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ADDENDUM TO USERS GUIDE TO VIPASA
(Vibration and Instability of Plate Assemblies including Shear and Anisotropy)

By

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and
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16. Abstract

The VIPASA program for panel buckling and vibration analysis was originally made available to NASA by the United Kingdom. It was found to be a very useful, efficient and accurate analysis tool. Extensions developed at Langley for plotting and laminate property input have further enhanced its capability. The program is now generally available and the purpose of this paper is to document the changes and extensions so that this report and the original VIPASA users manual will serve as the users manual for the current version of the program.

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ADDENDUM TO USERS GUIDE TO VIPASA
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SUMMARY

Extensions developed at Langley Research Center to the VIPASA computer program are described including a procedure for simple thermal stress analysis and options for graphical display of output. Input requirements for operation of the modified program are given in detail.

INTRODUCTION

The VIPASA program (References 1 and 2) for panel buckling and vibration analysis was originally made available to NASA by the United Kingdom. It was found to be a very useful, efficient and accurate analysis tool. Extensions developed at Langley for plotting,thermal stress, and orthotropic laminate property input have further enhanced its capability. The program is now generally available and the purpose of this paper is to document the changes and extensions so that this report and the original VIPASA users manual will serve as the users manual for the current version of the program.

Extensions to the VIPASA Program

A number of extensions to the VIPASA program which have been found to enhance its capability and efficiency have been incorporated at the Langley Research Center. These extensions are summarized below:

1. Input of a uniform axial strain so that individual plate loads can be automatically calculated for all plate structures.

2. Calculation of total axial load on the structure for each eigenvalue.

3. Input of layer temperatures so that simple constant strain thermal buckling problems can be handled.

4. Input of individual orthotropic layer properties with internal calculation of plate stiffnesses.

5. Calculation of geometry including consistency checks for sub structures and final structures.

6. Plotting of undeformed shape and buckling or vibration mode shapes. Plotting of eigenvalue as a function of wavelength.

7. An option to speed up the calculation process when only the minimum buckling load over a range of wavelengths is desired (It is only necessary to perform one iteration at a given wavelength if the eigenvalue is higher than that determined for some previous wavelength.)

8. Addition of a title card.

The details of the thermal stress calculation and stiffness properties of layered wall configurations are described briefly in Appendix A. Examples of plotting and geometry checks will be covered in the section entitled EXAMPLE PROBLEMS.

Program Operation

The modified program input is changed very little from the original VIPASA input with the exception of layered property input if that option is used. Input for the original program will also execute the current program if a title card is added prior to the C cards for each problem number.

The plotting and geometry calculation program is separate from VIPASA. The usual mode of operation is to run both programs in sequence. The complete input for the plotting program is generated in VIPASA and stored on an output file which becomes the input file for the second program. There are no other input requirements.

Because plotting commands are generally tied to facilities, the different subroutines that execute plotting are described with comment cards in the source listing. There is enough information given so that available routines that perform the same function can be easily substituted. In addition, a more detailed description of each plotting subroutine is given in Appendix B so that definitions of all the variables may be obtained. The programs are written in FORTRAN and do not use any complicated instructions so that they should be capable of running on a variety of machines with little or no modification except for the plotting instructions. Experience at Langley with the FTN compiler on CDC hardware has been that OPT = 0 is required. The program will compile at OPT = 1 but will give incorrect results.

INPUT REQUIREMENTS

The following section gives a description of the card input in the correct sequential order including the input for the extensions developed at Langley. The cards that remain unchanged will be dealt with rather briefly and the reader is referred to the original VIPASA users manual (Reference 1) for a more complete description when required. New cards or cards that have been changed are indicated by underlining the new input variables.

Card Input

The input is divided into several categories denoted by letters of the alphabet A through I with one or more cards in each category.

<u>GROUP A</u> Sets up array dimensions and plotting options,

NMK, NSR, NSC, IPAST, NSN, NSK, NOLAM, <u>IPLOT</u>, <u>NSPAC</u>, <u>PAGE</u>, <u>AMP</u>
(7I7, 2I4, 2E10.4)

NMK — Must be even and no less than highest plate number or doubly connected substructure number and less than or equal to 120. Must be double this value with shear or if either D13 or D23≠0.

NSR — Must be even and no less than the largest number of nodes comprising a substructure. Must be no less than the highest numbered node of the final structure (twice this value for shear or anisotropy). Must be at least 4.

NSC — Must be greater than the largest difference between connected node numbers and at least 3.

IPAST — Must be no less than the number of iterations required for one eigenvalue solution.

NSN — Must be no less than the total number of all the integers in group H and I cards.

NSK — Must be no less than the highest numbered singly connected substructure number minus 120 and less than 900.

NOLAM — Must be no less than the number of different values of λ for which solutions are required.

56*NMK + 16*NSR*NSC + 4*NSR + 2*IPAST + NSN + 18*NSK + 4*NOLAM + 9 $\leq$ IDUM
IDUM is currently set at 8009; see comment cards at beginning of VIPASA

IPLOT Controls geometry calculations and plotting

0 No geometry calculations made and no plotting done

± 1 Used for checking input. Geometry calculated and undeformed structure plotted. No eigenvalue calculations made.

± 2 Plots are made of undeformed structure and for each eigenvalue the buckling or vibration mode superimposed on the undeformed structure is plotted.

± 3 Plots are made of undeformed structure and for each eigenvalue, the buckling or vibration mode is plotted alone.

A negative value of IPLOT causes additional printout giving all of the coordinates of the substructures and the final structure.

If eigenvalues are calculated at more than one value of wavelength λ . a plot of FACTOR(Eigenvalue) versus λ is also made for $|IPLOT| > 1$

NSPAC Number of intervals between nodes where mode shape is calculated for plotting purposes. May be omitted and default value of 4 will be used. Large values cause smoother mode shapes but no increase in accuracy.

PAGE Controls size of plots. Overall dimensions of plots vary linearly with PAGE. If PAGE = 1., all plots will fit inside a 6 x 9 rectangle (this may be changed in the program as indicated in comment cards by changing the definition of variables PX and PY). May be omitted and default value of 1. will be used.

AMP Maximum amplitude of buckling or vibration mode. May be omitted and default value of .5*PAGE will be used.

GROUP B

NOPROB (I5) Number of problems. If more than one problem is desired, the A and B cards are not repeated for subsequent problems.

GROUP C

TITLE (I) (8A10)

May contain any Hollerith text

JBMAX, JBMIN, CONVER, FACLIM, FACLOW, SIGMA, ANV, MODE, LPLATE (2I5, F15.1, 2F15.6, 2F10.4, 2I2)

JBMAX, JBMIN If JBMAX positive all eigenvalues with eigenvalue numbers between and including JBMIN and JBMAX will be found. If JBMAX negative all eigenvalues having a value between FACLOW and FACLIM will be found. (In this case JBMIN should be left blank).

CONVER	Eigenvalues will be found to an accuracy of EIGENVALUE/CONVER
FACLIM	Should be set to maximum expected eigenvalue if JBMAX is positive (does not have to be accurate but good guesses improve computational efficiency). Should be set to upper limit of desired range of eigenvalues to be searched if JBMAX is negative. For thermal stress problems(IEP>1), FACLIM should be set to a number of the order one.
FACLOW	Should be set to zero if JBMAX is positive; should be set to lower limit of desired range of eigenvalue to be searched if JBMAX is negative.
SIGMA	SIGMA is not operative in the current version. Input of EPV and EPF on D card should now be used.
ANV	For vibration problems set to some positive value. Vibration frequency will be eigenvalue times ANV. Leave blank for buckling problems.
MODE	Print mode shape if MODE = 1. Leave blank if mode shapes not desired. Must be set = 1 to obtain plots.
LPLATE	Prints total loads in all plates if LPLATE = 1. Leave blank if loads not desired.

EL, ALAMIN, ALAMAX, RATLAM, EC, ANUC, DENSEC (4F10.4, F15.1, F7.3, F15.9)

EL	Panel length in x direction (See figure 1)
ALAMIN, ALAMAX, RATLAM	Allows several solutions at different values of axial buckle length, λ, to be obtained. If ALAMIN is positive, λ = ALAMIN x $(\text{RATLAM})^i$ for i = 1, 2, 3. . until λ greater than ALAMAX. If ALAMIN is negative λ = EL/j for j = RATLAM, (RATLAM + 1) . . .ALAMAX If ALAMAX is negative a prescribed set of λ's can be read on additional cards according to section 3C.4. of Reference 1.
EC, ANUC, DENSEC	Young's modulus, Poison's ratio, and material density. If a number of plates are of the same isotropic material, these values will be used if none are input on the E cards. Applies only to the E cards.

GROUP D

IA, IB, IC, ID, IE, IG, IFAST, IEP, EPV, EPF, P (8I5, 3F10.6)

IA	Number of isotropic plates defined by group E cards. (There are 2*IA group E cards).
IB	Number of orthotropic or anisotropic plates defined by group F cards (There are 3*IB group F cards).
IC	If IC = 0 no spring supports. If IC = 1 there are spring supports defined by a single group G card.
ID	Number of group H cards
IE	Number of group I cards
IG	Input of IG = 1 indicates material and layer properties will be read in. Otherwise IG = 0.
IFAST	Reduces computation time when calculating the buckling load at a number of wavelengths and only the minimum is desired. Should not be used for more than one eigenvalue at a given wavelength.

0 no effect on calculations.

1 Converged solution is determined only if lower than that for previous λ. The number of negative roots at FACTOR = 0 is checked.

2 Same as IFAST = 1 except number of negative roots at FACTOR = 0 is not checked. One iteration is saved for each wavelength but if negative roots do occur at FACTOR = 0, solution may not converge.

IEP Controls strain or temperature input.

0 No strain or temperature input.

1 Longitudinal loads calculated using strains EPV and EPF. Temperature may be present.

2 Fixed temperature input - axial load to cause buckling is determined.

3 Fixed load input P. Temperature distribution to cause buckling is determined.

No E or F cards may be used for IEP = 2 or 3. Group DD cards can always be used.

EPV The variable longitudinal load NLV is calculated based on the strain EPV for any plate which NLV is read in as zero if IEP = 1. Used only when IEP = 1.

EPF Same as EPV except it applies to fixed loading system.

P Used only when IEP = 3. Value of total fixed axial load on the panel.

GROUP DD Input when IG > 0. These cards are mandatory when IEP = 2 or 3 (no E or F cards). They are divided into 4 different categories: (1)Material properties, (2) Individual layer dimensions and temperatures, (3) Layer stacking sequence, and (4) plate definition and loading.

DD1 Cards (Orthotropic Material Properties)

E1, E2, E12, NU1, RHO, ALFA1, ALFA2 (7E10.3)

E1 Young's modulus in 1 direction

E2 Young's modulus in 2 direction

E12 Inplane shear modulus

NU1 Poisson's ratio such that NU1*E2 = NU2*E1

RHO Mass density of material

ALFA1 Coefficient of thermal expansion in 1 direction

ALFA2 Coefficient of thermal expansion in 2 direction

Materials are internally numbered in sequence starting at 1 for the first card, 2 for the second, etc. A card with a negative number in the first field signals that the previous card was the end of the DD1 cards.

DD2 Cards (Orthotropic Layer Characteristics)

MATL, H, ANGLE, T1V, T2V, T1F, T2F (I5, 6E10.3)

MATL Material number

H Layer thickness

ANGLE Angle between material axis and plate axis. See figure 1 for positive direction. Must be in degrees.

T1V, T2V Variable temperatures at inner and outer edges of layer, respectively. Inner edge has least value of z. Variable temperatures are multiplied by the eigenvalue.

T1F, T2F Same as T1V, T2V except applies to fixed temperatures.

Layers are numbered in sequence starting at 1 for first DD2 card, 2 for second, etc. A card with a negative integer in the first field signals that the previous card was the end of the DD2 cards.

DD3 Cards (Wall Generation)

LAYNO(I) (20I4) I = 1, 20

LAYNO (I) Layer number of the Ith layer

Layers are stacked in sequence in the direction of increasing z. The number of integers on the card will be equal to the number of layers for that particular wall. If the wall section contains more than 20 layers, continue on the next card by placing a zero in the first field followed by the additional layer numbers. More than one continuation card may be used so there is no limit to the number of layers in one wall.

The first DD3 card is wall number 1, the second (if not a continuation card) wall number 2, etc. A card with a negative number in the first field signals that the previous card was the end of the DD3 cards.

DD4 Cards (Plate Generation)

JPA, IWALL, B, ANTV, ANLV, ANSV, ANTF, ANLF, ANSF (2I5, F10.5, 6F10.2)

JPA	Plate number such that $1 \leq JPA \leq 120$
IWALL	Wall number defined by DD3 cards. If it is desired to neglect anisotropic stiffness terms set IWALL to the negative of the wall number.
B	Plate width
ANTV ANLV ANSV	Inplane transverse, longitudinal, and shear plate loadings that are multiplied by the eigenvalue. If ANLV is input as zero and IEP = 1, ANLV is calculated from equation A7 using EPV.
ANTF ANLF ANSF	Inplane transverse, longitudinal, and shear plate loading that make up the fixed load system. If ANLF is input as zero and IEP =1, ANLF is calculated from equation A7 using EPF.

A negative number in the first field signals that the previous card was the end of the DD4 cards.

GROUP E (Isotropic Plates)

Two consecutive cards,E1, and E2 required for each plate.

JPA, T, B, E, ANU, DENSE (I5, 2F10.5, F15.1 F5.3, F15.9)

JPA	Plate number
T	Plate thickness
B	Plate width
E,ANU, DENSE	Young's modulus, Poisson's ratio, and density for plate material. If any one is left blank value given on group C card will be used.

E2 Cards

ANTV, ANLV, ANSV, ANTF, ANLF, ANSF (6F10.2)

ANTV ANLV ANSV	Inplane transverse, longitudinal, and shear plate loadings that are multiplied by the eigenvalue. If ANLV is input as zero and IEP =1, ANLV is calculated from equation A7 using EPV.
ANTF ANLF ANSF	Inplane transverse, longitudinal, and shear plate loadings that make up the fixed load system. If ANLF is input as zero and IEP = 1, ANLF is calculated from equation A7 using EPF.

GROUP F (Orthotropic and Anisotropic Plates)

Three consecutive cards, F1, F2, and F3, required for each plate.

F1 Cards

JPA, B, ANTV, ANLV, ANSV, ANTF, ANLF, ANSF (I5, F10.5, 6F10.2)

JPA	Plate number
B	Plate width
ANTV ANLV ANSV	Inplane transverse, longitudinal, and shear plate loadings that are multiplied by the eigenvalue. If ANLV is input as zero and IEP = 1, ANLV is calculated from equation A7 using EPV.
ANTF ANLF ANSF	Inplane transverse, longitudinal, and shear plate loading that make up the fixed load system. If ANLF is input as zero and IEP = 1, ANLF is calculated from equation A7 using EPF.

F2 Cards

D11, D12, D22, D33, D13, D23 (6E13.6)

Dij Bending stiffnesses defined by equation A2

F3 Cards

AM, A11, A12, A22, A33 (F15.8, 4E15.8)

AM Mass per unit area

Aij Inplane stiffnesses defined by equation A1

GROUP G (Spring Stiffnesses)

Required (8E10.3) only if IC = 1. A single card which gives up to 8 different values of spring stiffness that can be placed anywhere in the structure by boundary condition cards in Group H and I.

GROUP H (Generation of Substructures)

(20I4) New plates or substructures can be defined from those previously generated by (1) rotation of a previously defined plate or substructure, (2) displacement of end points of previously defined plate or substructure, and (3) stringing together previously defined plates or substructures.

Denote the number on Group H cards by i_1, i_2, i_3 . .. Then

i_1 Number of additional numbers on the card.

i_2 Number of plate or substructure being generated.

i_3 Number of previously defined plate or substructure that is being modified. To accomplish a rotation enter i_2 negative.

Rotation.- To accomplish a rotation enter i_2 negative and i_3 positive. The counterclockwise rotation is $i_4 \times 10^{i_5}$. (In this case, i_1 must equal 4.)

Displacement.- To displace end points of a plate or substructure from node points, enter both i_2 and i_3 as negative. Then

$$EY1 = i_4 \times 10^{i_5}$$

$$EZ1 = i_6 \times 10^{i_7}$$

$$EY2 = i_8 \times 10^{i_9}$$

$$EZ2 = i_{10} \times 10^{i_{11}}$$

For this case i_1 must equal 10. EYj and EZj are the coordinates of the node points assuming the origin of the Y, Z coordinate system is at the intersection of the plate edge with its neutral surface.

Multiplate Substructures and Boundary Conditions.-

To string together a series of plates and substructure both i_2 and i_3 are entered as positive. Only substructures having nodes that form a simple chain can be constructed. If a substructure has one end that is not attached to other structure it is a singly connected substructure and must be numbered starting at 121. The unattached end must be the initial point of this substructure. All substructures have nodes temporarily numbered 1, 2. . . N_v. Thus i_3 is the first plate or doubly connected substructure number of this sequence. If other plates or doubly connected substructures connect nodes 1 and 2 they are entered but with a negative sign. If singly connected substructures are attached at node 1 they are entered with a negative sign. Boundary conditions at node 1 are also entered for node 1 using a negative sign as -9xxxx00 where the x's indicate restraint against rotation, w, v, u, respectively. An x = 0 means no restraint, x = 1-8 selects the corresponding spring constant read on the G card and x = 9 is an infinite restraint. Specification of a free edge anywhere in the structure is not necessary. Such a specification will cause a program error. After all elements connecting 1 and 2 and boundary conditions and singly connected substructures at 1 are accounted for the next number will be positive indicating a plate or substructure connecting 2 and 3; again additional negative numbers indicate other connections to 3 or boundary conditions at 2. This process is repeated until the substructure is described. If it cannot fit on one card an intermediate substructure can be defined and used to start a new card.

If a singly connected substructure or a boundary condition is at the last node (N_v) enter a zero then the substructure or boundary condition preceded by a negative sign.

For singly connected substructures, N_v must be greater than one, and for doubly connected substructures N_v must be greater than two. Violation of this rule will cause incorrect results or a dump. A diagnostic in the plotting program will be printed if this rule is violated.

Examples of the generation of a variety of substructures are illustrated in the sample problems of reference 1.

GROUP I (Generation of Final Structure)

(20I4)

Final structure is assembled from plates and substructures in Group I cards with format I4. If as in Group H we denote numbers on Group I as i_1, i_2. . then

i_1 Number of additional numbers in the card.

i_2 Node number. One card must be prepared for each node connected to a higher numbered node or having a prescribed boundary condition.

i_3 Node number (must be greater than i_2) that is connected to i_2

i_4 Plate or substructure that connects the two nodes.

i_5-i_n Additional pairs of numbers, the first being the number of the node which is connected to i_2 and the second, the number of the plate or substructure making the connection. Note, if more than one element connects the two nodes the higher numbered node number will be repeated.

i_{n+1} Boundary condition or the number of a singly connected substructure at node i_2 preceded by a minus sign. Notation for boundary conditions is the same as in the H cards (9xxxx00).

i_{n+2} Additional singly connected substructure or a boundary condition but not preceded by a minus sign.

EXAMPLE PROBLEMS

The first problem is buckling under compression and shear of the panel in figure 3. It is desired to obtain the two lowest eigenvalues for values of buckle length λ from 2 to 32. Buckling modes, including plots, are desired. The input data using the option for layered material property input, is shown in Table 1. The shear flow in the hat and skin was calculated by equating the shear deformation of the two paths accounting for the inplane shear stiffness. A portion of the output is shown in Table 2. Plots of the structure, buckling mode shape, and a plot of buckling strain versus λ are shown in figures 4 to 6. Note in figure 4 node locations are shown by circular symbols.

Several capabilities of the program are illustrated in this example. The flange of the hat section is bonded to the skin so that the two act together. Such a plate results in a non zero B matrix which cannot be handled in VIPASA. However, it still can be treated accurately by the procedure given in reference 3. The plate is modeled as a substructure with both the skin and flange tied together at a spacing of 1/8 the total plate width. The flange is given an eccentricity of one half the sum of the two plate thicknesses to give the resulting substructure the proper bending stiffness.

Another feature is the capability to treat structures with periodic buckling patterns in the transverse direction by giving the boundaries the same node number. Note in figure 4 that both edges of the panel are numbered 5 which causes the deformation on the left edge to be compatible with the deformations on the right edge. At the end of table 2, the diagnostic is printed that node 5 is in error. This is the result of assigning two different locations to the same node.

In order to construct the plate going from node 1 to node 5 it is necessary to rotate a plate by 180°. Even though this plate is physically identical to plate number 5, plate 5 cannot be used since it would not have the shear force in the proper direction or the fibers in the proper sequence upon rotation. Therefore, a new plate is generated with the sign on the angle plys reversed and the shear load reversed so that it will be identical to plate 5 after a 180°rotation.

The thermal stress capability is illustrated in the second problem. It is assumed the panel of problem 1 was in a stress free state at an elevated curing temperature. The effect of a uniform temperature drop of 300° F is investigated with option IEP = 2. The input cards are shown in table 3 with portions of the output in table 4. The thermal stress in each plate number is shown for no axial load and the prestress assumed for the buckling analysis is shown. The thermal stress was rather small and had little effect on the buckling load.

A check of the accuracy of the program for thermal stress problems is indicated in the third example. The compressive buckling load of a nonuniform temperature, titanium zee stiffened panel which was determined in reference 4 has also been determined with VIPASA. The input for the problem is given in table 5 and the pertinent output in table 6. Results from reference 4 are also shown for comparison. There is generally good agreement; the small difference in buckling load is attributed to effects of eccentric connections which were ignored in VIPASA.

CONCLUDING REMARKS

Extensions developed at Langley Research Center to the VIPASA computer program for panel buckling and vibration analysis have been described. A condensed version of the users manual including new input options is given. Example problems with sufficient documentation for checking results are also given.

REFERENCES

1. Williams, F. W.; and Anderson, M. E.: Users Guide to VIPASA. Department of Civil Engineering, University of Birmingham, January 1973.

2. Wittrick, W. H.; and Williams, F. W.: Buckling and Vibration of Anisotropic or Isotropic Plate Assemblies under Combined Loadings. International Journal of Mechanical Sciences, Vol. 16, 1974, p.209.

3. Williams, F. W.: Approximations in Complicated Buckling and Free Vibration Analysis of Prismatic Plate Structures. The Aeronautical Quarterly, Vol. XXV, August 1974.

4. Viswanathan, A. V.;and Tamekuni, M.: Analysis for Stresses and Buckling of Heated Composite Stiffened Panels and Other Structures. NASA CR-112227, March 1973.

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APPENDIX A

STRESS STRAIN RELATIONSHIPS AND THERMAL STRESS CALCULATION

The relations defining the elastic properties including temperature effects are:

$$\begin{bmatrix} N_L \\ N_T \\ N_S \end{bmatrix} = - \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{12} & A_{22} & A_{23} \\ A_{13} & A_{23} & A_{33} \end{bmatrix} \bullet \begin{bmatrix} \partial u/\partial x \\ \partial v/\partial y \\ \partial u/\partial y + \partial v/\partial x \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{12} & B_{22} & B_{23} \\ B_{13} & B_{23} & B_{33} \end{bmatrix} \bullet \begin{bmatrix} \partial^2 w/\partial x^2 \\ \partial^2 w/\partial y^2 \\ 2\partial^2 w/\partial x \partial y \end{bmatrix} + \begin{bmatrix} C_{1T} \\ C_{2T} \\ C_{3T} \end{bmatrix} \quad \text{(A1)}$$

$$\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{12} & B_{22} & B_{23} \\ B_{13} & B_{23} & B_{33} \end{bmatrix} \bullet \begin{bmatrix} \partial u/\partial x \\ \partial v/\partial y \\ \partial u/\partial y + \partial v/\partial x \end{bmatrix} - \begin{bmatrix} D_{11} & D_{12} & D_{13} \\ D_{12} & D_{22} & D_{23} \\ D_{13} & D_{23} & D_{33} \end{bmatrix} \bullet \begin{bmatrix} \partial^2 w/\partial x^2 \\ \partial^2 w/\partial y^2 \\ 2\partial^2 w/\partial x \partial y \end{bmatrix} \quad \text{(A2)}$$

where

$$\begin{bmatrix} A_{ij} \\ B_{ij} \\ D_{ij} \end{bmatrix} = \int Q_{ij} \begin{bmatrix} 1 \\ z \\ z^2 \end{bmatrix} dz \qquad \text{(A3)}$$

$$C_{iT} = \int Q_{iT} T dz \qquad \text{(A4)}$$

See figures 1 and 2 for positive values of variables. For an orthotropic lamina inclined at an angle θ from the plate coordinate system the Q's are first calculated in the material coordinate system and then transformed to the plate coordinate system as follows:

$$Q'_{11} = \frac{E_1}{1-\nu_1\nu_2}$$

$$Q'_{12} = \frac{\nu_2 E_1}{1-\nu_1\nu_2} = \frac{\nu_1 E_2}{1-\nu_1\nu_2}$$

$$Q'_{22} = \frac{E_2}{1-\nu_1\nu_2} \qquad \text{(A5)}$$

$$Q'_{33} = E_{12}$$

$$Q'_{1T} = Q'_{11}\alpha_1 + Q'_{12}\alpha_2$$

$$Q'_{2T} = Q'_{12}\alpha_1 + Q'_{22}\alpha_2$$

$$
\begin{aligned}
Q_{11} &= Q'_{11}\cos^4\theta + 2(Q'_{12} + 2Q'_{33})\sin^2\theta\cos^2\theta + Q'_{22}\sin^4\theta \\
Q_{12} &= (Q'_{11} + Q'_{22} - 4Q'_{33})\sin^2\theta\cos^2\theta + Q'_{12}(\sin^4\theta + \cos^4\theta) \\
Q_{22} &= Q'_{11}\sin^4\theta + 2(Q'_{12} + 2Q'_{33})\sin^2\theta\cos^2\theta + Q'_{22}\cos^4\theta \\
Q_{13} &= (Q'_{11} - Q'_{12} - 2Q'_{33})\sin\theta\cos^3\theta + (Q'_{12} - Q'_{22} + 2Q'_{33})\sin^3\theta\cos\theta \\
Q_{23} &= (Q'_{11} - Q'_{12} - 2Q'_{33})\sin^3\theta\cos\theta + (Q'_{12} - Q'_{22} + 2Q'_{33})\sin\theta\cos^3\theta \qquad \text{(A6)} \\
Q_{33} &= (Q'_{11} + Q'_{22} - 2Q'_{12} - 2Q'_{33})\sin^2\theta\cos^2\theta + Q'_{33}(\sin^4\theta + \cos^4\theta) \\
Q_{1T} &= Q'_{1T}\cos^2\theta + Q'_{2T}\sin^2\theta \\
Q_{2T} &= Q'_{1T}\sin^2\theta + Q'_{2T}\cos^2\theta \\
Q_{3T} &= (Q'_{1T} - Q'_{2T})\sin\theta\cos\theta
\end{aligned}
$$

Positive values of θ are in the direction of rotating x into y.

The limitations of VIPASA require that $A_{13} = A_{23} = 0$ as well as the entire B matrix must be zero. Symmetric balanced laminates will always satisfy this condition. When layer properties are input the A, B, and D matrices are printed and should be examined to insure input is valid.

With the above assumptions the transverse strain may be eliminated from the equations to yield

$$N_L = (A_{11} - A_{12}^2/A_{22})(-\partial u/\partial x) + A_{12}(N_T - C_{2T})/A_{22} + C_{1T} \qquad \text{(A7)}$$

The total load on the panel cross section is

$$P = -\partial u/\partial x \sum a_i b_i + \sum c_i b_i \qquad \text{(A8)}$$

The strain required to achieve this load is simply

$$-\partial u/\partial x = \frac{P - \sum c_i b_i}{\sum a_i b_i} \qquad \text{(A9)}$$

where

$a_i = A_{11} - A_{12}^2/A_{22}$ for plate i

b_i width of plate i (A10)

$c_i = A_{12}(N_T - C_{2T})/A_{22} + C_{2T}$ for plate i

Equation A7 is used to calculate the longitudinal loading on all the elements for a given longitudinal strain. For thermal stress calculations two options are possible. For a fixed temperature input (IEP = 2) the axial load required for buckling is determined by assuming the fixed longitudinal strain, EPF = -.02 and the variable strain EPV = .01 . (The large fixed tensile strain is to insure that buckling does not occur under the fixed loading conditions). Prior to this calculation the prestress is evaluated for a strain determined from equation A9 with P = 0. This solution is printed first followed by the prestress solution used for the buckling analysis.

For a variable temperature input with a fixed axial load P (IEP = 3). The fixed strain is calculated from equation (A9) and the variable strain also from equation A9 with P = 0. Thus the fixed load system results in an axial load P while the variable system results in no axial load. The eigenvalue multiplied by the variable temperature input then represents the temperature distribution required for buckling in the presence of the fixed axial load. Again the calculated prestress solution is printed.

It can be seen that the assumptions of constant strain over panel cross section is not good in all cases so caution should be exercised in the application of the thermal stress analysis. However, in some cases such a simple analysis is adequate, such as symmetrically heated cross sections or panels over many supports so that thermal bowing is restrained.

APPENDIX B

DESCRIPTION OF PLOTTING SUBROUTINES

SUBROUTINE PSEUDO

LANGUAGE: COMPASS

PURPOSE: To create and write an appropriately named Plot Vector File. Through linkages set up by an initial call to PSEUDO, all subsequent graphics data generated by the user will be routed through one of the PSEUDO entry points and written on the Plot Vector File. The PSEUDO processor is designed for use with the frame dependent post-processors described in Section 1.3, Volume IV, of the Computer Programing Manual.

USE:

```
CALL PSEUDO

    or

CALL PSEUDO(FN)
```

FN file name left-justified with zero fill. Default file name is SAVPLT.

<u>Example</u>:

```
CALL PSEUDO
```

This will establish a Plot Vector File named SAVPLT.

```
CALL PSEUDO(6LMYFILE)
```

This will establish a Plot Vector File named MYFILE.

<u>NOTE</u>: The Plot Vector File (or Files) will usually be written to disk (as opposed to tape) and may be postprocessed following user program termination via appropriate specification of one or more PLOT control cards (see Section 1.3, Volume IV, Computer Programing Manual).

RESTRICTIONS:

(1) An initializing call to PSEUDO (with or without a file name argument) must be made prior to any calls to CALPLT or any other graphics output routine.

(2) Every Plot Vector File should be terminated with a 999 pen code, CALL CALPLT(0.0,0.0,999). The transmission of the 999 code will cause an EOF write on the Plot Vector File, and the file will temporarily be closed. Thus, any given Plot Vector File will contain only one 999 pen code and/or one EOF.

(3) To continue plotting execution following transmission of a 999 code to a current Plot Vector File, the user program must call the PSEUDO processor to create new Plot Vector File (i.e., CALL PSEUDO(6LMYFIL2)).

METHOD: In addition to entry PSEUDO, this processor contains two other entry points, namely PLT9999 and PLT9998. An initializing call to PSEUDO will set PLT9999 into the processor switching mechanism (PLOTSW). Subsequent plot data generation will then be routed via CALPLT, PLOTSW, and PLT9999 and written on the Plot Vector File. The entry PLT9998 is used to record special purpose data from routines NFRAME and PLTSTOP.

ACCURACY:

REFERENCES: See Section 1.3, Volume IV, Computer Programing Manual.

STORAGE: 2155_8 locations total for direct subprograms

SUBPROGRAMS USED: NUMARG, PLOTSW

OTHER CODING INFORMATION:

SOURCE: E. C. Johnson, NASA-Langley Research Center

QUESTIONS ON THE USE OF THIS PROGRAM SHOULD BE DIRECTED TO THE ACD PROGRAMER SUPPORT GROUP, EXTENSION 3548.

SUBROUTINE NFRAME

LANGUAGE: FORTRAN

PURPOSE: To provide users specific means of executing frame advance movements on any plotter device via an appropriate frame oriented device postprocessor. Frame advance distances are generally defined to be incremental from current frame origin (i.e., comparable to frame advance executions for the DDI or 252 CRT devices). CALL NFRAME is intended to be used as a frame advance mechanism, not as a plot origin offset.

USE:

```
CALL NFRAME

    or

CALL NFRAME(H,V)
```

where

H and V — are Horizontal (parallel to device X) and Vertical (parallel to device Y) distances from the current frame origin. H and/or V must be expressed in floating point inches.

The short form CALL NFRAME will cause the device postprocessor to execute a frame advance move parallel to the device X (horizontal) axis. The movement will be the maximum horizontal distance used in inches plus h inches, where h will be an increment appropriate to the particular device ($0 < h \leq 2''$). The frame advance will be rounded to whole inches.

SUBROUTINE CALPLT

LANGUAGE: FORTRAN

PURPOSE: To move the plotter pen to a new location with pen up or down.

USE: CALL CALPLT(X,Y,IPEN)

where

X,Y are the floating point values for pen movement.

IPEN = 2 pen down

= 3 pen up

Negative IPEN will assign X = 0, Y = 0 as the location of the pen after moving the X,Y (create a new reference point).

= 999 Writes a terminating block address of 999 to terminate the Plot Vector File and all further processing is skipped.

CALL CALPLT(0.0,0.0,999)

RESTRICTIONS: All X and Y coordinates must be expressed as floating point inches (actual page dimensions) in deflection from the origin.

A TERMINATING BLOCK ADDRESS (IPEN = 999) MUST BE GIVEN AS THE LAST PLOTTING INSTRUCTION BEFORE ENDING A PROGRAM WHICH USES ANY OF THE PLOTTER SUBROUTINES: THIS IS TO BE SURE THAT ALL PLOTTER INSTRUCTIONS ARE WRITTEN ON THE PLOTTER TAPE.

SUBROUTINE NOTATE

LANGUAGE: FORTRAN

PURPOSE: To draw alphanumeric information for annotation and labeling and provide special centered symbols for annotation of data points.

USE: CALL NOTATE(X,Y,HEIGHT,BCD,THETA,NOCHAR)

where

X,Y — are the floating point coordinates of the first character.

For alphanumeric characters, the coordinates of the lower left-hand corner of the characters are specified.

For special symbols 0 - 5, the coordinates of the center of the symbol are specified.

For special symbols above 6, the coordinates of the lower left-hand corner of the character are specified.

HEIGHT — specifies character size and spacing in floating point inches for a full-size character. The smallest possible character is 0.07 inch high. The width of a character will be (4/7)*HEIGHT and the space between characters is (2/7)*HEIGHT + WADJ (see Figure 1), where WADJ is width adjustment.

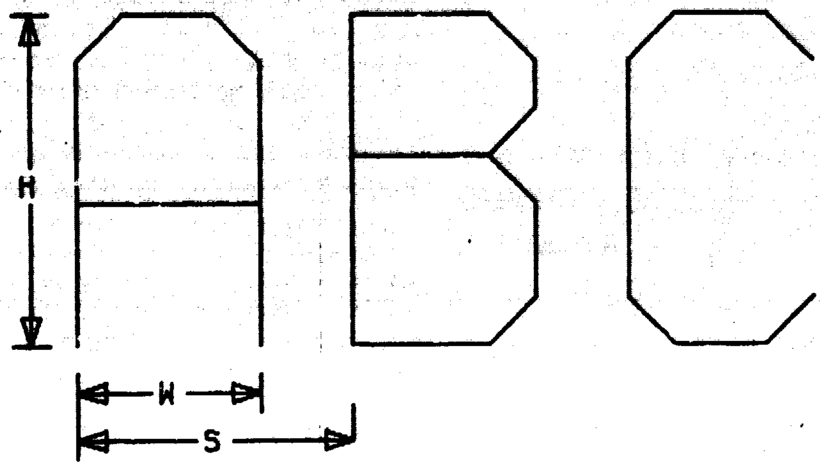
The ith character is plotted at:

$$x_i = X + (i-1)(6/7)(\text{HEIGHT})(\text{COS } \theta) + (i-1)(\text{WADJ})(\text{COS } \theta)$$

$$y_i = Y + (i-1)(6/7)(\text{HEIGHT})(\text{SIN } \theta) + (i-1)(\text{WADJ})(\text{SIN } \theta)$$

where WADJ = 0 for HEIGHT > .1
= .01 for HEIGHT ≤ .1

NOTATE



H = HEIGHT

W = (4/7) * HEIGHT

S = (6/7) * HEIGHT + WADJ

Figure 1

BCD is the string of characters to be drawn and is usually written in the form: nHXXXX--- (the same way an alpha message is written using FORTRAN format statements). Instead of specifying alpha information as above, one may give the beginning storage location of an array containing alphanumeric information.

Special symbols will be drawn when BCD is an integer reference and NOCHAR is negative (see Figure [illegible]).

NOTE: A binary zero in the BCD string will cause truncation of plotting at that point, and a normal return to the calling program.

THETA — is the angle in floating point degrees at which the information is to be drawn. Zero degrees will print horizontally reading from left to right, 90° will print the line vertically reading from bottom to top, 180° will print the line horizontally reading from right to left (i.e., upside down), and 270° will print vertically reading from top to bottom.

NOCHAR — is the number of characters, including blanks, in the label. A negative NOCHAR will produce a single special symbol from the integer reference table. (See METHOD for further explanation.)

RESTRICTIONS: Noted under METHOD.

METHOD: The character height is a variable entry parameter to the subroutine NOTATE. However, the width-to-height ratio is fixed at 4/7. This is because the characters are defined by a series of bi-octal offset pairs for a 4 by 7 matrix as shown by the examples in Figure 2. The reference origin for the offset pairs which define each character is the lower left-hand corner of the matrix. The X and Y values which are entry parameters to NOTATE define the location of the lower left-hand corner of the first character to be plotted for this entry to NOTATE. Subsequent characters to be plotted are spaced from the previous character origin by 6/7 of the specified character height plus width adjustment.

SUBROUTINE PNTPLT

LANGUAGE: FORTRAN

PURPOSE: To draw NASA Standard Plot symbols centered on a given coordinate value.

USE: CALL PNTPLT(X,Y,ISYM,IS)

where

X is the X coordinate for the centered symbol in floating point inches.

Y is the Y coordinate for the centered symbol in floating point inches.

ISYM is an integer specifying the symbol to be used. (See Figures 1 and 2.)

= 21 for a point ·

= 22 for a plus sign +

IS is an integer value specifying the size symbol to be used.

= 1 small

= 2 medium

= 3 large

(See Figure 1.)

RESTRICTIONS:

METHOD:

ACCURACY: A positive integer value for ISYM in the calling sequence will produce symbols of the same quality as in Figure 10. A negative integer value will produce symbols of less quality but will result in a considerably faster computer run.

PNTPLT

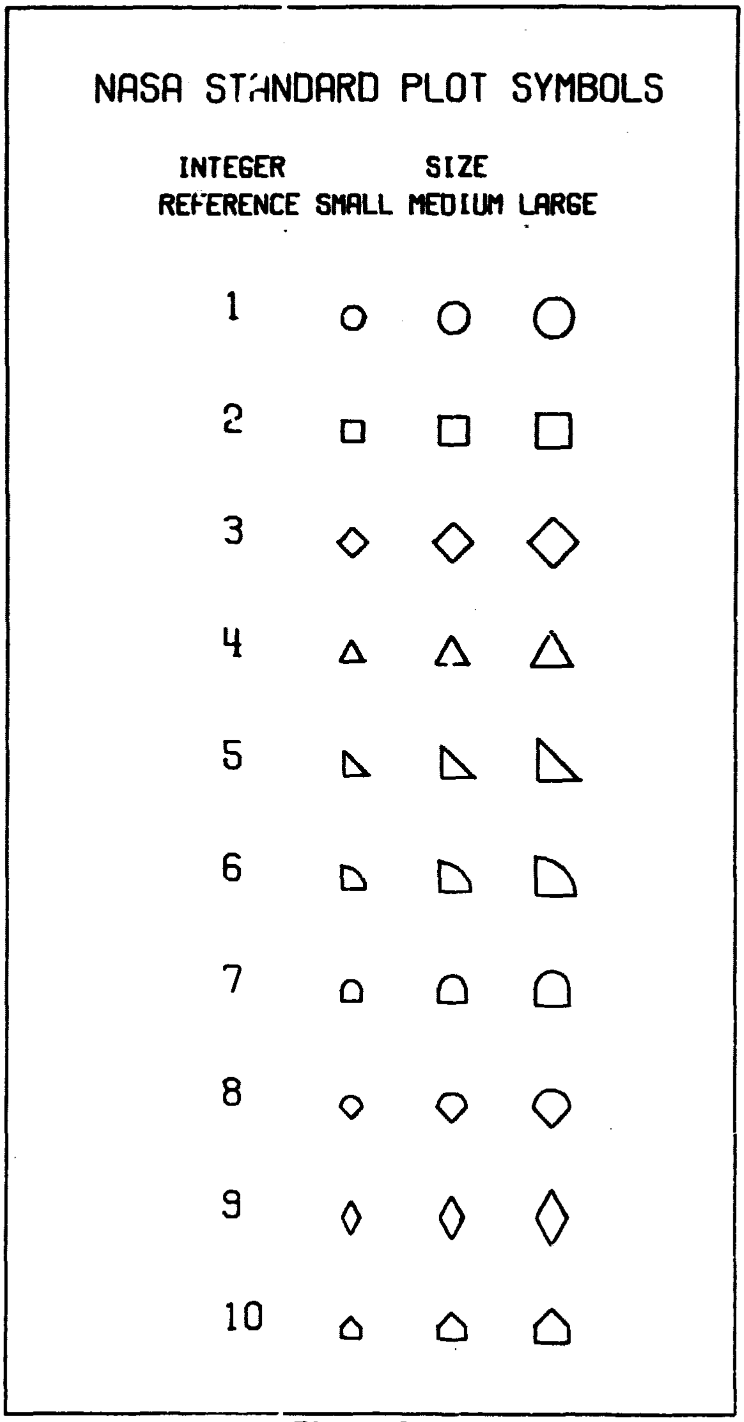


Figure 1.

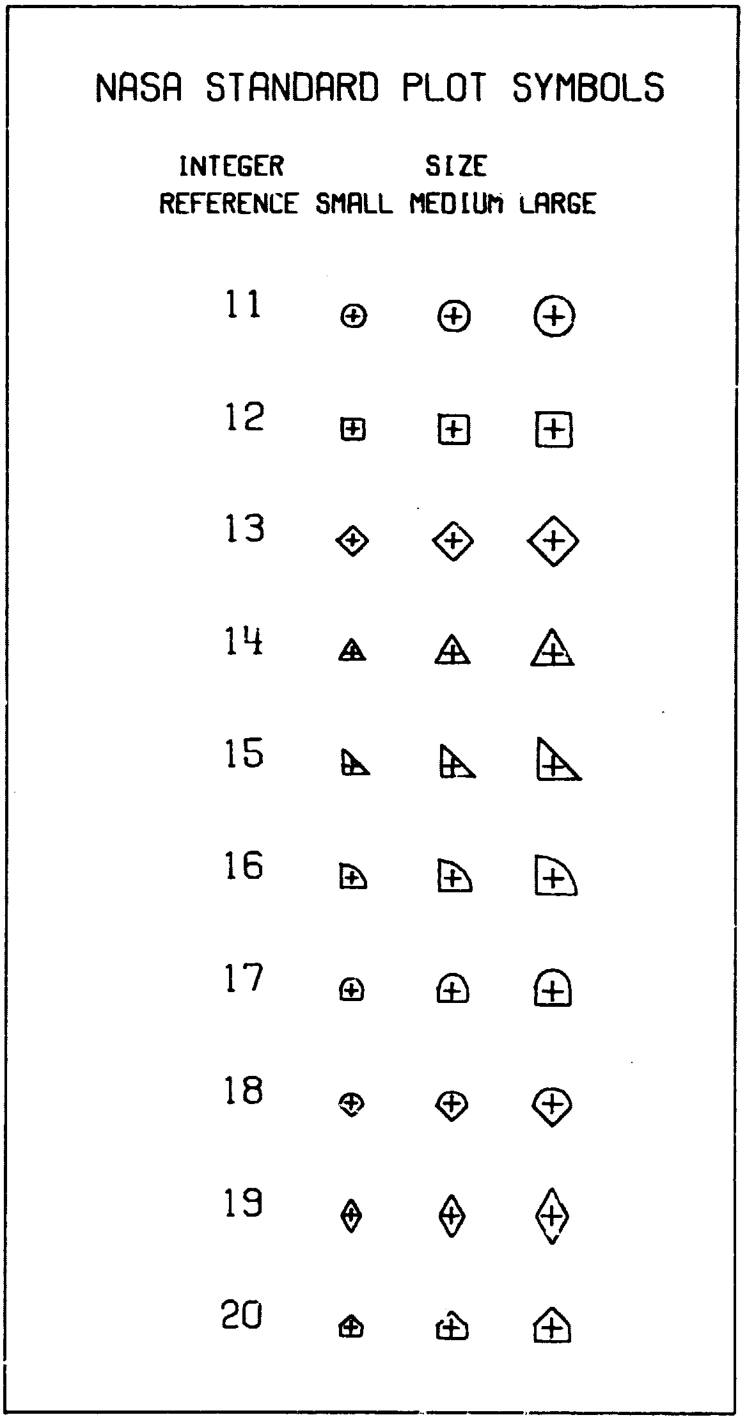

NASA STANDARD PLOT SYMBOLS
INTEGER REFERENCE
SIZE
SMALL MEDIUM LARGE
11
12
13
14
15
16
17
18
19
20

Figure 2

SUBROUTINE NUMBER

LANGUAGE: FORTRAN

PURPOSE: To convert a floating point number to BCD (expressed in F format), and draw the resulting alphanumeric characters.

USE: CALL NUMBER(X,Y,HEIGHT,FPN,THETA,NODIGIT)

where

X,Y are the coordinates in floating point inches of the left lower corner of the first digit of output.

HEIGHT is the height of the plotted number in floating point inches (see NOTATE routine).

FPN is the floating point number to be drawn.

THETA is the angle in floating point degrees at which the number is to be drawn (see NOTATE routine).

NODIGIT is the number of decimal digits to the right of the decimal point for output.

NODIGIT=-1 or NODIGIT=0 both specify no decimal places; however, -1 suppresses the decimal point.

RESTRICTIONS: The number is restricted to a maximum of 12 significant digits.

METHOD:

ACCURACY: The routine truncates the floating point number at the required decimal place.

REFERENCES:

SUBROUTINE AXES

LANGUAGE: FORTRAN

PURPOSE: To draw a line, annotate the value of the variable at specified intervals with or without tic marks, and provide an axis identification label.

USE: CALL AXES(X,Y,THETA,S,ORG,SFX,TMAJ,TMIN,BCD,HEIGHT,NOCHAR)

where

X,Y are the coordinates in floating point inches of the starting point of the axis with reference to the plotting area origin as established by CALPLT.

THETA is the angle of rotation measured counterclockwise from the X-axis in floating point degrees. Normally, THETA is 0° for an X-axis and 90° for a Y-axis.

S is the length of the axis in floating point inches. Should be a multiple of TMAJ.

+S will generate tic marks.
-S will eliminate tic marks.

ORG is the functional value to be assigned to the origin (i.e., the value of the first scale) in floating point.

SFX is the adjusted scale factor for the array to be plotted (change in value per inch).
NOTE: Values of ORG and SFX which will produce a reasonable scale may be calculated using the subroutine ASCALE or BSCALE.

TMAJ is the distance in floating point inches for major tic marks (0.25 inches high). Numbers are placed on the axis at the major tic marks in accordance with the values of ORG and SFX. The numbers written along the axis are adjusted to be between 1000.00 and 0.01 in magnitude. Immediately after the last number on the axis is placed the caption x10^{exp}, where exp is the required exponent.

If the values are integer multiples, the decimal point and decimal places are eliminated. A negative TMAJ will cause the actual value to be written instead of the adjusted value.

TMIN — is the number of divisions per inch in floating point for minor tic marks (0.125 inches high). To eliminate minor tic marks the following may be used:

TMIN = 0.

BCD — is the character label for the axis (see NOTATE routine).

HEIGHT — is the height of the full-size characters in the BCD title. Numbers at the tic marks will be (0.75 *HEIGHT) high. HEIGHT is in floating point inches.

If HEIGHT = 0., all annotation will be eliminated.

NOCHAR — is an integer specifying the number of characters in BCD title. A negative NOCHAR places the annotation on the clockwise side of the axis and a positive NOCHAR places the annotation on the counterclockwise side of the axis. NOCHAR = 0 is not allowed. If it is desired to have no label, then the BCD parameter should be 1H , and NOCHAR either +1 or -1.

RESTRICTIONS: Only perpendicular axes are recommended.

METHOD:

ACCURACY:

REFERENCES:

Table 1.- Input for Example Problem Number One.

```
    28      26      13     200     400             20  2
     1
PROBLEM 3C (C.S. FLANGES) SHEAR=450.
     2    1  10000.0                     2.               0.0        0.0        0.0 1 0
       32.        2.        32.1.41421356
     0    0     0     9     4     1     0     1     .001
     19.5E6    1.11E6    .488E6      .19       .057
-1.
     1    .0052      0.0
     1    .0052     45.0
     1    .0052    -45.0
     1    .0104      0.0
     1    .0520      0.0
    -1
    2   3   1   2   3   2   3   4   3   2   3   2   1   3   2
    2   3   1   2   3   3   2   1   3   2
    2   3   1   2   3   5   3   2   1   3   2
    2   3   1   2   3   2   3   3   2   3   2   1   3   2
    3   2   1   3   2   3   2   2   3   2   3   1   2   3
   -1
     1    4     0.125                                               334.84
     2    4     2.580                                               264.27
     3    2     1.328                                               185.73
     4    3     1.250                                               185.73
     5    4     1.310                                               450.00
     6    5     1.310                                              -450.00
     7    2     0.125                                               115.16
    -1
    4  -9    3 300
    4 -10    3  60
    4  11    9   4  10
    3  12    5   5
   10 -13   -7   0   0-624  -4   0   0-624  -4
    4 -14    6 180
    5   8    1 -13   1 -13
    5   3    8   8   8   8
    5   8    3   2 -11   3
    5   1    2   8   5  14
    3   2    3  12
    3   3    4   8
    3   4    5   5
```

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Table 2.- Selected Output from Example Problem Number One.

```
VIPASA RESULTS

INPUT DEVICE NUMBER IS     5 OUTPUT DEVICE NUMBER IS     6
    NMK     NSR     NSC  IPAST     NSN     NSK  NOLAM
     28      26      13    200     400       2     20

  IPLOT      NSPAC      PAGE           AMP
    2         -0       -0.00          -0.00
NUMBER OF PROBLEMS IS     1

DATA FOR PROBLEM NUMBER     1


PROBLEM 3C (O.S. FLANGES) SHEAR=450.
    2    1         10000.0        2.000000        0.000000    0.0000    0.0000 1 0
   32.0000    2.0000  32.0000     1.4142                -0.0 -0.000    -0.000000000

THE ABOVE TWO DATA CARDS HAVE THE FOLLOWING MEANING
    THE PROBLEM IS TO FIND ALL EIGENVALUES FROM NUMBER    1 DOWN TO NUMBER    1
    INCLUSIVE, TO AN ACCURACY OF AT LEAST ONE IN          10000.0
    THE LENGTH OF THE STRUCTURE IS   32.000000 AND LAMBDA IS INCREASED FROM
        2.000000 TO THE HIGHEST POSSIBLE VALUE OF LAMBDA NOT EXCEEDING
       32.000000 BY SCALING SUCCESSIVELY BY     1.414214
    MODES ARE FOUND AT ALL EIGENVALUES
    THE NUMBERS OF PLATES DEFINED IN SIMPLIFIED WAY, OF PLATES DEFINED IN
    GENERAL WAY, INDICATOR OF GENUINE SPRING SUPPORTS, NUMBERS OF
    SUB-STRUCTURES AND OF CARDS DEFINING FINAL STRUCTURE ARE, RESPECTIVELY,
        0    0    0    9    4

IG=  1      IFAST=  0      IEP=  1
THE FIXED LONGITUDINAL STRAIN IS -0.000000
THE VARIABLE LONGITUDINAL STRAIN IS   .001000



                                   MATERIAL INPUT

MATERIAL   E1         E2         E12        NU1        RHO        ALFA1      ALFA2

    1    .195E+08  .111E+07  .488E+06  .190E+00  .570E-01-0.          -0.
```

Table 2.- Continued.

WALL	MATL	H	ANGLE	T1V	T2V	T1F	T2F
1	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	0.	-0.	-0.	-0.	-0.
	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.1040E-01	0.	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	0.	-0.	-0.	-0.	-0.
	1	.5200E-02	-.4500E+02	-0.	-0.	-0.	-0.
	1	.5200E-02	.4500E+02	-0.	-0.	-0.	-0.

ZREF FOR WALL NO. 1= .4160E-01

MASS PER UNIT AREA OF WALL NO. 1= .4742E-02

A-MATRIX FOR WALL NO. 1			D-MATRIX FOR WALL NO. 1		
.7657E+06	.3027E+06	0.	.3952E+03	.1900E+03	.3368E+02
.3027E+06	.3824E+06	0.	.1900E+03	.2362E+03	.3368E+02
0.	0.	.3257E+06	.3368E+02	.3368E+02	.2033E+03

			THERMAL LOADING TERMS	
B-MATRIX FOR WALL NO. 1			VARIABLE	FIXED
.1164E-09	-.1746E-09	-.1455E-10	0.	0.
-.1746E-09	-.2910E-09	-.7276E-11	0.	0.
-.1455E-10	-.7276E-11	-.1746E-09	0.	0.

ORIGINAL PAGE IS OF POOR QUALITY

Table 2.- Continued.

NEGATIVE WALL NUMBERS INDICATE ANISOTROPIC STIFFNESS TERMS NEGLECTED

PLATE NO.	WALL NO.	BREADTH	NTV	NLV	NSV	NTF	NLF	NSF
1	4	.12500	-0.00	318.88	-0.00	-0.00	0.00	334.84
2	4	2.58000	-0.00	318.88	-0.00	-0.00	0.00	264.27
3	2	1.32800	-0.00	281.65	-0.00	-0.00	0.00	185.73
4	3	1.25000	-0.00	1313.19	-0.00	-0.00	0.00	185.73
5	4	1.31000	-0.00	318.88	-0.00	-0.00	0.00	450.00
6	5	1.31000	-0.00	318.88	-0.00	-0.00	0.00	-450.00
7	2	.12500	-0.00	281.65	-0.00	-0.00	0.00	115.16

SUB-STRUCTURES ARE DEFINED AS FOLLOWS

```
 4  -9   3 300   -0
 4 -10   3  60   -0
 4  11   9   4   10
 3  12   5   5
10 -13  -7   0    0-624   -4    0    0-624   -4
 4 -14   6 180   -0
 5   8   1 -13    1 -13
 5   3   8   8    8   8
 5   8   3   2  -11   3
```

THE FINAL STRUCTURE IS DEFINED AS FOLLOWS

```
5   1   2   8   5  14
3   2   3  12
3   3   4   8
3   4   5   5
```

THE PANEL MASS IS .326960E+01

Table 2.- Concluded.

```
EIGENVALUE NO.      LAMBDA            FACTOR                  LIMITS ON FACTOR
      1        .319999996E+02  .298361918E+01  .298361918E+01  .298364258E+01
   THE TOTAL AXIAL LOAD IS   .31320508E+05
THE MODE IS
CLOCKWISE ROT. DEFLN. DOWN DEFLN. TO RT. LONG. DEFLN.
REAL PARTS ON ALTERNATE LINES, WITH IMAGINARY PARTS INSET BENEATH
  .10000000E+00 -.25599137E+01  .82871725E-03  .75670988E-01
         .00352492     -.01483189      .00109697      .00013147
 -.99999997E-01 -.25599137E+01 -.82871735E-03  .75670988E-01
         .00352492      .01483188      .00109697     -.00013147
  .99999997E-01 -.25599137E+01  .82871735E-03  .75670988E-01
         .00352492     -.01483188      .00109697      .00013147
 -.10000000E+00 -.25599137E+01 -.82871724E-03  .75670988E-01
         .00352492      .01483189      .00109697     -.00013147
 -.15744425E-10 -.26443110E+01  .16103591E-11  .74481098E-01
        -.01996355      .00000000      .00110327     0.00000000
ALL REQUIRED EIGENVALUES HAVE BEEN FOUND FOR LAMBDA =          32.000000
         COORDINATES OF NODES
   NODE             Y                          Z
     1        0.                     -0.
     2         .45800000E+01         -0.
     3         .72000000E+01         -0.
     4         .11780000E+02         -0.
     5         .13090000E+02         -0.
 Y COORDINATE OF NODE=    5IS IN ERROR BY     14.400
```

Table 3.- Input for example Problem Number Two.

```
    28     26     13    200    400      2    20   2
     1
PROBLEM 3C (O.S. FLANGES) SHEAR=450, TEMP=-300.
     1    1   10000.0                   2.           0.0        0.0        0.0 1 0
        32.            2.        32.1.41421356
     0    0    0    9    4    1    2    2     .001
     19.5E6    1.11E6    .488E6          .19    .057    .3E-6    .15E-4
-1.
     1    .0052      0.0                          -300.     -300.
     1    .0052     45.0                          -300.     -300.
     1    .0052    -45.0                          -300.     -300.
     1    .0104      0.0                          -300.     -300.
     1    .0520      0.0                          -300.     -300.
    -1
    2   3   1   2   3   2   3   4   3   2   3   2   1   3   2
    2   3   1   2   3   3   2   1   3   2
    2   3   1   2   3   5   3   2   1   3   2
    2   3   1   2   3   2   3   3   2   3   2   1   3   2
    3   2   1   3   2   3   2   2   3   2   3   1   2   3
   -1
     1    4    0.125                                               334.84
     2    4    2.580                                               264.27
     3    2    1.328                                               185.73
     4    3    1.250                                               185.73
     5    4    1.310                                               450.00
     6    5    1.310                                              -450.00
     7    2    0.125                                               115.16
    -1
    4   -9    3 300
    4  -10    3  60
    4   11    9   4   10
    3   12    5   5
   10  -13   -7   0    0-624   -4    0    0-624   -4
    4  -14    6 180
    5    8    1 -13    1 -13
    5    3    8   8    8   8
    5    8    3   2  -11   3
    5    1    2   8    5  14
    3    2    3  12
    3    3    4   8
    3    4    5   5
```

Table 4.- Selected Output from Example Problem Number Two.

```
DATA FOR PROBLEM NUMBER     1

PROBLEM 3C (O.S. FLANGES) SHEAR=450, TEMP=-300.
    1    1          10000.0        2.000000        0.000000    0.0000    0.0000 1 0
   32.0000    2.0000  32.0000     1.4142             -0.0 -0.000   -0.000000000

THE ABOVE TWO DATA CARDS HAVE THE FOLLOWING MEANING
    THE PROBLEM IS TO FIND ALL EIGENVALUES FROM NUMBER    1 DOWN TO NUMBER    1
    INCLUSIVE, TO AN ACCURACY OF AT LEAST ONE IN         10000.0
    THE LENGTH OF THE STRUCTURE IS   32.000000 AND LAMBDA IS INCREASED FROM
        2.000000 TO THE HIGHEST POSSIBLE VALUE OF LAMBDA NOT EXCEEDING
      32.000000 BY SCALING SUCCESSIVELY BY     1.414214
    MODES ARE FOUND AT ALL EIGENVALUES
    THE NUMBERS OF PLATES DEFINED IN SIMPLIFIED WAY, OF PLATES DEFINED IN
    GENERAL WAY, INDICATOR OF GENUINE SPRING SUPPORTS, NUMBERS OF
    SUB-STRUCTURES AND OF CARDS DEFINING FINAL STRUCTURE ARE, RESPECTIVELY,
        0    0    0    9    4

IG=  1      IFAST=  2      IEP=  2
BUCKLING LOAD WILL BE CALCULATED FOR FIXED TEMPERATURE INPUT
EIGENVALUE DETERMINED ONLY IF LESS THAN THAT FOR PREVIOUS LAMBDA
CONVERGENCE MAY NOT BE OBTAINED IF THERE ARE NEGATIVE ROOTS AT FACTOR=0
```

MATERIAL INPUT

MATERIAL	E1	E2	E12	NU1	RHO	ALFA1	ALFA2
1	.195E+08	.111E+07	.488E+06	.190E+00	.570E-01	.300E-06	.150E-04

ORIGINAL PAGE IS OF POOR QUALITY

Table 4.- Continued.

WALL	MATL	H	ANGLE	T1V	T2V	T1F	T2F
1	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	0.	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.1040E-01	0.	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	0.	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	-.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03
	1	.5200E-02	.4500E+02	-0.	-0.	-.3000E+03	-.3000E+03

ZREF FOR WALL NO. 1= .4160E-01

MASS PER UNIT AREA OF WALL NO. 1= .4742E-02

A-MATRIX FOR WALL NO. 1			D-MATRIX FOR WALL NO. 1		
.7657E+06	.3027E+06	0.	.3952E+03	.1900E+03	.3368E+02
.3027E+06	.3824E+06	0.	.1900E+03	.2362E+03	.3368E+02
0.	0.	.3257E+06	.3368E+02	.3368E+02	.2033E+03

B-MATRIX FOR WALL NO. 1			THERMAL LOADING TERMS VARIABLE	FIXED
.1164E-09	-.1746E-09	-.1455E-10	0.	-.2977E+03
-.1746E-09	-.2910E-09	-.7276E-11	0.	-.3458E+03
-.1455E-10	-.7276E-11	-.1746E-09	0.	0.

Table 4.- Concluded.

THERMAL STRESS FOR AXIAL LOAD P = 0.

PLATE NUMBER	BREADTH	NTV	NLV	NSV	NTF	NLF	NSF
1	.12500	-0.00	0.00	-0.00	-0.00	-12.24	334.84
2	2.58000	-0.00	0.00	-0.00	-0.00	-12.24	264.27
3	1.32800	-0.00	0.00	-0.00	-0.00	-1.29	185.73
4	1.25000	-0.00	0.00	-0.00	-0.00	75.30	185.73
5	1.31000	-0.00	0.00	-0.00	-0.00	-12.24	450.00
6	1.31000	-0.00	0.00	-0.00	-0.00	-12.24	-450.00
7	.12500	-0.00	0.00	-0.00	-0.00	-1.29	115.16

PRESTRESS ASSUMED FOR EIGENVALUE ANALYSIS

PLATE NUMBER	BREADTH	NTV	NLV	NSV	NTF	NLF	NSF
1	.12500	-0.00	3188.76	-0.00	-0.00	-6409.09	334.84
2	2.58000	-0.00	3188.76	-0.00	-0.00	-6409.09	264.27
3	1.32800	-0.00	2816.46	-0.00	-0.00	-5651.27	185.73
4	1.25000	-0.00	13131.92	-0.00	-0.00	-26268.11	185.73
5	1.31000	-0.00	3188.76	-0.00	-0.00	-6409.09	450.00
6	1.31000	-0.00	3188.76	-0.00	-0.00	-6409.09	-450.00
7	.12500	-0.00	2816.46	-0.00	-0.00	-5651.27	115.16

EIGENVALUE NO.	LAMBDA	FACTOR	LIMITS ON FACTOR	
1	.319999996E+02	.230451309E+01	.230444102E+01	.230451309E+01

THE TOTAL AXIAL LOAD IS .31330239E+05

THE MODE IS

CLOCKWISE ROT. DEFLN. DOWN DEFLN. TO RT. LONG. DEFLN.

REAL PARTS ON ALTERNATE LINES, WITH IMAGINARY PARTS INSET BENEATH

```
 .99999971E-01 -.25994701E+01  .83811557E-03  .76889688E-01
        .00352555     -.01487365      .00110046      .00013180
-.10000000E+00 -.25994702E+01 -.83811443E-03  .76889692E-01
        .00352553      .01487369      .00110046     -.00013181
 .10000000E+00 -.25994702E+01  .83811443E-03  .76889692E-01
        .00352553     -.01487369      .00110046      .00013181
-.99999970E-01 -.25994701E+01 -.83811557E-03  .76889688E-01
        .00352555      .01487365      .00110046     -.00013180
-.59103120E-11 -.26839116E+01 -.17345568E-11  .75681095E-01
       -.02001181     -.00000000      .00110677     0.00000000
```

ALL REQUIRED EIGENVALUES HAVE BEEN FOUND FOR LAMBDA = 32.000000

M	LAMDA	FACTOR
1	.4000E+01	.2388E+01
2	.3200E+02	.2304E+01

Table 5.- Input for Heated Titanium Panel

```
      24      36       7     200     500         2       20    2    6        1.0
    1
BUCLASP-3 HEATED PANEL BUCKLING ANALYSIS
    1    1          10000.0              2.0               0.0    00000.0        0.0 1 1
      27.5         -1.         1.        1.
    0    0     0    2     9    1    0    2.001
    1.64E7     1.64E7     6.31E6         .3                4.45E-6    4.45E-6
    1.61E7     1.61E7     6.19E6         .3                4.50E-6    4.50E-6
    1.60E7     1.60E7     6.15E6         .3                4.52E-6    4.52E-6
    1.56E7     1.56E7     6.00E6         .3                4.58E-6    4.58E-6
    1.52E7     1.52E7     5.85E6         .3                4.65E-6    4.65E-6
    1.50E7     1.50E7     5.77E6         .3                4.69E-6    4.69E-6
-1.
    1       .14
    2       .14                                           80.        80.
    3       .14                                          100.       100.
    4      .065                                          175.       175.
    5      .065                                          250.       250.
    6       .14                                          280.       280.
   -1
   1
   2
   3
   4
   5
   6
  -1
    1    1      1.32
    2    2     .6575
    3    3       .48
    4    4      1.07
    5    5      1.07
    6    6     .9725
    9    2     .7025
   10    3     .4925
   -1
   4   -7    4 270
   4   -8    5 270
   5    1    2    1-9909000
   3    2    4    2
   3    3    4    3
   5    4    5    9    7   10
   3    5    6    1
   3    6-9909000
   3    7    8    7
   3    8    9    8
   3    9   10    6
```

Table 6.- Selected Output for Heated Titanium Panel

THERMAL STRESS FOR AXIAL LOAD P = 0.

PLATE NUMBER	BREADTH	NTV	NLV	NSV	NTF	NLF	NSF	NLF (ref. 4)
1	1.32000	0.00	0.00	0.00	0.00	-1018.12	0.00	-1020
2	.65750	0.00	0.00	0.00	0.00	-188.06	0.00	-189
3	.48000	0.00	0.00	0.00	0.00	19.19	0.00	18
4	1.07000	0.00	0.00	0.00	0.00	363.08	0.00	373
5	1.07000	0.00	0.00	0.00	0.00	710.44	0.00	710
6	.97250	0.00	0.00	0.00	0.00	1826.51	0.00	1820
9	.70250	0.00	0.00	0.00	0.00	-188.06	0.00	-189
10	.49250	0.00	0.00	0.00	0.00	19.19	0.00	18

PRESTRESS ASSUMED FOR EIGENVALUE ANALYSIS

PLATE NUMBER	BREADTH	NTV	NLV	NSV	NTF	NLF	NSF
1	1.32000	0.00	22960.00	0.00	0.00	-45920.00	0.00
2	.65750	0.00	22540.00	0.00	0.00	-44268.56	0.00
3	.48000	0.00	22400.00	0.00	0.00	-43787.52	0.00
4	1.07000	0.00	10140.00	0.00	0.00	-19467.28	0.00
5	1.07000	0.00	9880.00	0.00	0.00	-18611.45	0.00
6	.97250	0.00	21000.00	0.00	0.00	-39242.28	0.00
9	.70250	0.00	22540.00	0.00	0.00	-44268.56	0.00
10	.49250	0.00	22400.00	0.00	0.00	-43787.52	0.00

EIGENVALUE NO.	LAMBDA	FACTOR	LIMITS ON FACTOR		TOTAL AXIAL LOAD (ref. 4)
1	.275000000E+02	.224138941E+01	.224133301E+01	.224138941E+01	.45515 E+05

THE TOTAL AXIAL LOAD IS .44259060E+05

Reproduced from Reference 1

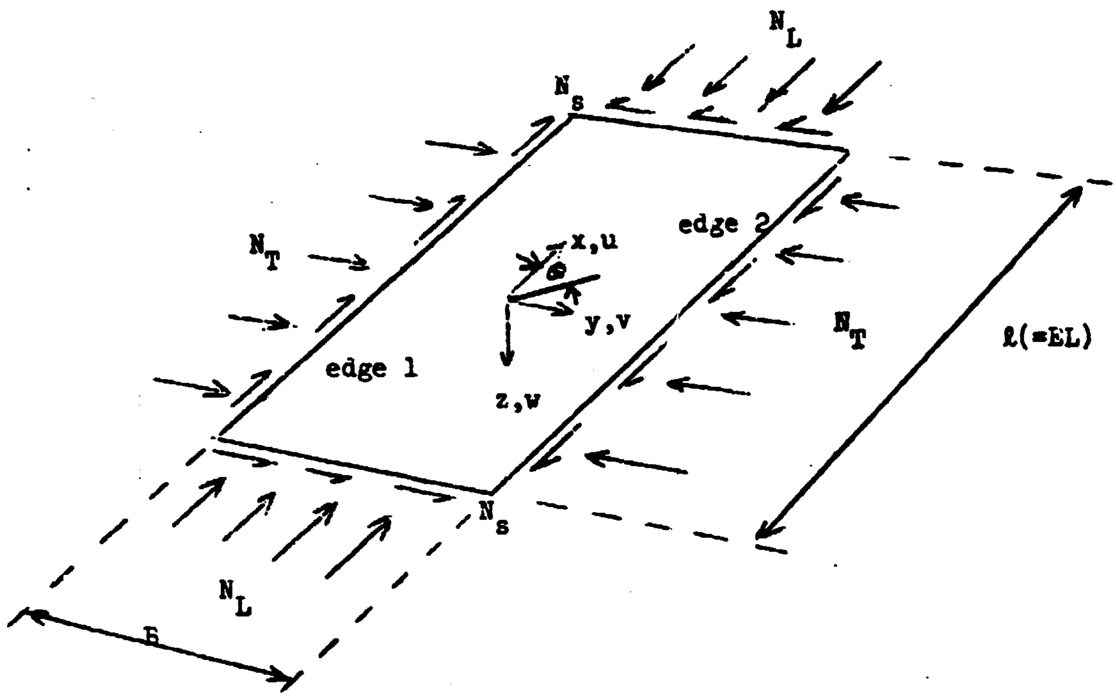
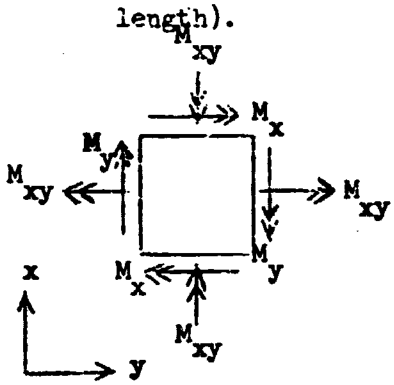
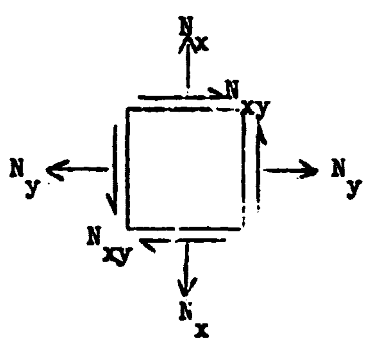


Fig. 1 Basic load system for a plate (N_L, N_T and N_s are forces per unit length).



$$\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix} = - \begin{bmatrix} D_{11} & D_{12} & D_{13} \\ D_{12} & D_{22} & D_{23} \\ D_{13} & D_{23} & D_{33} \end{bmatrix} \begin{bmatrix} \frac{\partial^2 w}{\partial x^2} \\ \frac{\partial^2 w}{\partial y^2} \\ 2\frac{\partial^2 w}{\partial x \partial y} \end{bmatrix}$$



$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & 0 \\ A_{12} & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} \frac{\partial u}{\partial x} \\ \frac{\partial v}{\partial y} \\ \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \end{bmatrix}$$

Fig. 2 Defines the elastic properties (D_{11}, D_{12}, D_{13}, D_{22}, D_{23}, D_{33}, A_{11}, A_{12}, A_{22}, A_{33}) of a plate, see also Fig. 1.

$E_1 = 19.5 \times 10^6$
$E_2 = 1.11 \times 10^6$
$E_{12} = 0.488 \times 10^6$
$\nu_1 = 0.19$

ply thickness = 0.0052

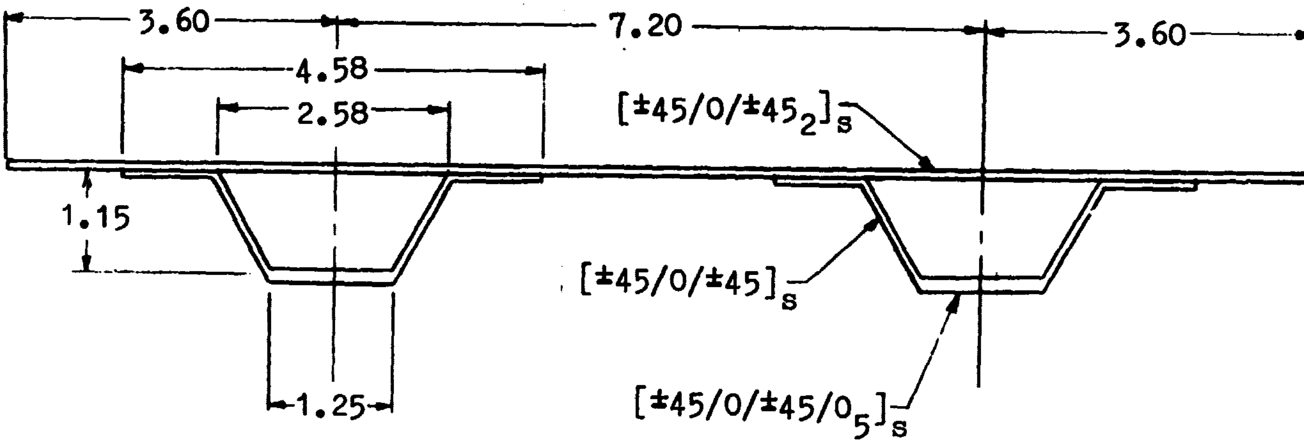


Figure 3.- Cross section of hat section panel used in example problems.

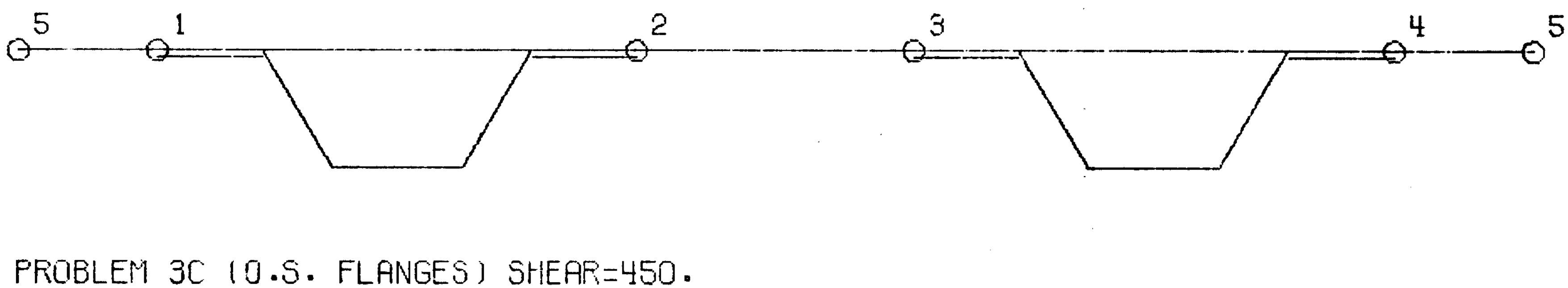


Figure 4.- Machine plot of geometry for example problems.

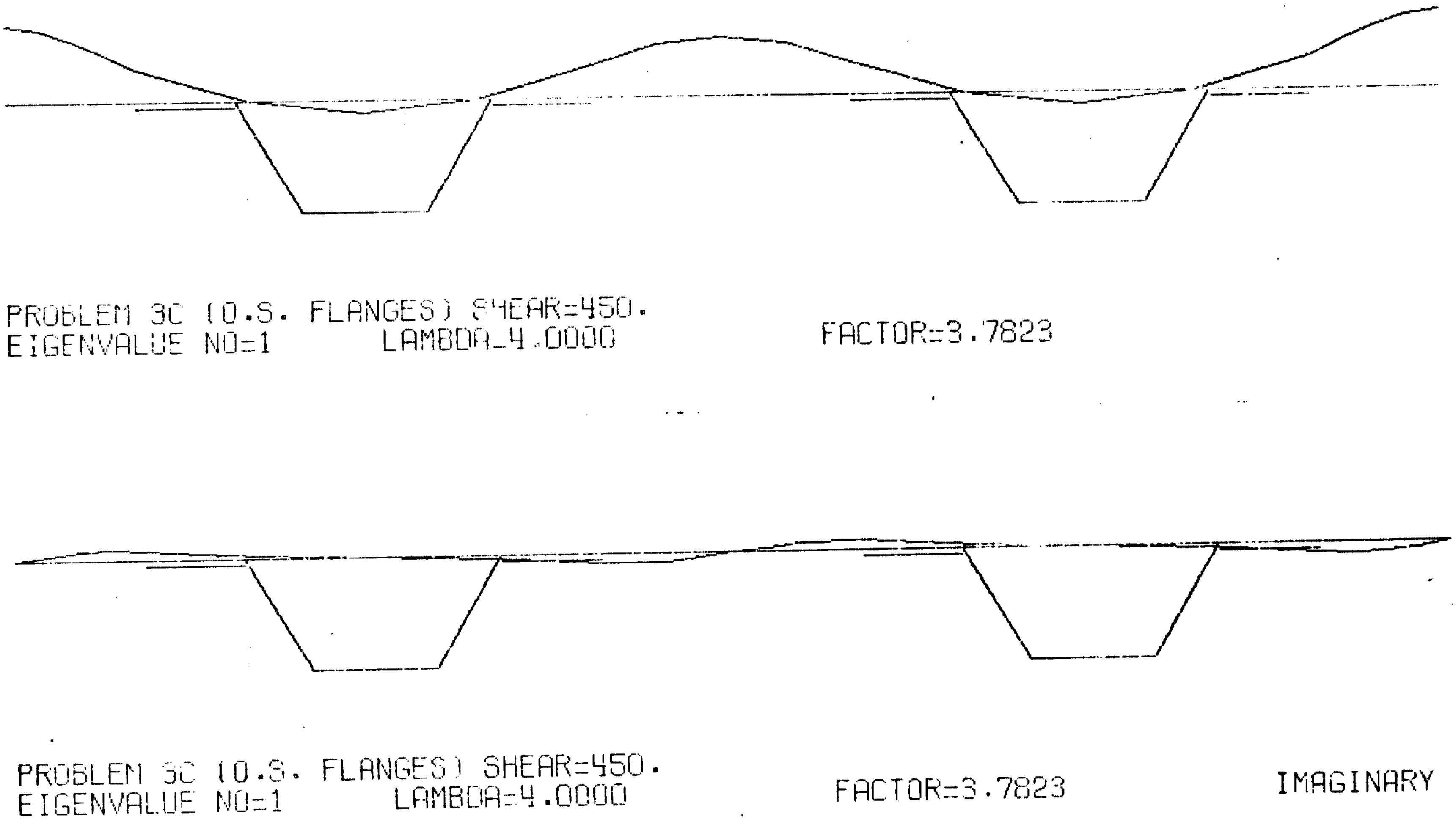


Figure 5.- Machine plot of buckling mode shape for example problem number 1.
For problems with shear or anisotropy,the mode contains a real and an imaginary part and both are shown.

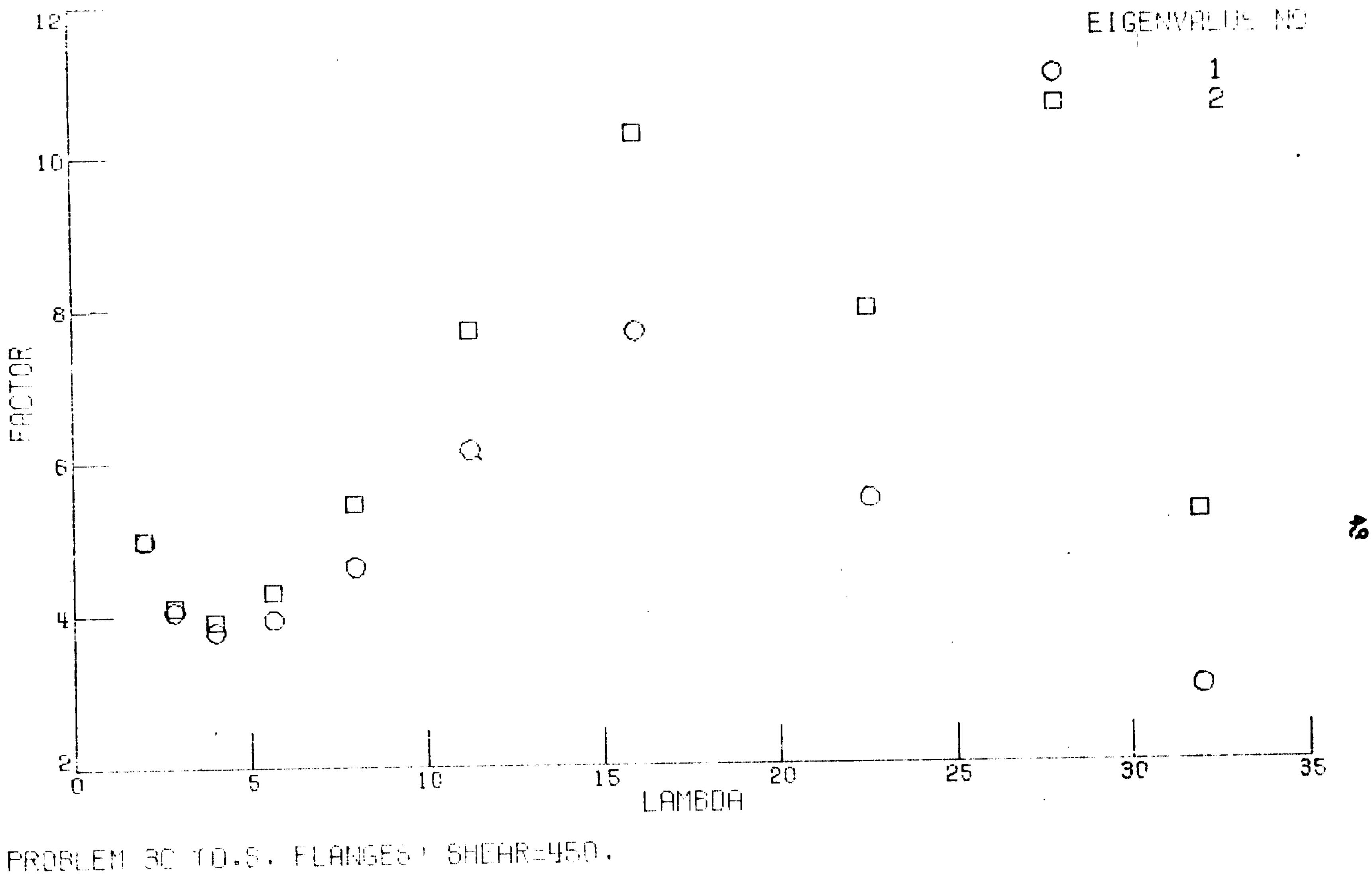


Figure 6.- Machine plot of panel buckling strain as a function of buckle length for example problem number one. Strain = Factor x10^3.