER request, the appropriate input data are typed on the same line, with each item separated by a space or comma.

An option is provided in the computer program for rerunning a previously defined problem, with one or more input items revised. Following the output for the current problem, the message

```
BEGIN ALTER
MODIFY DATA (Y/N)?
```

is printed. If the next analysis to be done differs from the last in only a few parameters, requests for revisions to the data are initiated with the response

```
MODIFY DATA (Y/N)?  Y  (CR)
```

A request is made by the program for the first parameter to be modified, as follows:

```
GIVE *PARAMETER NAME
     *                       .
```

Immediately following the asterisk, the user enters the name of a program variable whose value is to be changed, and depresses the carriage return.

---

* The symbol (CR) indicates that the carriage return key is depressed. All commands and data entered by the user are underlined.

Variable names recognized by the program are given in the list below.

```
E1      E2      NU1     NU2
GX      GY      T1      T2
TC      A       B       NX
NXY     NY      NXB     NYB
END
```

The program responds by requesting the new value of the data parameter. For example, the process of changing the modulus of the lower face sheet of a sandwich panel proceeds as follows:

```
BEGIN ALTER
MODIFY DATA (Y/N)?  Y   CR
GIVE  *PARAMETER NAME
      *E1  CR
      E1          =  10. 2 E6   CR

      *END  CR
```

The keyword END signals the end of modifications to the data. Normal completion of all data revisions is verified by the message

```
ALTER COMPLETED,
```

and the solution to the new problem is begun.

If no revisions are to be made by ALTER, the appropriate response is

```
BEGIN ALTER
MODIFY DATA (Y/N)?  N   CR
```

The next line to be printed is then

```
BEGIN NEW PROBLEM (Y/N)?
```

The response N CR at this point causes execution to be terminated. A response of Y CR initiates the input sequence for a new problem beginning with the ENTER requests as previously described.

3.3 DESCRIPTION OF OUTPUT

Output from the program for each individual problem solution consists of:

i) input data verification

ii) results of intermediate calculations

iii) problem solution

iv) diagnostic information.

The current set of problem data is reprinted upon completion of the input procedure for each problem. During interactive use, the data is also printed after each set of modifications in order to provide a readable summary of the current problem.

During batch processing, the results of each solution iteration are included in the output. This information includes the number of terms in the displacement approximation (Equation 1.2), current values of the critical loads, and processing times for matrix assembly and eigenvalue extraction. Intermediate results are not displayed during interactive execution of the program.

Final results displayed by the program include the critical load magnitudes, the eigenvalue solution, and the mode shapes for the first buckling mode. When executing the program interactively, the user can suppress the display of eigenvalues and mode shapes. It should be noted that, in a linear buckling analysis, only the relative magnitudes of the mode shape coefficients are meaningful; therefore, the vector of coefficients is normalized to unit length before printing.

Diagnostic messages output by the computer program are of two types. In the event that a solution using the maximum allowable number of terms has failed to converge within one quarter of one percent (see Paragraph 1.2), the message

```
WARNING: RELATIVE CONVERGENCE TOLERANCE
         OF .0025 NOT SATISFIED
TOLERANCE OF (        ) ACHIEVED
```

is printed. This situation will occur in the analysis of panels having very large aspect ratios, and subjected to edgewise shear or bending loads. It should be remarked that the tolerance of .25% for convergence of the iteration is quite stringent; in nearly all practical applications, convergence to within one or two percent can be expected using a maximum of seven terms (N= 7) in Equation 1.2.

Messages may be printed during execution of the ALTER sequence, to identify invalid parameter names (see Paragraph 3.2) entered by the user. For example, the following sequence occurs due to the use of the invalid name E3:

```
BEGIN ALTER
MODIFY DATA (Y/N)? Y (CR)
GIVE   *PARAMETER NAME
       *E3  (CR)
INVALID DATA:       E3
RETRY OR TYPE END
       *
```

Multiple errors of the above type during a single pass through the ALTER sequence will cause execution to be terminated.

SECTION IV

EXAMPLE PROBLEMS

Typical analyses performed using the subject computer program are presented in this section. The examples are intended to familiarize the reader with the mechanics of input and output, and to demonstrate most of the important features of the program. In each of the following examples, information supplied by the user is identified by underscoring.

4.1 EXAMPLE 1: INTERACTIVE EXECUTION

This example is an interactive session which demonstrates many of the available program features. Two separate problems are solved, each involving various combinations of material parameters and loading conditions. Output for the session is shown in Figure 6.

For the first problem, a 24 in. by 40 in. panel having 0.025 in. aluminum face sheets is analyzed for buckling in axial compression. Following the command to execute, the problem data is read in and echo-printed by the program. A converged solution, corresponding to three terms in the displacement series, is printed out, followed by the eigenvalues and first mode shape requested by the user. It should be noted that the mode shape coefficients shown are not deflections, but modal participation factors; for the present case, since only $W_{11} \neq 0$, the deflection of the panel is of the form

$$w(x, y) = A \sin \frac{\pi x}{a} \sin \frac{\pi y}{b} .$$

In the ALTER sequence, the face sheet thicknesses are increased to 0.32 in., and the core shear modulus in the direction of the loading is made slightly larger. Once the modifications to the problem are complete, the new set of data is echo-printed, and a new solution is performed. In this instance the user does not request a listing of the eigenvalue solution and buckled mode shape, so that only the critical load is printed. The ALTER sequence is also bypassed, in order to begin the next problem.

```
ENTER MODULI & POISSONS RATIOS, E1 E2 NU1 NU2 : 10.2E6 10.2E6 .33 .33 CR
ENTER CORE MODULI,  GX   GY                   : 23500. 23500. CR
ENTER GEOMETRIC PARAMETERS, T1 T2 TC A B      : .025 .025 .5 24. 40. CR
ENTER LOADING PROPORTIONS, NX NXY NY NXB NYB  : 1 0 0 0 0 CR


   FACE SHEET PARAMETERS

                      E           NU          T
   FACE 1:        .1020E+08     .33000     .02500
   FACE 2:        .1020E+08     .33000     .02500

   CORE PARAMETERS

                      GX              GY            TC
   CORE   :       .2350E+05      .2350E+05     .50000

   PLANFORM DIMENSIONS

       A =    24.0000
       B =    40.0000

   LOAD FACTORS

   NX= 1.00    NXY= 0.00    NY= 0.00

   NXB= 0.00                NYB= 0.00

         ***** SOLUTION FOR M=N= 3 ****

         ******* CRITICAL LOADS *******
         NX =        -1168.0004
         NXY=            0.0000
         NY =            0.0000
         NXB=            0.0000 *(1-2*Y/B)
         NYB=            0.0000 *(1-2*X/A)


         PRINT EIGENVALUES AND MODE SHAPES (Y/N)?Y   CR


         ********** EIGENVALUES *********
        -.99572E+04 -.68738E+04 -.64344E+04 -.53044E+04
        -.44249E+04 -.38981E+04 -.35719E+04 -.26188E+04
        -.11680E+04
```

Figure 6.   Computer Output: Example 1

```
     ◆◆◆◆◆◆◆◆◆ MODE SHAPE ◆◆◆◆◆◆◆◆◆
            AT CRITICAL LOADS

     (W11,W12,...,W13,W21,W22,...,W33)

    1.0000000000     0.0000000000     0.0000000000     0.0000000000
    0.0000000000     0.0000000000     0.0000000000     0.0000000000
    0.0000000000

     ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

     BEGIN ALTER
     MODIFY DATA(Y/N)?Y  CR

     GIVE ◆PARAMETER NAME
          ◆T1 CR

           T1    =   .032   CR

          ◆T2 CR

           T2    =   .032   CR

          ◆GX CR

           GX    =  27500.CR

          ◆END CR

     ALTER COMPLETED

     ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆


FACE SHEET PARAMETERS

                     E            NU         T
FACE 1:         .1020E+08     .33000     .03200
FACE 2:         .1020E+08     .33000     .03200

CORE PARAMETERS

                    GX             GY           TC
CORE   :        .2750E+05     .2350E+05     .50000

PLANFORM DIMENSIONS

    A =   24.0000
    B =   40.0000

LOAD FACTORS

NX= 1.00   NXY= 0.00   NY= 0.00

NXB= 0.00              NYB= 0.00

     ◆◆◆◆◆ SOLUTION FOR M=N= 3 ◆◆◆◆
```

Figure 6. (cont.)

```
        ******* CRITICAL LOADS *******
        NX =      -1521.5248
        NXY=          0.0000
        NY =          0.0000
        NXB=          0.0000 *(1-2*Y/B)
        NYB=          0.0000 *(1-2*X/A)

        PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N (CR)

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

        BEGIN ALTER
        MODIFY DATA(Y/N)?N (CR)

        BEGIN NEW PROBLEM(Y/N)?Y (CR)

ENTER MODULI & POISSONS RATIOS, E1 E2 NU1 NU2  : 10.25E6 10.25E6 .32 .32 (CR)

ENTER CORE MODULI,  GX   GY                     : 24000. 20000. (CR)

ENTER GEOMETRIC PARAMETERS, T1 T2 TC A B        : .063 .063 .375 20. 20. (CR)

ENTER LOADING PROPORTIONS, NX NXY NY NXB NYB    : 0 1 0 0 0 (CR)


   FACE SHEET PARAMETERS

                        E           NU         T
   FACE 1:        .1025E+08     .32000     .06300
   FACE 2:        .1025E+08     .32000     .06300

   CORE PARAMETERS

                       GX            GY            TC
   CORE   :       .2400E+05     .2000E+05     .37500

   PLANFORM DIMENSIONS

       A =    20.0000
       B =    20.0000

   LOAD FACTORS

   NX= 0.00    NXY= 1.00    NY= 0.00

   NXB= 0.00                NYB= 0.00

        ***** SOLUTION FOR M=N= 7 ****
```

Figure 6. (cont.)

```
******** CRITICAL LOADS ********
NX =             0.0000
NXY=        -7910.7914
NY =             0.0000
NXB=             0.0000 *(1-2*Y/B)
NYB=             0.0000 *(1-2*X/A)


PRINT EIGENVALUES AND MODE SHAPES (Y/N)?Y CR


********** EIGENVALUES *********
 .79108E+04  .86317E+04  .10403E+05  .10568E+05
 .11421E+05  .11649E+05  .12078E+05  .12183E+05
 .13799E+05  .14276E+05  .16366E+05  .16651E+05
 .17443E+05  .18458E+05  .21855E+05  .22029E+05
 .23787E+05  .25746E+05  .17179E+19  .29699E+19
 .34403E+19  .48689E+19  .85186E+19  .55543E+21
-.72231E+20 -.16755E+20 -.10351E+20 -.57143E+19
-.55875E+19 -.24292E+19 -.14840E+19 -.25746E+05
-.23787E+05 -.22029E+05 -.21855E+05 -.18458E+05
-.17443E+05 -.16651E+05 -.16366E+05 -.14276E+05
-.13799E+05 -.12183E+05 -.12078E+05 -.11649E+05
-.11421E+05 -.10568E+05 -.10403E+05 -.86317E+04
-.79108E+04

********** MODE SHAPE **********
        AT CRITICAL LOADS

(W11,W12,...,W17,W21,W22,...,W77)

-.8739802967    0.0000000000     .1370574839    0.0000000000
 .0124294550    0.0000000000     .0036143155    0.0000000000
 .4234021377    0.0000000000    -.0309768881    0.0000000000
-.0066975347    0.0000000000     .1225200199    0.0000000000
-.1412267597    0.0000000000    -.0101696869    0.0000000000
-.0010723403    0.0000000000    -.0255942697    0.0000000000
 .0278419188    0.0000000000     .0069832008    0.0000000000
 .0114336978    0.0000000000    -.0102646080    0.0000000000
-.0066047085    0.0000000000    -.0026283641    0.0000000000
-.0052079206    0.0000000000     .0063383261    0.0000000000
 .0036197630    0.0000000000     .0033627821    0.0000000000
-.0016528048    0.0000000000    -.0023758143    0.0000000000
-.0024294065

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

BEGIN ALTER
MODIFY DATA(Y/N)?Y CR

GIVE *PARAMETER NAME
     *NXY  CR

      NXY  =  0  CR

     *NY  CR
```

Figure 6 (cont.)

```
          NY    =  3 (CR)
         *NXB (CR)
          NXB   =  1 (CR)
         *END (CR)
      ALTER COMPLETED

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


FACE SHEET PARAMETERS

                       E              NU           T
FACE 1:          .1025E+08       .32000       .06300
FACE 2:          .1025E+08       .32000       .06300

CORE PARAMETERS

                       GX               GY              TC
CORE    :        .2400E+05        .2000E+05       .37500

PLANFORM DIMENSIONS

    A =    20.0000
    B =    20.0000

LOAD FACTORS

NX= 0.00     NXY= 0.00     NY= 3.00

NXB= 1.00                  NYB= 0.00

      ***** SOLUTION FOR M=N= 6 ****

      ******* CRITICAL LOADS *******
      NX  =           0.0000
      NXY=            0.0000
      NY  =       -5149.7155
      NXB=        -1716.5718 *(1-2*Y/B)
      NYB=            0.0000 *(1-2*X/A)

      PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N (CR)
```

Figure 6. (cont.)

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

    BEGIN ALTER
    MODIFY DATA(Y/N)?N  (CR)


    BEGIN NEW PROBLEM(Y/N)?N  (CR)

STOP
11.928 CP SECONDS EXECUTION TIME
```

Figure 6. (concluded)

The second problem in the session consists of a square panel with identical face sheets and orthotropic core ($G_x/G_y = 1.20$), analyzed for buckling under two different loading conditions. First, a shear loading is considered, for which a seven-term solution is required to obtain a converged result (it can be seen that the shear-buckling mode shape of the panel is quite complicated; thus, more terms are needed in the displacement approximation). The ALTER sequence is next used to modify the data for the second loading condition. A critical load magnitude is then found such that $N_y = 3\overline{N}_{xb}$, where $\overline{N}_{xb}$ defines an edgewise bending load as defined in Equations 3.1 and 3.2.

The session is terminated when the user bypasses the ALTER sequence, and does not elect the option of beginning a new problem. Execution time for the session is displayed following the normal exit from the program. It should be noted that the solution for a compressive load only is started with two terms in the displacement series, and for bending and shear loads with five terms in the series. Thus, the execution time listed for this session (11.928 sec.) is the time required for nine separate eigenvalue solutions, even though only four separate problems have been solved.

4.2 EXAMPLE 2: BATCH MODE EXECUTION

Two problems are solved in this example to illustrate the use of the program in the batch execution mode, with data input from cards. Output for the problems is reproduced in Figure 7. Input data required for running both problems in a single submission is as follows:

Card 1:	0	(Flag for batch mode)
Card 2:	2	(Number of problems)

```
FACE SHEET PARAMETERS

                     E            NU         T
FACE 1:         .1020E+08     .30000     .02300
FACE 2:         .1020E+08     .30000     .02300

CORE PARAMETERS

                    GX              GY            TC
CORE  :         .2350E+05      .2350E+05      .37500

PLANFORM DIMENSIONS

    A =    23.5000
    B =    23.5000

LOAD FACTORS

NX= 1.00    NXY= 0.00    NY= 0.00

NXB= 0.00                NYB= 0.00


TERMS         NX          NXB          NXY          NY           NYB   ASSEM(SEC)EIGEN(SEC)
  2    -1361.303     0.000        0.000        0.000        0.000        .005        .002
  3    -1361.303     0.000        0.000        0.000        0.000        .010        .020
     ***** SOLUTION FOR M=N= 3 ****

     ******* CRITICAL LOADS *******
    NX =        -1361.3028
    NXY=             0.0000
    NY =             0.0000
    NXB=             0.0000 *(1-2*Y/B)
    NYB=             0.0000 *(1-2*X/A)

     ********* EIGENVALUES ********
    -.26723E+05 -.10449E+05 -.79203E+04 -.77165E+04
    -.46441E+04 -.45182E+04 -.29692E+04 -.19291E+04
    -.13613E+04

     ********* MODE SHAPE *********
            AT CRITICAL LOADS

     (W11,W12,....,W13,W21,W22,....,W33)

    1.0000000000    0.0000000000    0.0000000000    0.0000000000
    0.0000000000    0.0000000000    0.0000000000    0.0000000000
    0.0000000000
```

Figure 7.   Computer Output: Example 2

```
FACE SHEET PARAMETERS

                  E              NU          T
FACE 1:      .1000E+08      .30000      .05000
FACE 2:      .1000E+08      .30000      .05000

CORE PARAMETERS

                 GX             GY            TC
CORE  :      .2500E+04      .2500E+04      .25000

PLANFORM DIMENSIONS

    A =   15.0000
    B =   30.0000

LOAD FACTORS

NX=  .50    NXY= 3.00    NY=  .50

NXB= 1.00               NYB= 2.00

TERMS        NX        NXB        NXY        NY         NYB    ASSEM(SEC)EIGEN(SEC)
  5    -143.558  -287.116  -861.348  -143.558  -574.232        .055      1.530
  6    -140.769  -281.538  -844.614  -140.769  -563.076        .095      4.520
  7    -139.638  -279.276  -837.827  -139.638  -558.552        .159     11.406

     ** WARNING: RELATIVE CONVERGENCE TOLERANCE
        OF .0025 NOT SATISFIED
     ** TOLERANCE OF   .0081 ACHIEVED

     ***** SOLUTION FOR M=N= 7 ****

     ******* CRITICAL LOADS *******
     NX =         -139.6379
     NXY=         -837.8274
     NY =         -139.6379
     NXB=         -279.2758 *(1-2*Y/B)
     NYB=         -558.5516 *(1-2*X/A)

     ********* EIGENVALUES ********
     .39611E+03  .40235E+03  .46256E+03  .47083E+03
     .58136E+03  .58715E+03  .71186E+03  .72767E+03
     .79390E+03  .82964E+03  .92363E+03  .10033E+04
     .13640E+04  .13951E+04  .17949E+04  .18189E+04
     .42621E+04  .45488E+04  .11677E+05 -.97258E+04
    -.42598E+04 -.34401E+04 -.26895E+04 -.24556E+04
    -.23551E+04 -.21135E+04 -.13154E+04 -.16094E+04
    -.14168E+04 -.11426E+04 -.10078E+04 -.92326E+03
    -.85177E+03 -.68178E+03 -.66506E+03 -.62259E+03
    -.60383E+03 -.52885E+03 -.52424E+03 -.46860E+03
    -.45848E+03 -.40208E+03 -.39892E+03 -.37724E+03
    -.37313E+03 -.31172E+03 -.30895E+03 -.28093E+03
    -.27928E+03

     ********* MODE SHAPE *********
             AT CRITICAL LOADS

     (W11,W12,....,W17,W21,W22,....,W77)

    -.3122565410      .4883808221      .0234377730     -.3504191233
     .1389985001      .0233234865     -.0240176481      .0892184216
     .1203941242     -.4678519343      .2804119503      .1034325660
    -.1501831671      .0460869559      .0522174011     -.1588350382
     .1017833486      .1683781658     -.2312605004      .0789717120
     .0197829947     -.0012185526      .0033624638      .0481633053
    -.1004224132      .0372105207      .0451331127     -.0364715153
     .0020476607     -.0071070220     -.0109879094      .0275040830
     .0012483811     -.0197431818      .0048219853      .0004122317
    -.0003442618      .0087447705     -.0117641349     -.0049163268
     .0117571279     -.0039680473      .0006310114     -.0021763316
    -.0020389207      .0044697613      .0025877265     -.0035189119
    -.0008360206
```

Figure 7. (concluded)

```
Card 3:   10.2E6  10.2E6  .30  .30
Card 4:   23500.  23500.
Card 5:   .023  .023  .375  23.5  23.5      (Data for Problem 1)
Card 6:   1  0  0
Card 7:   0  0
Card 8:   10.0E6  10.0E6  .30  .30
Card 9:   2500.  2500.
Card 10:  .050  .050  .250  15.  30.        (Data for Problem 2)
Card 11:  .50  3.0  .50
Card 12:  1.0  2.0
Card 13:  7/8/9  END OF RECORD.
```

The first case considered is that of a square panel with an isotropic core, analyzed for buckling under a single compression load. It can be seen from Figure 7 that the output is identical to that obtained in an interactive session, with additional information printed concerning intermediate calculations and execution times. For the present problem, the solution is begun with two terms in the displacement series, and converges immediately due to the simplicity of the buckling mode.

The second problem considers a panel with a 2:1 aspect ratio, subjected to a complicated system of loading which includes compression, bending and shear forces. All input data is echo-printed, followed by the results of intermediate calculations. Due to the complexity of the loading, the solution is begun using five terms in the displacement series, and proceeds through the maximum number of terms, (seven). Since the relative change in the last two solutions is greater than the preset tolerance of 0.25%, a diagnostic is printed, followed by the current solution. In this case, the diagnostic indicates that, although the solution has not fully converged, the relative change in the result is less than one percent; hence, it appears that the buckling solution is still quite accurate.

4.3 EXAMPLE 3: A DESIGN PROBLEM

This example illustrates the use of the program for a simple design application. Consider the design of a simply-supported sandwich panel which, due to design constraints and material availability, has the following properties:

Face sheet material - Aluminum 5052-H32
$E = 10.2 \times 10^6$ psi, $\nu = 0.33$
Core shear moduli - $G_x = G_y = 21300.$ psi
Core thickness - $t_c = 0.5$ in.
Planform dimensions - $a = 30.$ in. $b = 24.$ in.
Maximum thickness - $t_1 + t_2 + t_c \leq 0.65$ in.
Minimum thickness of faces - $t_1 = t_2 \geq 0.016$ in.

The face sheet thickness, t, is to be selected from standard gage sizes (.016, .020, .025, .032, .040, .050, .063) so as to satisfy stability constraints for the following loading conditions:

(i) $N_x = N_y = -750.$ lb/in

(ii) $N_{xy} = 600.$ lb./in. ; $N_{xb} = 300.$ lb/in.

Output for the present problem is shown in Figure 8. A solution is performed first for the compressive loading case, using the minimum gage size of .016 for each face. Load condition (ii) is next checked, to determine which loading case is more critical in determining face sheet thicknesses. Since the panel is unstable only for load case (i), the facing thickness is increased to .020 in., and both load conditions are reanalyzed. The critical loads are then found to be

(i) $N_x = N_y = -809.$ lb./in.

(ii) $N_{xy} = 3249.$ lb./in. ; $N_{xb} = 1624$ lb./in.

and the proper face sheet thickness is therefore t = .020 in.

```
ENTER MODULI & POISSONS RATIOS, E1 E2 NU1 NU2 : 10.2E6 10.2E6 .33 .33 CR

ENTER CORE MODULI,  GX   GY                   : 21300. 21300. CR

ENTER GEOMETRIC PARAMETERS, T1 T2 TC A B      : .016 .016 .5 30. 24. CR

ENTER LOADING PROPORTIONS, NX NXY NY NXB NYB  : 1 0 1 0 0 CR


   FACE SHEET PARAMETERS

                      E           NU          T
   FACE 1:        .1020E+08     .33000     .01600
   FACE 2:        .1020E+08     .33000     .01600

   CORE PARAMETERS

                     GX              GY            TC
   CORE   :       .2130E+05      .2130E+05      .50000

   PLANFORM DIMENSIONS

        A =    30.0000
        B =    24.0000

   LOAD FACTORS

   NX= 1.00     NXY= 0.00     NY= 1.00

   NXB= 0.00                  NYB= 0.00

         ***** SOLUTION FOR M=N= 3 ****

         ******* CRITICAL LOADS *******
         NX =        -646.3383
         NXY=           0.0000
         NY =        -646.3383
         NXB=           0.0000 *(1-2*Y/B)
         NYB=           0.0000 *(1-2*X/A)

         PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N  CR


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

         BEGIN ALTER
         MODIFY DATA(Y/N)?Y  CR
```

Figure 8. Computer Output: Example 3

```
        GIVE ◆PARAMETER NAME
                  ◆NX  (CR)

                   NX     =   0 (CR)

                  ◆NY  (CR)

                   NY     =   0 (CR)

                  ◆NXY (CR)

                   NXY    =   1 (CR)

                  ◆NXB (CR)

                   NXB    =   .5(CR)

                  ◆END (CR)

        ALTER COMPLETED

        ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆


FACE SHEET PARAMETERS

                       E             NU           T
FACE 1:           .1020E+08     .33000      .01600
FACE 2:           .1020E+08     .33000      .01600

CORE PARAMETERS

                       GX              GY              TC
CORE   :          .2130E+05       .2130E+05       .50000

PLANFORM DIMENSIONS

     A =    30.0000
     B =    24.0000

LOAD FACTORS

NX= 0.00    NXY= 1.00    NY= 0.00

NXB=  .50                NYB= 0.00

        ◆◆◆◆◆ SOLUTION FOR M=N= 6 ◆◆◆◆
```

Figure 8. (cont.)

```
******** CRITICAL LOADS ********
NX =           0.0000
NXY=       -2666.4770
NY =           0.0000
NXB=       -1333.2385 *(1-2*Y/B)
NYB=           0.0000 *(1-2*X/A)

PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N  (CR)


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

BEGIN ALTER
MODIFY DATA(Y/N)?Y  (CR)

GIVE *PARAMETER NAME
      *T1 (CR)

       T1   =   .020  (CR)

      *T2 (CR)

       T2   =   .020  (CR)

      *END (CR)

ALTER COMPLETED

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



FACE SHEET PARAMETERS

                    E             NU          T
FACE 1:        .1020E+08     .33000     .02000
FACE 2:        .1020E+08     .33000     .02000

CORE PARAMETERS

                    GX              GY              TC
CORE   :       .2130E+05      .2130E+05      .50000

PLANFORM DIMENSIONS

    A =   30.0000
    B =   24.0000
```

Figure 8. (cont.)

```
LOAD FACTORS

NX= 0.00    NXY= 1.00    NY= 0.00

NXB=  .50                NYB= 0.00

      ***** SOLUTION FOR M=N= 6 ****

      ******* CRITICAL LOADS *******
      NX =           0.0000
      NXY=       -3248.6376
      NY =           0.0000
      NXB=       -1624.3188 *(1-2*Y/B)
      NYB=           0.0000 *(1-2*X/A)


      PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N (CR)


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


      BEGIN ALTER
      MODIFY DATA(Y/N)?Y (CR)

      GIVE *PARAMETER NAME
           *NXY (CR)

            NXY   =  0 (CR)

           *NXB (CR)

            NXB   =  0 (CR)

           *NX  (CR)

            NX    =  1 (CR)

           *NY  (CR)

            NY    =  1 (CR)

           *END (CR)
       ALTER COMPLETED

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

Figure 8. (cont.)

```
FACE SHEET PARAMETERS

                    E             NU         T
FACE 1:       .1020E+08      .33000     .02000
FACE 2:       .1020E+08      .33000     .02000

CORE PARAMETERS

                   GX              GY            TC
CORE   :      .2130E+05       .2130E+05     .50000

PLANFORM DIMENSIONS

    A =    30.0000
    B =    24.0000

LOAD FACTORS

NX= 1.00    NXY= 0.00    NY= 1.00

NXB= 0.00                NYB= 0.00

     ***** SOLUTION FOR M=N= 3 ****

     ******** CRITICAL LOADS ********
     NX =        -809.1307
     NXY=           0.0000
     NY =        -809.1307
     NXB=           0.0000 *(1-2*Y/B)
     NYB=           0.0000 *(1-2*X/A)

     PRINT EIGENVALUES AND MODE SHAPES (Y/N)?N  (CR)

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

     BEGIN ALTER
     MODIFY DATA(Y/N)?N  (CR)

     BEGIN NEW PROBLEM(Y/N)?N  (CR)

 STOP
 12.011 CP SECONDS EXECUTION TIME
```

Figure 8. (concluded)

SECTION V

SUMMARY AND RECOMMENDATIONS

A computer program for the analysis of stability of flat, rectangular sandwich panels has been presented. The program is capable of considering very general systems of applied loading, and takes into account the effects of orthotropic core materials and unbalanced face sheets.

The subject computer program is capable of obtaining solutions with a relatively small amount of computation, and requires very little computer storage (the compiled program occupies 11460 decimal words of memory). As such, it is ideally suited for use in optimization or automated design systems.

A number of extensions of the present analysis are possible, and should be investigated. Within the confines of a linear analysis, generalizations of the present code to include layered composite faces, elastic edge reinforcements and more general panel shapes would represent a valuable capability. The existing code can be extended to consider the case of multicore constructions and panels which undergo normal deformations, although both of these modifications require the solution of larger numbers of degrees of freedom. The analysis of other than simply supported panels can be achieved by altering the assumed-mode approximation, although computational effort will be increased for other cases.[1]

In conclusion, a useful and reliable tool for the analysis of sandwich structural components has been described herein. Furthermore, the subject computer code provides a suitable starting place for the consideration of many more general types of sandwich construction.

REFERENCES

1. Brockman, R. A., Stability of Flat, Simply-Supported Rectangular Sandwich Panels Subjected to Combined Inplane Loadings, AFFDL-TR-76-14, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio, 1976.

APPENDIX A

MAIN PROGRAM

```
      PROGRAM PLATE3(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     MAIN PROGRAM
C     GENERAL BUCKLING OF FLAT RECTANGULAR SANDWICH PANEL
C     WITH SIMPLY-SUPPORTED EDGES, SUBJECTED TO COMBINED
C     EDGEWISE BENDING, COMPRESSION AND SHEAR LOADINGS
C
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/MATL/E(2),T(2),XNU(2),XLMDA(2),BETA(2),SIGN(2)
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SOLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      LOGICAL BEND,INTER
      READ(5,*)I
      NRUN=0
      INTER=(I.GT.0)
      CALL TITLE (I)
    5 ISTART=10
10    CALL INDATA
   15 CALL ECHO
20    TIME1=SECOND(Q)
      CALL ASSMBL
      BEND=(LXB.NE.0.OR.LYB.NE.0)
      IF(BEND)CALL BEND1
      TIME2=SECOND(Q)
      TIME1=TIME2-TIME1
      K2=K*K
      CALL NROOT(K2,BB,AA,EIG,EIGV)
      TIME2=SECOND(Q)-TIME2
      CALL CHECK,RETURNS(20,30)
30    CALL OUTPUT,RETURNS(10,40)
   40 IF(INTER) CALL ALTER,RETURNS(5,15,50)
   50 STOP
      END
```

APPENDIX B

SUBROUTINE INDATA

```
      SUBROUTINE INDATA
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/MATL/E(2),T(2),XNU(2),XLMDA(2),BETA(2),SIGN(2)
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      LOGICAL INTER
      IF(INTER)GO TO 2
      IF(ISTART)2,2,1
 1    READ(5,*)NRUN
 2    ICONV=0
      MAX=7
      PREV=0.
      LIMIT=10
      IF(NRUN.GT.LIMIT)STOP
      IF(INTER)WRITE(6,100)
      READ(5,*)E(1),E(2),XNU(1),XNU(2)
      IF(INTER)WRITE(6,125)
      READ(5,*)GX,GY
      IF(INTER)WRITE(6,150)
      READ(5,*)T(1),T(2),TC,A,B
      IF(INTER)WRITE(6,175)
      READ(5,*)NX,LXY,NY,NXB,NYB
      ENTRY RESET
      LXB=2*NXB
      LYB=2*NYB
      LX =NX-NXB
      LY =NY-NYB
      K=2
      IF(LXY.NE.0)K=5
      IF(LXB.NE.0.OR.LYB.NE.0)K=5
      THICK=T(2)+TC+T(1)
      SIGN(1)=-1.
      SIGN(2)=1.
      DO 3 I=1,2
      XLMDA(I)=1.-XNU(I)*XNU(I)
 3    BETA(I)=T(I)-THICK/2.
      ISTART=10
      RETURN
 100  FORMAT(/2X,48HENTER MODULI & POISSONS RATICS, E1 E2 NU1 NU2 : )
 125  FORMAT( 2X,28HENTER CORE MODULI,   GX   GY ,
     1       18X,2H: )
 150  FORMAT( 2X,40HENTER GEOMETRIC PARAMETERS, T1 T2 TC A B,
     1       6X,2H: )
 175  FORMAT( 2X,48HENTER LOADING PROPORTIONS, NX NXY NY NXB NYB  : )
      END
```

APPENDIX C

SUBROUTINE ASSMBL

```
      SUBROUTINE ASSMBL
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/MATL/E(2),T(2),XNU(2),XLMDA(2),BETA(2),SIGN(2)
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SOLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      DIMENSION AC(4,4),BC(4),XC(4)
       LOGICAL INTER
      DATA PI/3.1415926535898/
      K2=K*K
      K4=K2*K2
      DO 1 I=1,K4
      AA(I)=0.
1     BB(I)=0.
      DO 110 N=1,K
      DO 110 M=1,K
      JJ=K*(M-1)+N
      JJ=K2*(JJ-1)+JJ
      DO 3 I=1,4
      DO 2 J=1,4
2     AC(I,J)=0.
3     BC(I)=0.
      CM=M*PI/A
      CN=N*PI/B
      DO 60 I=1,2
      C1=E(I)*T(I)*BETA(I)*BETA(I)/XLMDA(I)
      C2=E(I)*T(I)*BETA(I)*SIGN(I)/XLMDA(I)
      C3=E(I)*T(I)/XLMDA(I)
      C4=C3*T(I)*BETA(I)
      C5=C3*T(I)*SIGN(I)
      AC(1,1)=AC(1,1)+.5*GX*TC+C1*(CM*CM+.5*(1.-XNU(I))*CN*CN)
      AC(1,2)=AC(1,2)+.5*C1*(1.+XNU(I))*CM*CN
      AC(1,3)=AC(1,3)+C2*(CM*CM+.5*(1.-XNU(I))*CN*CN)
      AC(1,4)=AC(1,4)+.5*C2*CM*CN*(1.+XNU(I))
      AC(2,2)=AC(2,2)+.5*GY*TC+C1*(CN*CN+.5*(1.-XNU(I))*CM*CM)
      AC(2,4)=AC(2,4)+C2*(CN*CN+.5*(1.-XNU(I))*CM*CM)
      AC(3,3)=AC(3,3)+C3*(CM*CM+.5*(1.-XNU(I))*CN*CN)
      AC(3,4)=AC(3,4)+.5*C3*(1.+XNU(I))*CM*CN
      AC(4,4)=AC(4,4)+C3*(CN*CN+.5*(1.-XNU(I))*CM*CM)
      BC(1)=BC(1)+.5*C4*CM*(CM*CM+CN*CN)+GX*TC*CM/2.
      BC(2)=BC(2)+.5*C4*CN*(CN*CN+CM*CM)+GY*TC*CN/2.
      BC(3)=BC(3)+.5*C5*CM*(CM*CM+CN*CN)
60    BC(4)=BC(4)+.5*C5*CN*(CN*CN+CM*CM)
      DO 65 I=1,4
65    BC(I)=-BC(I)
      AC(2,1)=AC(1.2)
      AC(2,3)=AC(1.4)
      AC(3,1)=AC(1,3)
      AC(3,2)=AC(2,3)
      AC(4,1)=AC(1,4)
      AC(4.2)=AC(2,4)
      AC(4,3)=AC(3,4)
      BC5=0.
      DO 70 I=1,2
      C3=E(I)*T(I)/XLMDA(I)
70    BC5=BC5+(C3*T(I)*T(I)/3.)*(CM*CM+CN*CN)*(CM*CM+CN*CN)
```

```
      BC5=BC5+CM*CM*GX*TC+CN*CN*GY*TC
      CALL CRAMER(AC,BC,XC)
      AA(JJ)=BC5
      DO 100 I=1,4
100   AA(JJ)=AA(JJ)-BC(I)*XC(I)
110   CONTINUE
      DO 150 M=1,K
      DO 150 N=1,K
      DO 150 IR=1,K
      DO 150 IS=1,K
      CM=M*PI/A
      CN=N*PI/B
      IROW=(M-1)*K+N
      ICOL=(IR-1)*K+IS
      JJ=(ICOL-1)*K2+IROW
      IF(IROW.EQ.ICOL)GO TO 125
      ICHK=(M+IR)/2
      XCHK=.5*FLOAT(M+IR)
      IF(ABS(FLOAT(ICHK)-XCHK).LT..100)GO TO 150
      ICHK=(N+IS)/2
      XCHK=.5*FLOAT(N+IS)
      IF(ABS(FLOAT(ICHK)-XCHK).LT..100)GO TO 150
      BB(JJ)=-32.*LXY*M*N*IR*IS/(A*B*(IR*IR-M*M)*(N*N-IS*IS))
      GO TO 150
125   BB(JJ)=-CM*CM*LX-CN*CN*LY
150   CONTINUE
      RETURN
      END
```

APPENDIX D

SUBROUTINE CRAMER

```
      SUBROUTINE CRAMER(A,B,X)
      DIMENSION A(4,4),B(4),X(4),T(4)
      CALL DET(A,DENOM)
      DO 500 J=1,4
      DO 450 I=1,4
      T(I)=A(I,J)
450   A(I,J)=B(I)
      CALL DET(A,X(J))
      X(J)=X(J)/DENOM
      DO 475 I=1,4
475   A(I,J)=T(I)
500   CONTINUE
      RETURN
      END
```

APPENDIX E

SUBROUTINE DET

```
SUBROUTINE DET(A,D)
DIMENSION A(4,4)
D1=(A(3,3)*A(4,4)-A(4,3)*A(3,4))*(A(1,1)*A(2,2)-A(1,2)*A(2,1))
D2=(A(3,2)*A(4,4)-A(4,2)*A(3,4))*(A(1,3)*A(2,1)-A(1,1)*A(2,3))
D3=(A(3,1)*A(4,4)-A(4,1)*A(3,4))*(A(1,2)*A(2,3)-A(1,3)*A(2,2))
D4=(A(3,2)*A(4,3)-A(4,2)*A(3,3))*(A(1,1)*A(2,4)-A(1,4)*A(2,1))
D5=(A(3,1)*A(4,3)-A(4,1)*A(3,3))*(A(1,4)*A(2,2)-A(1,2)*A(2,4))
D6=(A(3,1)*A(4,2)-A(3,2)*A(4,1))*(A(1,3)*A(2,4)-A(1,4)*A(2,3))
D=D1+D2+D3+D4+D5+D6
RETURN
END
```

APPENDIX F

SUBROUTINE NROOT

```
      SUBROUTINE NROOT(M,A,B,XL,X)
C
C     ..................................................................
C
C        SUBROUTINE NROOT
C
C        PURPOSE
C           COMPUTE EIGENVALUES AND EIGENVECTORS OF A REAL NONSYMMETRIC
C           MATRIX OF THE FORM B-INVERSE TIMES A.  THIS SUBROUTINE IS
C           NORMALLY CALLED BY SUBROUTINE CANOR IN PERFORMING A
C           CANONICAL CORRELATION ANALYSIS.
C
C        USAGE
C           CALL NROOT (M,A,B,XL,X)
C
C        DESCRIPTION OF PARAMETERS
C           M  - ORDER OF SQUARE MATRICES A, B, AND X.
C           A  - INPUT MATRIX (M X M).
C           B  - INPUT MATRIX (M X M).
C           XL - OUTPUT VECTOR OF LENGTH M CONTAINING EIGENVALUES OF
C                B-INVERSE TIMES A.
C           X  - OUTPUT MATRIX (M X M) CONTAINING EIGENVECTORS COLUMN-
C                WISE.
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           EIGEN
C
C        METHOD
C           REFER TO W. W. COOLEY AND P. R. LOHNES, "MULTIVARIATE PRO-
C           CEDURES FOR THE BEHAVIORAL SCIENCES", JOHN WILEY AND SONS,
C           1962, CHAPTER 3.
C
C     ..................................................................
C
      DIMENSION A(1),B(1),XL(1),X(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
C     DOUBLE PRECISION A,B,XL,X,SUMV
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE PRECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION WITH THIS
C        ROUTINE.
C
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  SQRT IN STATEMENTS
C        110 AND 175 MUST BE CHANGED TO DSQRT.  ABS IN STATEMENT 110
C        MUST BE CHANGED TO DABS.
C
C        ...............................................................
```

```
C
C     COMPUTE EIGENVALUES AND EIGENVECTORS OF B
C
      K=1
      DO 100 J=2,M
      L=M*(J-1)
      DO 100 I=1,J
      L=L+1
      K=K+1
  100 B(K)=B(L)
C
C         THE MATRIX B IS A REAL SYMMETRIC MATRIX.
C
      MV=0
      CALL EIGEN (B,X,M,MV)
C
C     FORM RECIPROCALS OF SQUARE ROOT OF EIGENVALUES.  THE RESULTS
C     ARE PREMULTIPLIED BY THE ASSOCIATED EIGENVECTORS.
C
      L=0
      DO 110 J=1,M
      L=L+J
  110 XL(J)=1.0/ SQRT( ABS(B(L)))
      K=0
      DO 115 J=1,M
      DO 115 I=1,M
      K=K+1
  115 B(K)=X(K)*XL(J)
C
C     FORM (B**(-1/2))PRIME * A * (B**(-1/2))
C
      DO 120 I=1,M
      N2=0
      DO 120 J=1,M
      N1=M*(I-1)
      L=M*(J-1)+I
      X(L)=0.0
      DO 120 K=1,M
      N1=N1+1
      N2=N2+1
  120 X(L)=X(L)+B(N1)*A(N2)
      L=0
      DO 130 J=1,M
      DO 130 I=1,J
      N1=I-M
      N2=M*(J-1)
      L=L+1
      A(L)=0.0
      DO 130 K=1,M
      N1=N1+M
      N2=N2+1
  130 A(L)=A(L)+X(N1)*B(N2)
C
C     COMPUTE EIGENVALUES AND EIGENVECTORS OF A
C
      CALL EIGEN (A,X,M,MV)
      L=0
```

```
      DO 140 I=1,M
      L=L+I
  140 XL(I)=A(L)
C
C     COMPUTE THE NORMALIZED EIGENVECTORS
C
      DO 150 I=1,M
      N2=0
      DO 150 J=1,M
      N1=I-M
      L=M*(J-1)+I
      A(L)=0.0
      DO 150 K=1,M
      N1=N1+M
      N2=N2+1
  150 A(L)=A(L)+B(N1)*X(N2)
      L=0
      K=0
      DO 180 J=1,M
      SUMV=0.0
      DO 170 I=1,M
      L=L+1
  170 SUMV=SUMV+A(L)*A(L)
  175 SUMV= SQRT(SUMV)
      DO 180 I=1,M
      K=K+1
  180 X(K)=A(K)/SUMV
      RETURN
      END
```

APPENDIX G

SUBROUTINE EIGEN

```
C
C
C     ..................................................................
C
C        SUBROUTINE EIGEN
C
C        PURPOSE
C           COMPUTE EIGENVALUES AND EIGENVECTORS OF A REAL SYMMETRIC
C           MATRIX
C
C        USAGE
C           CALL EIGEN(A,R,N,MV)
C
C        DESCRIPTION OF PARAMETERS
C           A - ORIGINAL MATRIX (SYMMETRIC), DESTROYED IN COMPUTATION.
C               RESULTANT EIGENVALUES ARE DEVELOPED IN DIAGONAL OF
C               MATRIX A IN DESCENDING ORDER.
C           R - RESULTANT MATRIX OF EIGENVECTORS (STORED COLUMNWISE,
C               IN SAME SEQUENCE AS EIGENVALUES)
C           N - ORDER OF MATRICES A AND R
C           MV- INPUT CODE
C                   0   COMPUTE EIGENVALUES AND EIGENVECTORS
C                   1   COMPUTE EIGENVALUES ONLY (R NEED NOT BE
C                       DIMENSIONED BUT MUST STILL APPEAR IN CALLING
C                       SEQUENCE)
C
C        REMARKS
C           ORIGINAL MATRIX A MUST BE REAL SYMMETRIC (STORAGE MODE=1)
C           MATRIX A CANNOT BE IN THE SAME LOCATION AS MATRIX R
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           DIAGONALIZATION METHOD ORIGINATED BY JACOBI AND ADAPTED
C           BY VON NEUMANN FOR LARGE COMPUTERS AS FOUND IN "MATHEMATICAL
C           METHODS FOR DIGITAL COMPUTERS", EDITED BY A. RALSTON AND
C           H.S. WILF, JOHN WILEY AND SONS, NEW YORK, 1962, CHAPTER 7
C
C     ..................................................................
C
      DIMENSION A(1),R(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
C     DOUBLE PRECISION A,R,ANORM,ANRMX,THR,X,Y,SINX,SINX2,COSX,
C    1                 COSX2,SINCS
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE PRECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION WITH THIS
C        ROUTINE.
C
```

```
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  SQRT IN STATEMENTS
C        40, 68, 75, AND 78 MUST BE CHANGED TO DSQRT.  ABS IN STATEMENT
C        62 MUST BE CHANGED TO DABS.
C
C        ...............................................................
C
C        GENERATE IDENTITY MATRIX
C
      IF(MV-1) 10,25,10
   10 IQ=-N
      DO 20 J=1,N
      IQ=IQ+N
      DO 20 I=1,N
      IJ=IQ+I
      R(IJ)=0.0
      IF(I-J) 20,15,20
   15 R(IJ)=1.0
   20 CONTINUE
C
C        COMPUTE INITIAL AND FINAL NORMS (ANORM AND ANORMX)
C
   25 ANORM=0.0
      DO 35 I=1,N
      DO 35 J=I,N
      IF(I-J) 30,35,30
   30 IA=I+(J*J-J)/2
      ANORM=ANORM+A(IA)*A(IA)
   35 CONTINUE
      IF(ANORM) 165,165,40
   40 ANORM=1.414*SQRT(ANORM)
      ANRMX=ANORM*1.0E-6/FLOAT(N)
C
C        INITIALIZE INDICATORS AND COMPUTE THRESHOLD, THR
C
      IND=0
      THR=ANORM
   45 THR=THR/FLOAT(N)
   50 L=1
   55 M=L+1
C
C        COMPUTE SIN AND COS
C
   60 MQ=(M*M-M)/2
      LQ=(L*L-L)/2
      LM=L+MQ
   62 IF( ABS(A(LM))-THR) 130,65,65
   65 IND=1
      LL=L+LQ
      MM=M+MQ
      X=0.5*(A(LL)-A(MM))
   68 Y=-A(LM)/ SQRT(A(LM)*A(LM)+X*X)
      IF(X) 70,75,75
   70 Y=-Y
   75 SINX=Y/ SQRT(2.0*(1.0+( SQRT(1.0-Y*Y))))
      SINX2=SINX*SINX
   78 COSX= SQRT(1.0-SINX2)
```

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```
      COSX2=COSX*COSX
      SINCS =SINX*COSX
C
C         ROTATE L AND M COLUMNS
C
      ILQ=N*(L-1)
      IMQ=N*(M-1)
      DO 125 I=1,N
      IQ=(I*I-I)/2
      IF(I-L) 80,115,80
   80 IF(I-M) 85,115,90
   85 IM=I+MQ
      GO TO 95
   90 IM=M+IQ
   95 IF(I-L) 100,105,105
  100 IL=I+LQ
      GO TO 110
  105 IL=L+IQ
  110 X=A(IL)*COSX-A(IM)*SINX
      A(IM)=A(IL)*SINX+A(IM)*COSX
      A(IL)=X
  115 IF(MV-1) 120,125,120
  120 ILR=ILQ+I
      IMR=IMQ+I
      X=R(ILR)*COSX-R(IMR)*SINX
      R(IMR)=R(ILR)*SINX+R(IMR)*COSX
      R(ILR)=X
  125 CONTINUE
      X=2.0*A(LM)*SINCS
      Y=A(LL)*COSX2+A(MM)*SINX2-X
      X=A(LL)*SINX2+A(MM)*COSX2+X
      A(LM)=(A(LL)-A(MM))*SINCS+A(LM)*(COSX2-SINX2)
      A(LL)=Y
      A(MM)=X
C
C         TESTS FOR COMPLETION
C
C         TEST FOR M = LAST COLUMN
C
  130 IF(M-N) 135,140,135
  135 M=M+1
      GO TO 60
C
C         TEST FOR L = SECOND FROM LAST COLUMN
C
  140 IF(L-(N-1)) 145,150,145
  145 L=L+1
      GO TO 55
  150 IF(IND-1) 160,155,160
  155 IND=0
      GO TO 50
C
C         COMPARE THRESHOLD WITH FINAL NORM
C
  160 IF(THR-ANRMX) 165,165,45
C
C         SORT EIGENVALUES AND EIGENVECTORS
```

```
C
  165 IQ=-N
      DO 185 I=1,N
      IQ=IQ+N
      LL=I+(I*I-I)/2
      JQ=N*(I-2)
      DO 185 J=I,N
      JQ=JQ+N
      MM=J+(J*J-J)/2
      IF(A(LL)-A(MM)) 170,185,185
  170 X=A(LL)
      A(LL)=A(MM)
      A(MM)=X
      IF(MV-1) 175,185,175
  175 DO 180 K=1,N
      ILR=IQ+K
      IMR=JQ+K
      X=R(ILR)
      R(ILR)=R(IMR)
  180 R(IMR)=X
  185 CONTINUE
      RETURN
      END
```

APPENDIX H

SUBROUTINE CHECK

```
      SUBROUTINE CHECK,RETURNS(R1,R2)
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SOLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
       LOGICAL INTER
      TOLR=.0025
      K2=K*K
      IF(ABS(EIG(1)).LT.1.E-40)EIG(1)=1.E-40
      EIG(1)=1./EIG(1)
      VAL=EIG(1)
      MODE=1
      DO 1 I=2,K2
      IF(ABS(EIG(I)).LT.1.E-40)EIG(I)=1.E-40
      EIG(I)=1./EIG(I)
      IF(ABS(EIG(I)).GE.ABS(VAL))GO TO 1
      VAL=EIG(I)
      MODE=I
 1    CONTINUE
      IF(ISTART.GT.0)GO TO 10
      IF(ABS(VAL).EQ.ABS(PREV))ICONV=1
      DIFF=ABS((ABS(VAL)-ABS(PREV))/VAL)
      IF(DIFF.LT.TOLR)ICONV=1
      IF(.NOT.INTER)CALL PRINT
      PREV=VAL
      K=K+1
      IF(ICONV.EQ.1)RETURN R2
      IF(K.LE.MAX)RETURN R1
      WRITE(6,900)DIFF
      RETURN R2
 10   ISTART=0
      IF(.NOT.INTER)CALL PRINT
      PREV=VAL
      K=K+1
      RETURN R1
 900  FORMAT(/10X,42H** WARNING: RELATIVE CONVERGENCE TOLERANCE,
     1      /13X,22HOF .0025 NOT SATISFIED,
     2      /10X,16H** TOLERANCE OF ,F7.4,9H ACHIEVED/)
      END
```

APPENDIX I

SUBROUTINE OUTPUT

```
      SUBROUTINE OUTPUT,RETURNS(R1,R2)
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/MATL/E(2),T(2),XNU(2),XLMDA(2),BETA(2),SIGN(2)
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SOLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      LOGICAL INTER
      DATA YES/1HY/
      NRUN=NRUN-1
      K=K-1
      ISTART=0
      WRITE(6,890)K
      K2=K*K
      X=VAL*NX
      Y=VAL*NY
      XY=VAL*LXY
      XB=VAL*NXB
      YB=VAL*NYB
      WRITE(6,910)
      WRITE(6,915)X,XY,Y
      WRITE(6,917)XB,YB
      IF(.NOT.INTER) GO TO 100
      WRITE(6,895)
      READ(5,897)ANS
      IF(ANS.NE.YES)RETURN R2
  100 CONTINUE
      WRITE(6,900)
      WRITE(6,905)(EIG(JJ),JJ=1,K2)
      J=K2*(MODE-1)+1
      JJ=K2*MODE
      WRITE(6,920)
      WRITE(6,919)
      IF(K.LT.10)WRITE(6,940)K,K,K
      WRITE(6,925)(EIGV(I),I=J,JJ)
      IF(NRUN.LE.0)RETURN R2
      RETURN R1
  890 FORMAT(10X,23H***** SOLUTION FOR M=N=,I2,5H ****)
  895 FORMAT(//10X,40HPRINT EIGENVALUES AND MODE SHAPES (Y/N)?)
  897 FORMAT(A5)
  900 FORMAT(/10X,30H********* EIGENVALUES ********)
  905 FORMAT(3X,4E12.5)
  910 FORMAT(/10X,30H******* CRITICAL LOADS *******)
  915 FORMAT(10X,4HNX =.F16.4,/10X,4HNXY=,F16.4,/10X,4HNY =,F16.4)
  917 FORMAT(10X,4HNXB=,F16.4,11H *(1-2*Y/B),
     1       /10X,4HNYB=,F16.4,11H *(1-2*X/A))
  919 FORMAT(17X,17HAT CRITICAL LOADS)
  920 FORMAT(/10X,30H********* MODE SHAPE *********)
  925 FORMAT(5X,4F16.10)
  940 FORMAT(/10X,15H(W11,W12,....,W1,I1,14H,W21,W22,....,W,2I1,1H)/)
      ENTRY ECHO
      WRITE(6,948)
      WRITE(6,949)
      WRITE(6,950)E(1),XNU(1),T(1)
      WRITE(6,951)E(2),XNU(2),T(2)
      WRITE(6,947)
      WRITE(6,952)GX,GY,TC
```

```
      WRITE(6,946)
      WRITE(6,953)A
      WRITE(6,954)B
      WRITE(6,945)
      WRITE(6,955)NX,LXY,NY
      WRITE(6,957)NXB,NYB
      IF(.NOT.INTER)WRITE(6,960)
  945 FORMAT(/5X,12HLOAD FACTORS)
  946 FORMAT(/5X,19HPLANFORM DIMENSIONS)
  947 FORMAT(/5X,15HCORE PARAMETERS)
  948 FORMAT(1H1,/5X,21HFACE SHEET PARAMETERS)
  949 FORMAT(/23X,1HE,10X,2HNU,8X,1HT)
 950  FORMAT(5X,7HFACE 1:,2X,E14.4,2F10.5)
 951  FORMAT(5X,7HFACE 2:,2X,E14.4,2F10.5)
  952 FORMAT(/22X,2HGX,12X,2HGY,10X,2HTC,
     1      / 5X,7HCORE  :,2X,2E14.4,F10.5)
 953  FORMAT(/5X,7H     A =,F10.4)
 954  FORMAT( 5X,7H     B =,F10.4)
 955  FORMAT(/5X,3HNX=,F5.2,3X,4HNXY=,F5.2,3X,3HNY=,F5.2/)
 957  FORMAT(5X,4HNXB=,F5.2,14X,4HNYB=,F5.2/)
 960  FORMAT(/5X,5HTERMS,7X,2HNX,7X,3HNXB,8X,3HNXY,7X,
     12HNY,8X,3HNYB,3X,20HASSEM(SEC)EIGEN(SEC))
      RETURN
      ENTRY PRINT
      X=VAL*NX
      Y=VAL*NY
      XY=VAL*LXY
      XB=VAL*NXB
      YB=VAL*NYB
      WRITE(6,970)K,X,XB,XY,Y,YB,TIME1,TIME2
 970  FORMAT(6X,I2,2X,7F10.3)
      RETURN
      END
```

APPENDIX J

SUBROUTINE BENDI

```
      SUBROUTINE BEND1
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SOLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      LOGICAL MREQ,NSEQ,MRODD,NSODD,INTER
      DATA PI/3.1415926535898/
      DO 100 M=1,K
      DO 100 N=1,K
      DO 100 IR=1,K
      MREQ=(M.EQ.IR)
      ICHK=(M+IR)/2
      XCHK=.5*FLOAT(M+IR)
      MRODD=(ABS(FLOAT(ICHK)-XCHK).GT..10)
      DO 100 IS=1,K
      NSEQ=(N.EQ.IS)
      ICHK=(N+IS)/2
      XCHK=.5*FLOAT(N+IS)
      NSODD=(ABS(FLOAT(ICHK)-XCHK).GT..10)
      ICHK=(IR-1)*K+IS-1
      JJ=ICHK*K*K+(M-1)*K+N
      IF((.NOT.MREQ).AND.(.NOT.NSEQ))GO TO 100
      IF(MREQ.AND.NSEQ)BB(JJ)=BB(JJ)-.125*PI*PI*
     1                              (M*M*B*LXB/A+N*N*A*LYB/B)*4./(A*B)
      IF(MREQ.AND.NSODD)BB(JJ)=BB(JJ)+2.*M*M*N*IS*LXB
     1                              *B/(A*(N*N-IS*IS)**2)*4./(A*B)
      IF(MRODD.AND.NSEQ)BB(JJ)=BB(JJ)+2.*N*N*M*IR*LYB
     1                              *A/(B*(M*M-IR*IR)**2)*4./(A*B)
  100 CONTINUE
      RETURN
      END
```

APPENDIX K

SUBROUTINE ALTER

```
      SUBROUTINE ALTER,RETURNS(R1,R2,R3)
      REAL LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      COMMON/MATL/E(2),T(2),XNU(2),XLMDA(2),BETA(2),SIGN(2)
      COMMON/CORE/GX,GY,TC,A,B
      COMMON/CNTL/INTER,PREV,VAL,ISTART,K,MAX,NRUN,ICONV,TIME1,TIME2
      COMMON/SCLN/AA(2401),BB(2401),EIG(49),EIGV(2401),MODE
      COMMON/LOAD/LX,LXB,LY,LYB,LXY,NX,NXB,NY,NYB
      LOGICAL INTER
      DIMENSION VAR(17)
      DATA YES/1HY/
      DATA VAR/4HE1  ,4HE2  ,4HNU1 ,4HNU2 ,
     1         4HT1  ,4HT2  ,
     2         4HGX  ,4HGY  ,4HTC  ,
     3         4HA   ,4HB   ,
     4         4HNX  ,4HNXY ,4HNY  ,
     5         4HNXB ,4HNYB ,4HEND /
      KOUNT=0
      WRITE(6,900)
      WRITE(6,910)
      READ(5,920) ANS
      IF (ANS.EQ.YES) GO TO 10
      WRITE(6,960)
      READ(5,920) ANS
      IF(ANS.EQ.YES) RETURN R1
      RETURN R3
   10 CONTINUE
      WRITE(6,930)
   15 CONTINUE
      WRITE(6,940)
      READ(5,950)V
      IF(V.EQ.VAR(17))GO TO 800
      DO 20 I=1,17
      IF(V.NE.VAR(I)) GO TO 20
      J=I
      GO TO 25
   20 CONTINUE
      WRITE(6,970) V
      KOUNT=KOUNT+1
      IF (KOUNT.GT.3) RETURN R3
      WRITE(6,975)
      GO TO 10
  25  WRITE(6,990) V
      READ(5,*)VAL
      GO TO (101,102,103,104,105,106,107,108,
     1      109,110,111,112,113,114,115,116,800),J
  101 E(1)=VAL
      GO TO 15
  102 E(2)=VAL
      GO TO 15
  103 XNU(1)=VAL
      GO TO 15
  104 XNU(2)=VAL
      GO TO 15
  105 T(1)=VAL
      GO TO 15
  106 T(2)=VAL
      GO TO 15
```

```
 107  GX=VAL
      GO TO 15
 108  GY=VAL
      GO TO 15
 109  TC=VAL
      GO TO 15
 110  A=VAL
       GO TO 15
111   B=VAL
      GO TO 15
 112  NX= VAL
      GO TO 15
 113  LXY= VAL
      GO TO 15
 114  NY= VAL
       GO TO 15
 115  NXB= VAL
      GO TO 15
 116  NYB= VAL
      GO TO 15
 800  CONTINUE
C     SET RESTART PARAMETERS
      NRUN=0
      ICONV=0
      PREV=0.
      CALL RESET
      WRITE(6,980)
      WRITE(6,900)
      RETURN R2
C       FORMATS
 900  FORMAT(/10X,30H******************************)
 910  FORMAT(/10X,11HBEGIN ALTER,/10X,17HMODIFY DATA(Y/N)?)
  920 FORMAT(A1)
 930  FORMAT(10X,20HGIVE *PARAMETER NAME)
 940  FORMAT(15X,1H*)
 950  FORMAT(A5)
 960  FORMAT(/10X,23HBEGIN NEW PROBLEM(Y/N)?)
 970  FORMAT(/10X,14HINVALID DATA :,A5/)
 975  FORMAT (10X,17HRETRY OR TYPE END  /1X)
 980  FORMAT( 10X,15HALTER COMPLETED)
 990  FORMAT(16X,A5,3H=  )
      END
```

APPENDIX L

SUBROUTINE TITLE

```
      SUBROUTINE TITLE (I)
 1    FORMAT(//)
 2    FORMAT(18X,43H*******************************************)
 3    FORMAT(18X,43H*                                         *)
 4    FORMAT(18X,43H*      GENERAL STABILITY ANALYSIS OF      *)
 5    FORMAT(18X,43H*    FLAT, RECTANGULAR SANDWICH PANELS    *)
 6    FORMAT(18X,43H*             REVISED 10/15/76            *)
 7    FORMAT(18X,43H* UNIVERSITY OF DAYTON RESEARCH INSTITUTE *)
 8    FORMAT(18X,43H*              DAYTON, OHIO               *)
 9    FORMAT(1H1)
      IF (I.LE.0) WRITE(6,9)
      WRITE(6,1)
      IF (I.GT.1) RETURN
      WRITE(6,2)
      WRITE(6,3)
      WRITE(6,4)
      WRITE(6,5)
      WRITE(6,6)
      WRITE(6,3)
      WRITE(6,7)
      WRITE(6,8)
      WRITE(6,3)
      WRITE(6,2)
      WRITE(6,1)
      RETURN
      END
```

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