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SKIN-STRINGER PANEL NORMAL MODE RESPONSE EXPERIMENTAL DATA AND FINITE ELEMENT COMPUTER PROGRAM DOCUMENTATION

A Supplement to "Study of Effects of Design Details on Structural Response to Acoustic Excitation," NASA CR-1959

by

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

This report contains the detail information for the analytical and the experimental programs described in the report "Study of Effects of Design Details on Structural Response to Acoustic Excitation," NASA CR- 1959 (reference 1) and is intended as a supplement to that report. Since this report is a supplement the contents of reference 1 are continuously quoted, and the reader must refer to the original text for complete continuity.

INTRODUCTION

The analytical and experimental program described in reference 1 was concerned with the application of the finite element displacement method for the prediction of displacements and strain distributions for the normal mode vibration of flat stiffened panels. Panels with stiffeners in one direction (one dimensional panels) and panels with orthogonal stiffening (two-dimensional panels) were considered. Details of the stiffener and its attachment to the plate were taken into account. In the case of the one-dimensional panel, elastic edge conditions on the boundary along the panel width were considered analytically. The material presented in reference 1 is essentially a summary of the analytical approach and the experimental results, and this report provides essential documentation for persons interested in more detailed information.

The stiffness and consistent mass matrix for both the stiffener model and the plate element developed in reference 1 is discussed and presented in detail in the appendix. An outline of the computer programs is presented along with pertinent details of the analysis. Detailed experimental data from all the specimens described in reference 1 is discussed and presented in tabulated form.

ANALYTICAL PROGRAM

One aspect of the analytical program described in reference 1 considered the derivation of a beam element to represent a thin-walled open-section stiffener as is usually encountered in aircraft structure. This element was used to model the stiffeners for the panel configurations under consideration. For the one-dimensional panel configuration, the stiffener warping coordinate was taken to be zero since warping is an odd function along the stiffener length and is zero at the panel centerline for the assumed fundamental mode in the direction of the stiffener (see equations 20a and 20b, reference 1). For the two-dimensional panel analysis the stiffener warping coordinate was taken equal to the panel twist to insure compatibility of slope between the stiffener element and the plate element. The two-dimensional panel configuration required consideration of a coordinate transformation to describe stiffeners parallel to the x-axis and the y-axis, and since it was necessary to consider rotation of the stiffener about a general point on the stiffener profile line (the 'attach' point), it was also necessary to develop transformations for the elastic forces from the shear center to the attach point and for the inertia forces from the centroid to the attach point (equations 10 through 13, reference 1). All of these transformations have been carried out and are summarized as a composite stiffness and mass matrix for the stiffener element. The adjective 'composite' is used to denote the use of logic numbers to compute the stiffness or the mass matrix for a stiffener parallel to the x-axis or the y-axis. The composite stiffness and mass matrices are presented in Appendix A. The notation and the sign conventions are as described in reference 1.

The rectangular plate bending element described in reference 1 was based upon the 16 degree-of-freedom plate bending element described by Bogner, Fox, and Schmidt (reference 2). The modification introduced in reference 1 was to consider an internal mode for the element in the form of clamped-clamped beam functions described by the coordinate W_o (equation 23, ref. 1). The introduction of the coordinate W_o resulted in the definition of modifying terms for the basic stiffness and mass matrices. These modifying terms (equations 26 and 27, ref. 1) are presented in Appendix B. The notation and sign convention are as described in reference 1.

COMPUTER PROGRAMS

The basic computer program flow chart for the one-dimensional panel analysis is presented in figure 1. The program computes, sequentially, the element properties for a bay of structure and assembles the element in the free-free stiffness and mass matrices by application of displacement compatibility and equilibrium conditions at each element node. The desired elastic supports are assembled in the free-free stiffness and mass matrices introducing the elastic constraints. If a lumped mass is desired, the data is introduced as a lumped support with zero stiffness. The stiffness and mass matrices are non-dimensionalized, and kinematic constraints are applied at either end of the structure as desired. The kinematic constraint is of the form of a clamped support at either or both ends of the structure and is realized computationally by deleting the row-column terms in the stiffness and mass matrices corresponding to the constrained coordinates and appropriately reordering the stiffness and mass matrices. The eigenvalue problem is formulated and the eigenvalues and eigenvectors are obtained using standard routines (reference 3) based upon the Jacobi's method (reference 4). The non-dimensionalizing parameters and the eigenvalues and corresponding eigenvectors are printed. If mode shapes, shear, and bending moment distributions are desired, the values are computed, normalized to the maximum value, and printed. Values for the displacement, shear, and bending moment for points interior to an element are computed using equations 16, 17, and 18 of reference 1.

The basic flow chart for the two-dimensional panel computer program is presented in figure 2. The program computes the system stiffness characteristics, non-dimensionalizes the matrix, removes the constrained coordinates (clamped-edges), and reassembles the stiffness matrix. The plate stiffness is computed first and then the rib stiffness is computed. Each element is introduced into the free-free system by applying displacement compatibility and equilibrium conditions at each grid point. The consistent mass matrix is assembled identically to the stiffness matrix, the eigenvalue problem is formulated, and the eigenvalues and eigenvectors are obtained as previously described. Figure 3 illustrates the stiffened plate in plan view showing the bay (plate element) and the rib nomenclature. The plate stiffness and mass matrices are assembled in the sequence indicated by the plate bay number, and the rib stiffness and mass matrices are assembled in the sequence indicated by the rib number and rib segment number as indicated in figure 3. The assembly of the rib and the plate elements at the intersection of two orthogonal ribs is illustrated in figure 4. The positive coordinate directions are as indicated. Computer program listings, flow charts, and descriptions for the one-dimensional and two-dimensional panel arrays are presented in Appendix C. The necessary information for data input and program output is presented in Appendix D.

EXPERIMENTAL DATA

One of the objectives of the program described in reference 1 was to provide data for comparison with the analytical results. The technique used to determine mode shapes and strain distributions is described in reference 1. Comparison of theory and experiment is given in reference 1 for frequencies, mode shapes, and strain (bending moment) distribution (in the case of one-dimensional panels).

Each specimen was mounted in the test frame and cork particles were sprinkled on the specimen. The specimen was excited by discrete frequency sinusoidal excitation using a specially designed speaker enclosure as described in reference 1. Frequency sweeps were conducted for four speaker phase conditions (ref. 1). The predominant modes as indicated by the Chladni patterns formed by the cork particles were photographed. These patterns, for the indicated specimen, frequency, and speaker phase condition, are presented in Appendix E.

For the one-dimensional panel specimens, mode shapes were determined using two (2) accelerometers. One accelerometer was fixed in position for a reference value and the other accelerometer was stepped in position along the centerline of the panel. At each position of the stepped accelerometer, amplitude and phase of both accelerometers (as observed on an oscilloscope) was recorded. The accelerometer positions for the one-dimensional specimens is given in figure 5. The accelerometers were calibrated to give identical output for a given input, but no attempt was made to force an absolute output since only relative acceleration (displacement) was desired. Data reduction was accomplished by determining the accelerometer output in millivolts for both accelerometers, dividing the value at a position by the reference value for the positions, and then normalizing the set of data to the largest value of the ratio (not necessarily the reference position). The normalized acceleration data (mode shape) for the specimen, the indicated position (figure 5), frequency, and speaker phase conditions are tabulated in Tables 1 through 8. A minus sign as a value indicates a 180° phase shift with respect to the reference value and an asterisk denotes a 90° phase shift. To compare the normalized experimental values with the computed normalized mode shapes, the ratio of the experimental value and the computed value at a point on the structure was determined, all experimental values for the mode were multiplied by this ratio, and the data plotted. The plotted data comparison for the one-dimensional panel specimens is given in figures 22 through 38 of reference 1.

Strain measurements in the direction of the panel length (perpendicular to the ribs) was accomplished by placing fifteen strain gages along the panel as indicated in figure 5. Detailed location of the strain gages is indicated in figure 18 of reference 1. Data reduction for the strain measurements was accomplished as described for the acceleration data. The strain gage system was calibrated so that one millivolt of output corresponded to 417 microinches per inch of strain. Strain gage output in millivolts and phase with the indicated reference is tabulated in Tables 9 through 16 for the indicated specimen, strain gage, frequency, and speaker phase condition. The plotted comparison between the experimental and calculated values for strain are given in figures 22 through 38 of reference 1.

As described in reference 1, experimental determination of mode shapes for the two-dimensional panel specimens was more difficult than for the one-dimensional specimens. A detailed experimental mode investigation was possible only for the machined panel specimen. For specimens SP II-1 and SP II-2, only the basic phase relationship between adjacent panel bays could be determined. Acceleration measurements for the machined panel specimen were taken at the locations illustrated in figure 6. Tabulated values for accelerometer output in millivolts with phase relative to the reference are given in Table 17 for the indicated position, frequency, and speaker phase condition. For the machined panel specimen the strain gage locations are indicated in figure 7 with the exact location indicated by the (x, y) coordinate position given in Table 18.

For specimens SP II-1 and SP II-2 the tabulated values for acceleration in millivolts for the center of each panel bay is given in Table 19. Strain gage location and nomenclature for specimens SP II-1 and SP II-2 are given in figures 8 and 9, respectively, with the exact location tabulated. Strain measurements for the indicated specimen, frequency, and speaker phase condition are given in Tables 20 through 22. The strain gage calibration was such that 417 microinches per inch equaled one millivolt of strain gage output.

Damping was measured for selected strain gages by determining the logarithmic decrement from the photograph of the decaying strain signal (ref. 5). The specimen was excited in a given mode with the selected strain gage signal displayed on an oscilloscope. The excitation was suddenly stopped and the decaying strain signal photographed with a camera mounted on the oscilloscope. The logarithmic decrement and the damping ratio were determined from the photograph. For the indicated specimen, strain gage, and frequency, values of the damping ratio (percent of critical damping) are given in Table 23.

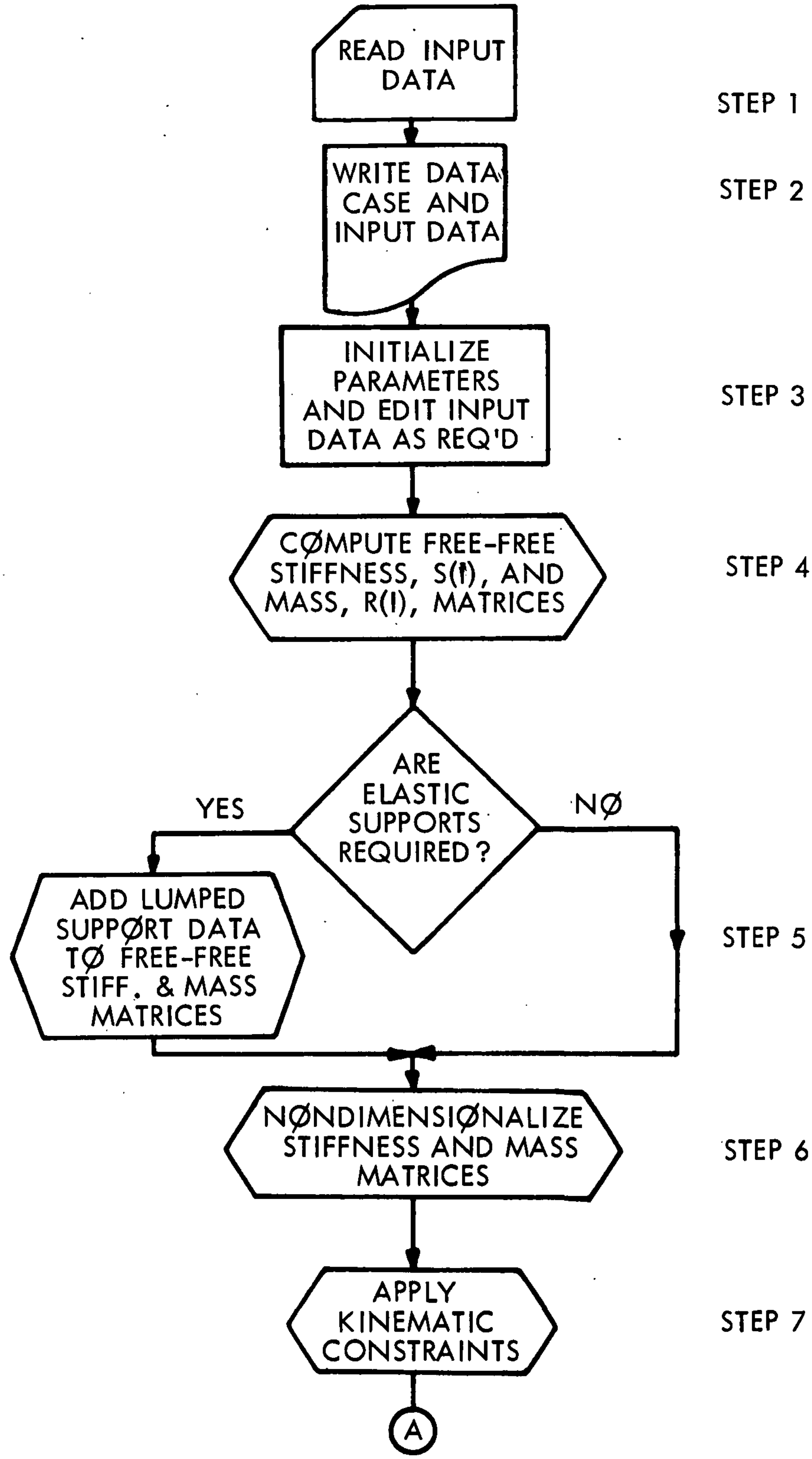


FIGURE 1. FLOW CHART: PROGRAM BMPROP(MAIN)/ONE-DIMENSIONAL PANEL ARRAYS (CONTINUED)

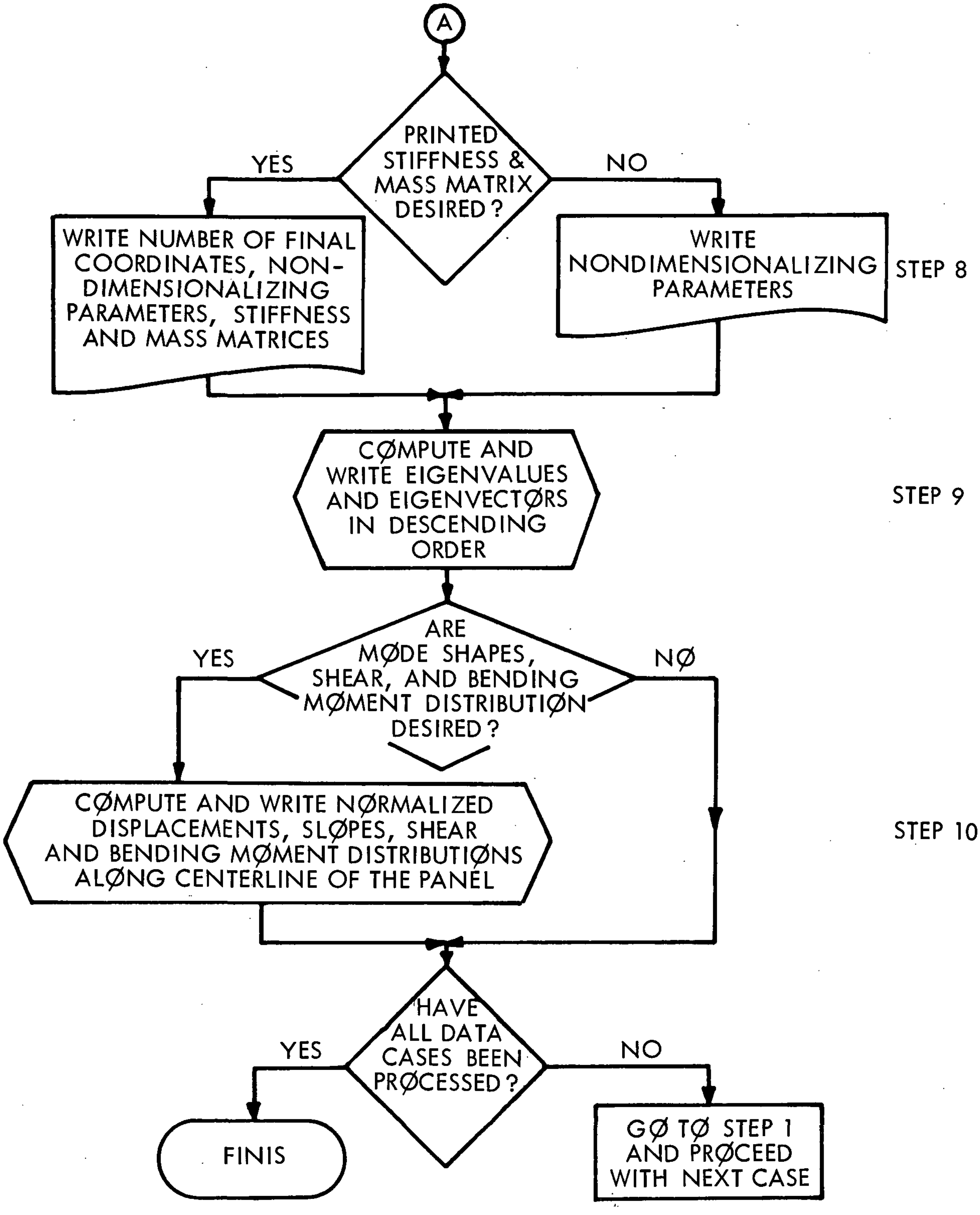


FIGURE 1. FLOW CHART: PROGRAM BMPROP(MAIN)/ONE-DIMENSIONAL PANEL ARRAYS (CONCLUDED)

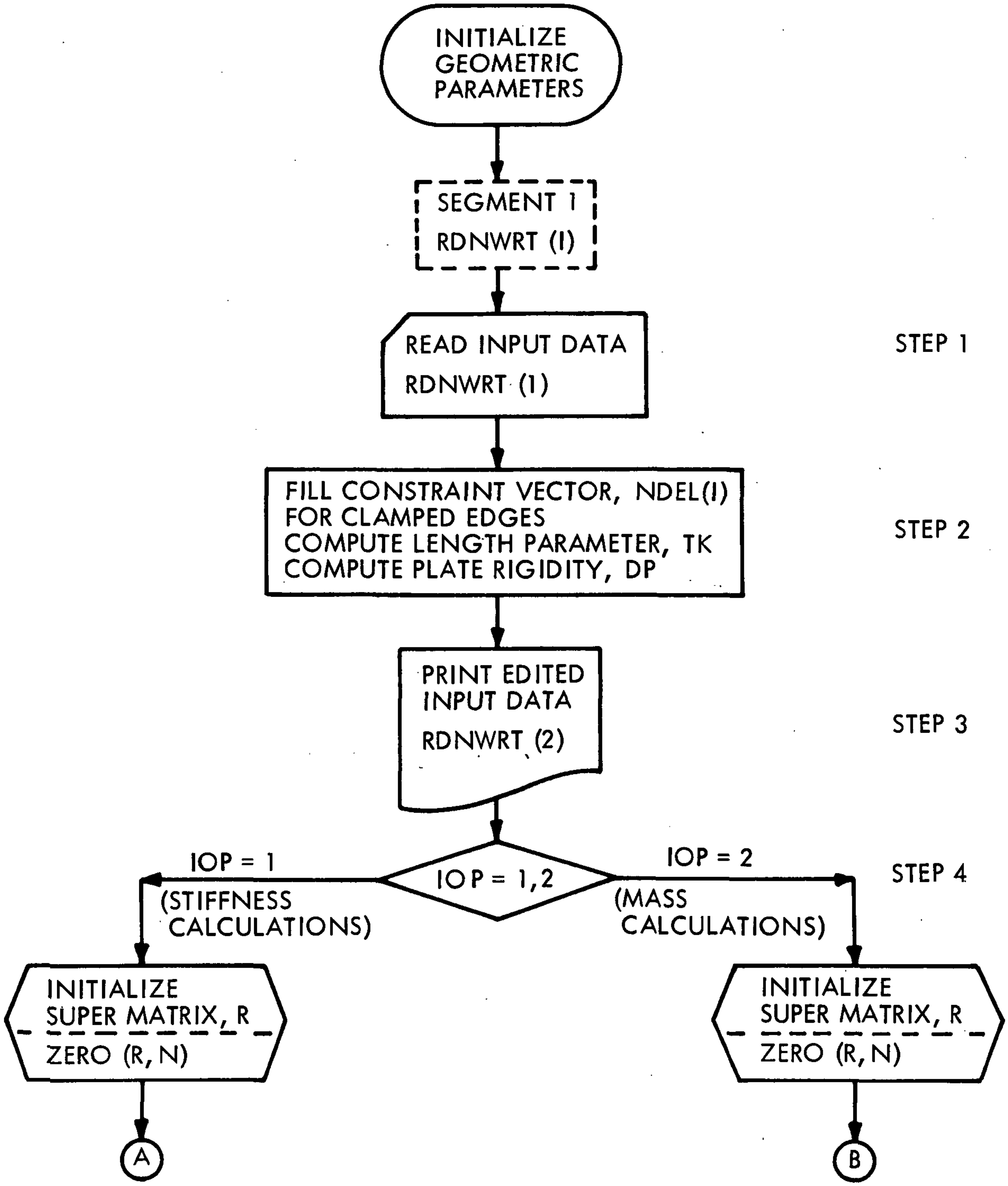


FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)

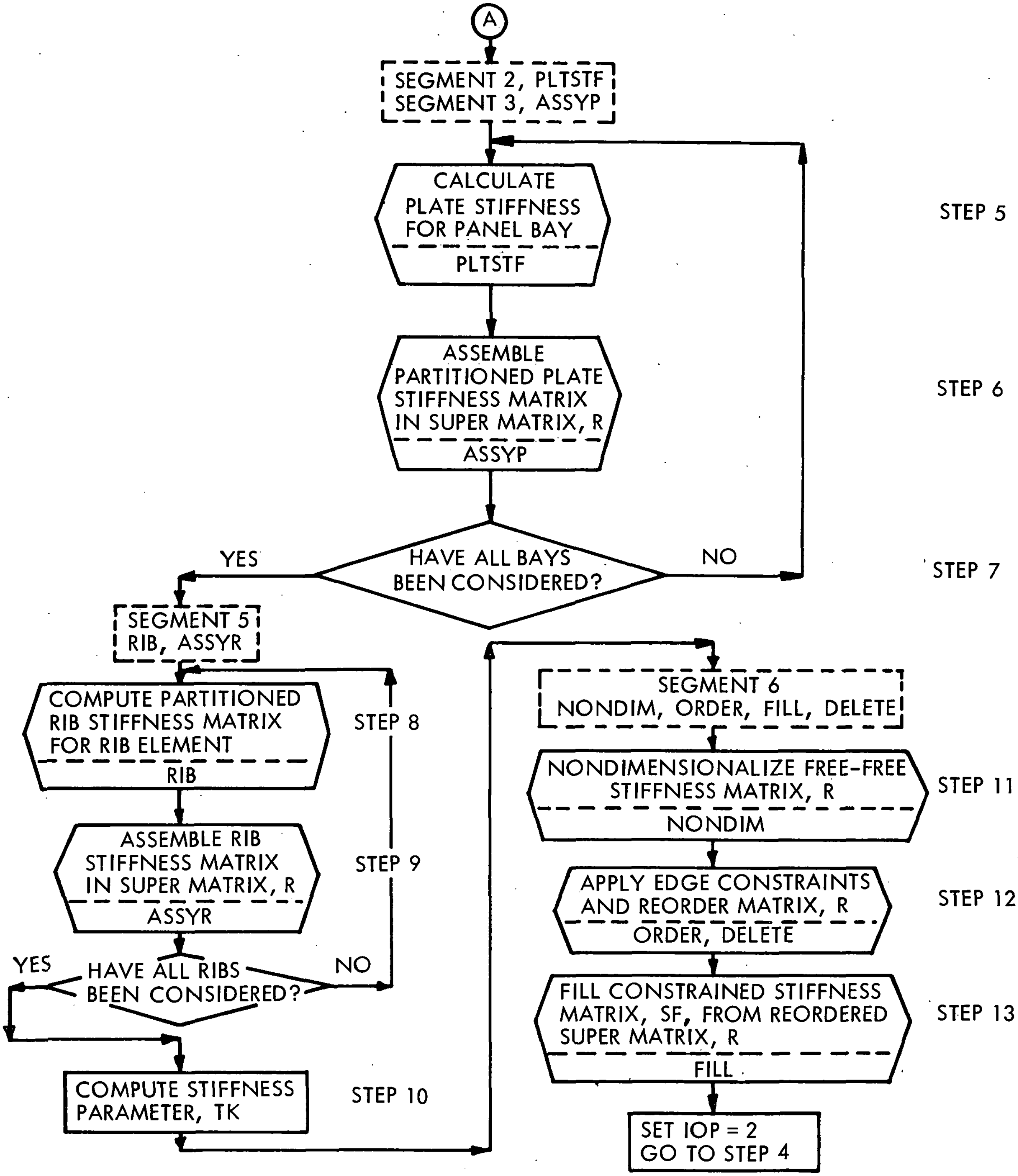


FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)

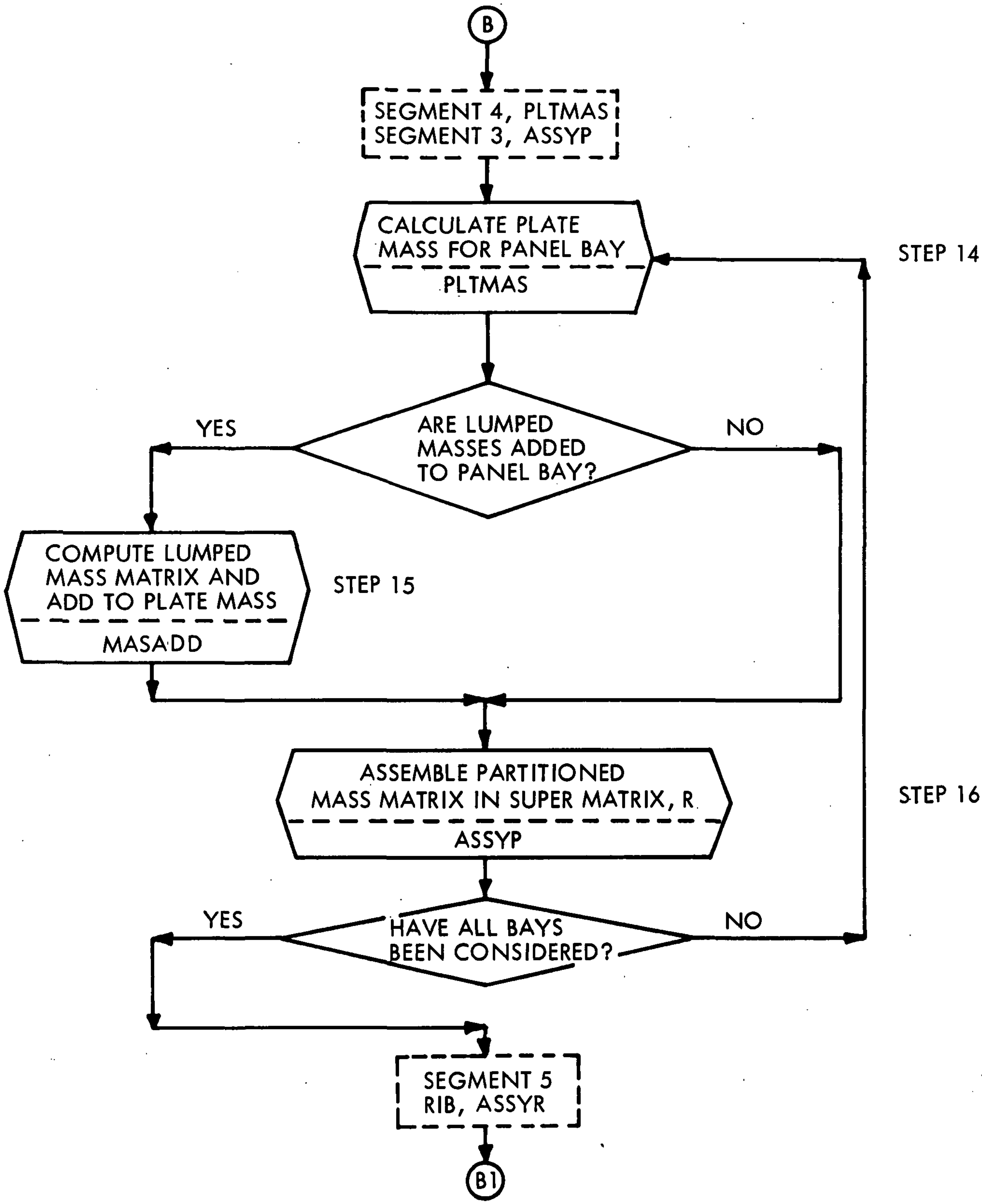


FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)

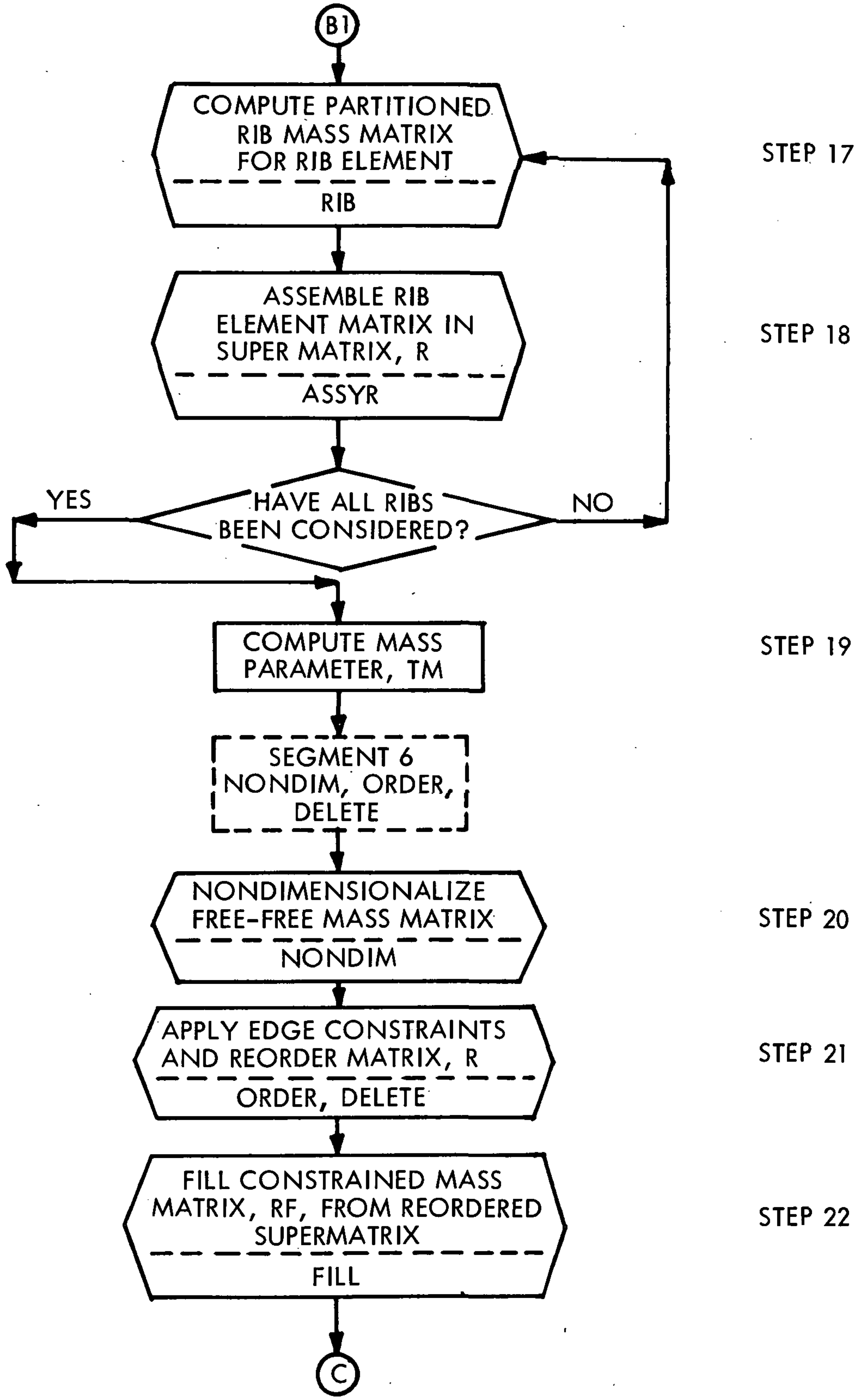


FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)

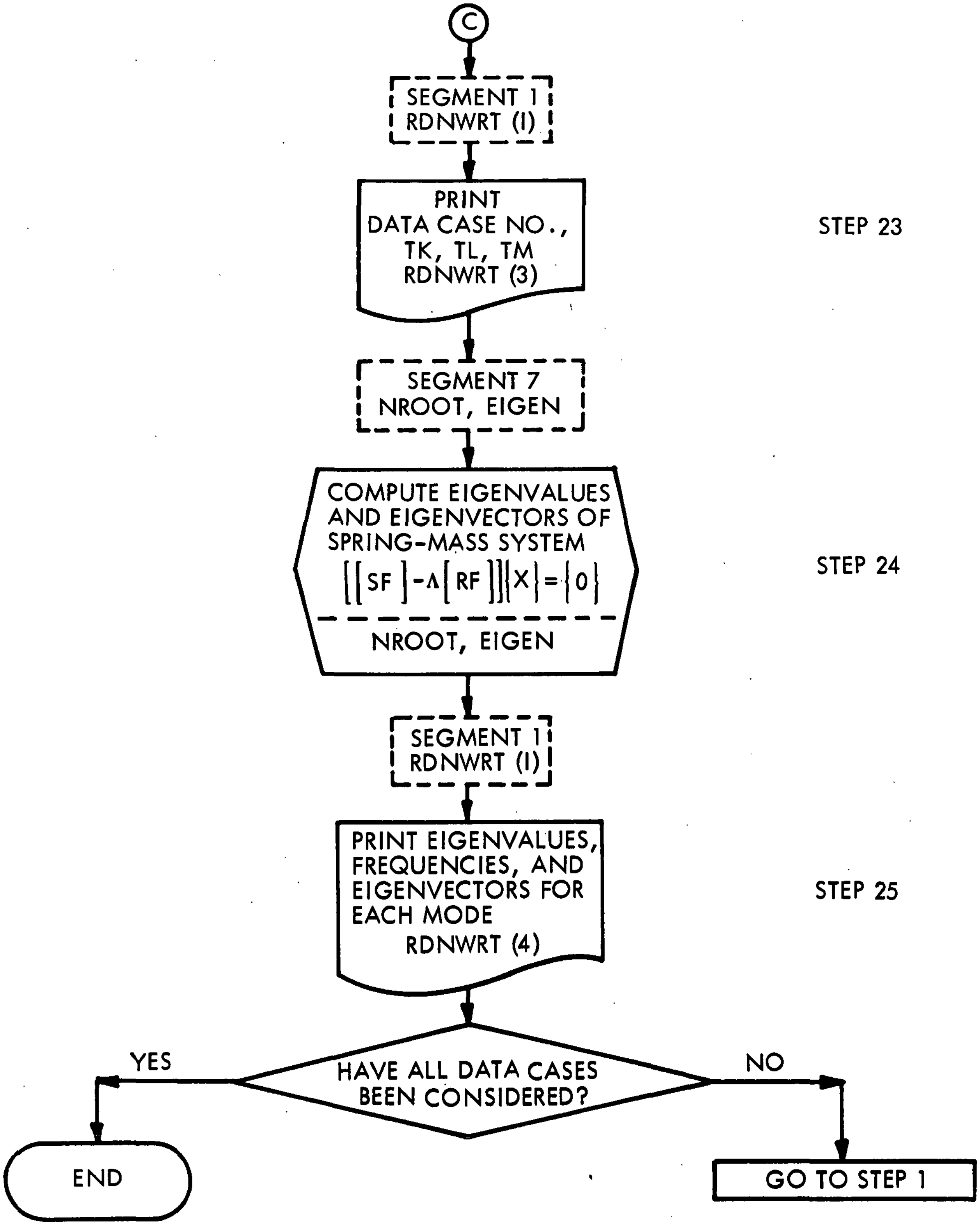
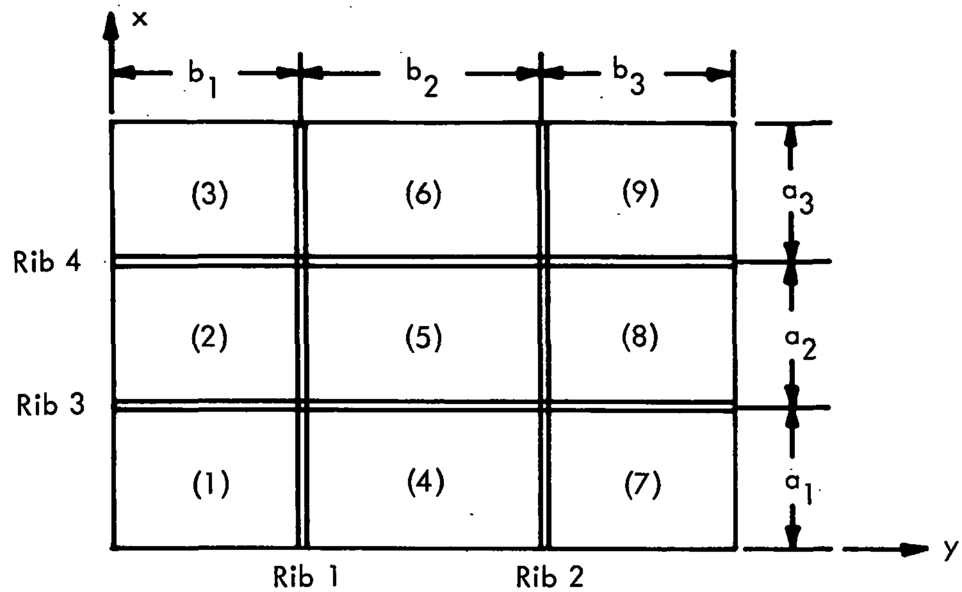


FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONCLUDED)



bay or plate element no. ( )

FIGURE 3. TWO-DIMENSIONAL PANEL GEOMETRY AND ELEMENT NOMENCLATURE

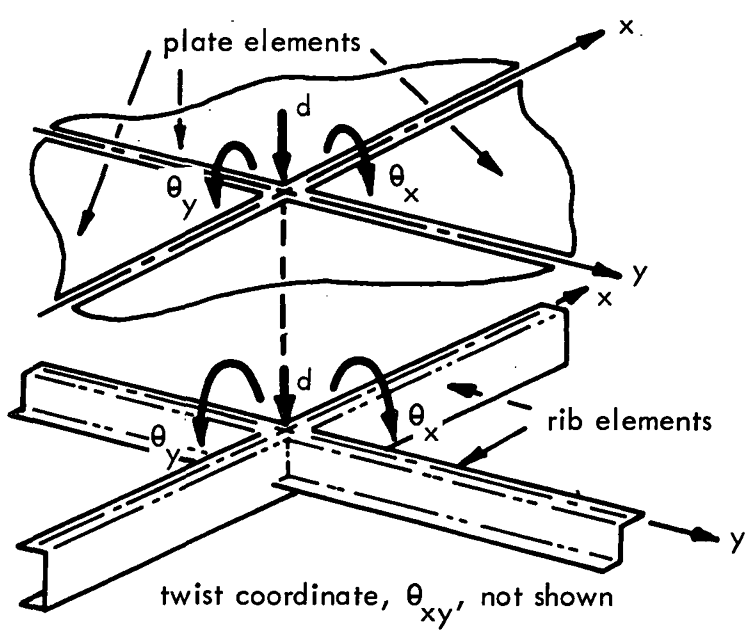
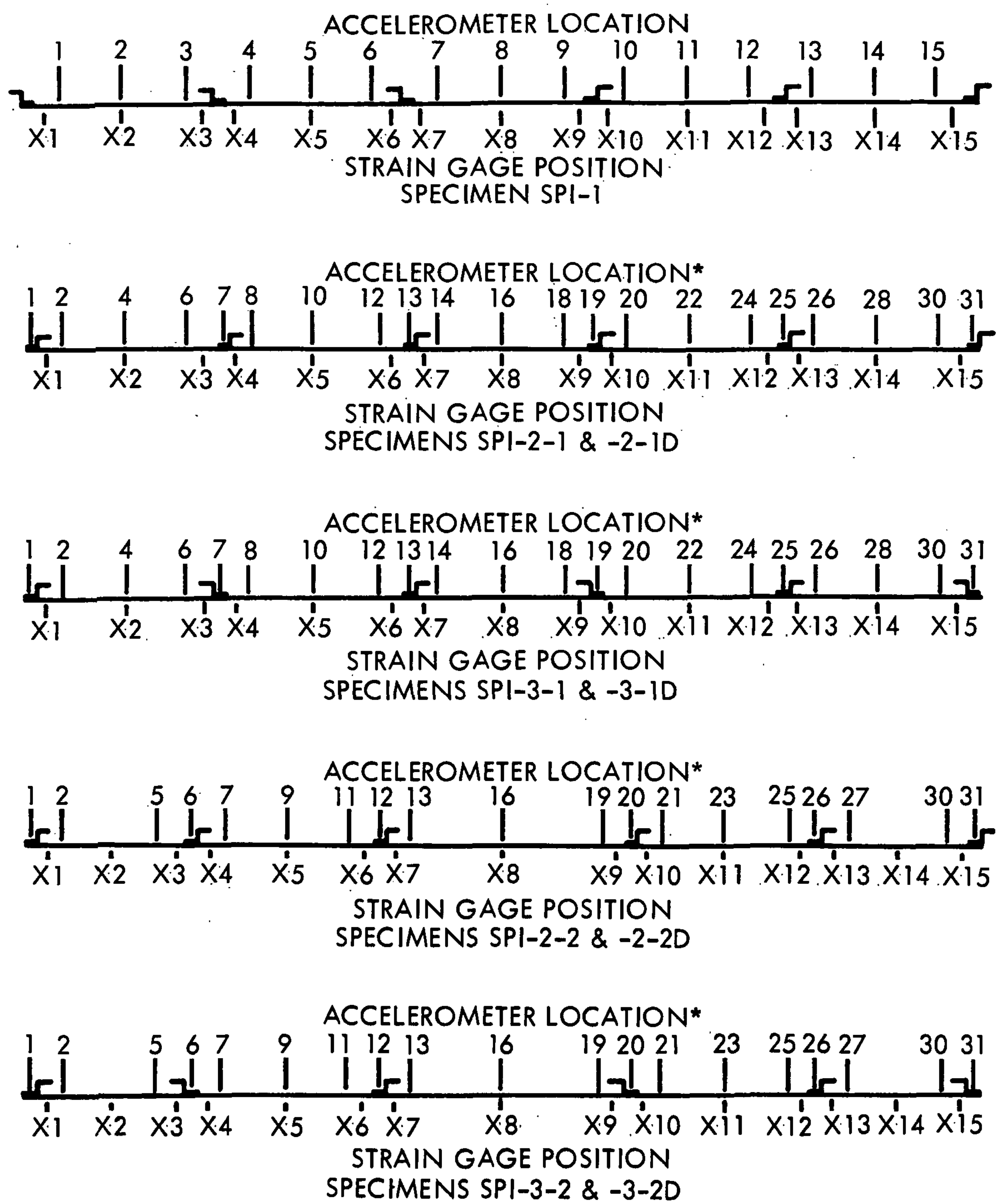


FIGURE 4. PLATE AND RIB ELEMENT ASSEMBLY



*Note: Locations not indicated are sequentially spaced at one inch intervals.

FIGURE 5. ACCELEROMETER AND STRAIN GAGE LOCATIONS
FOR ONE-DIMENSIONAL PANELS

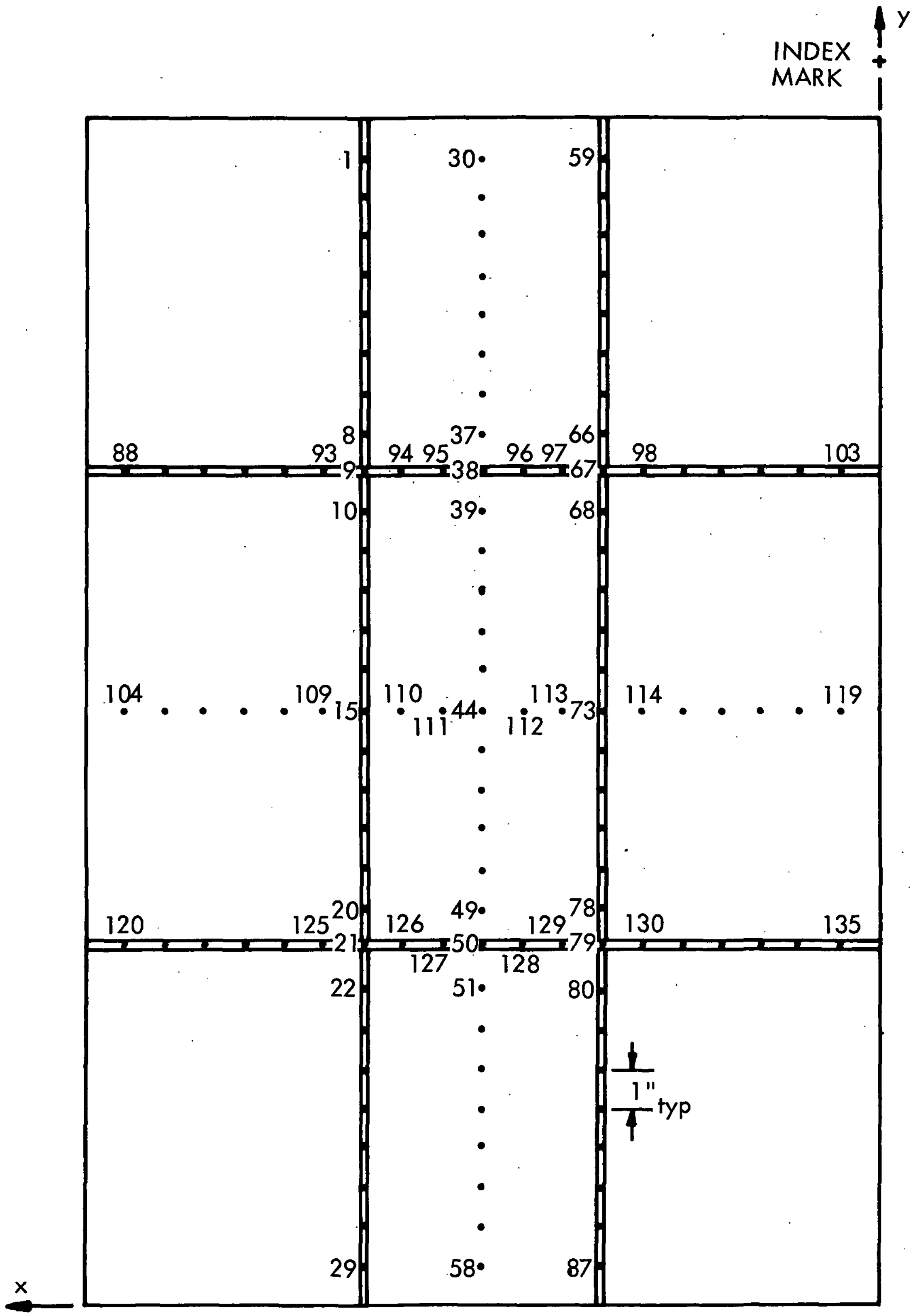
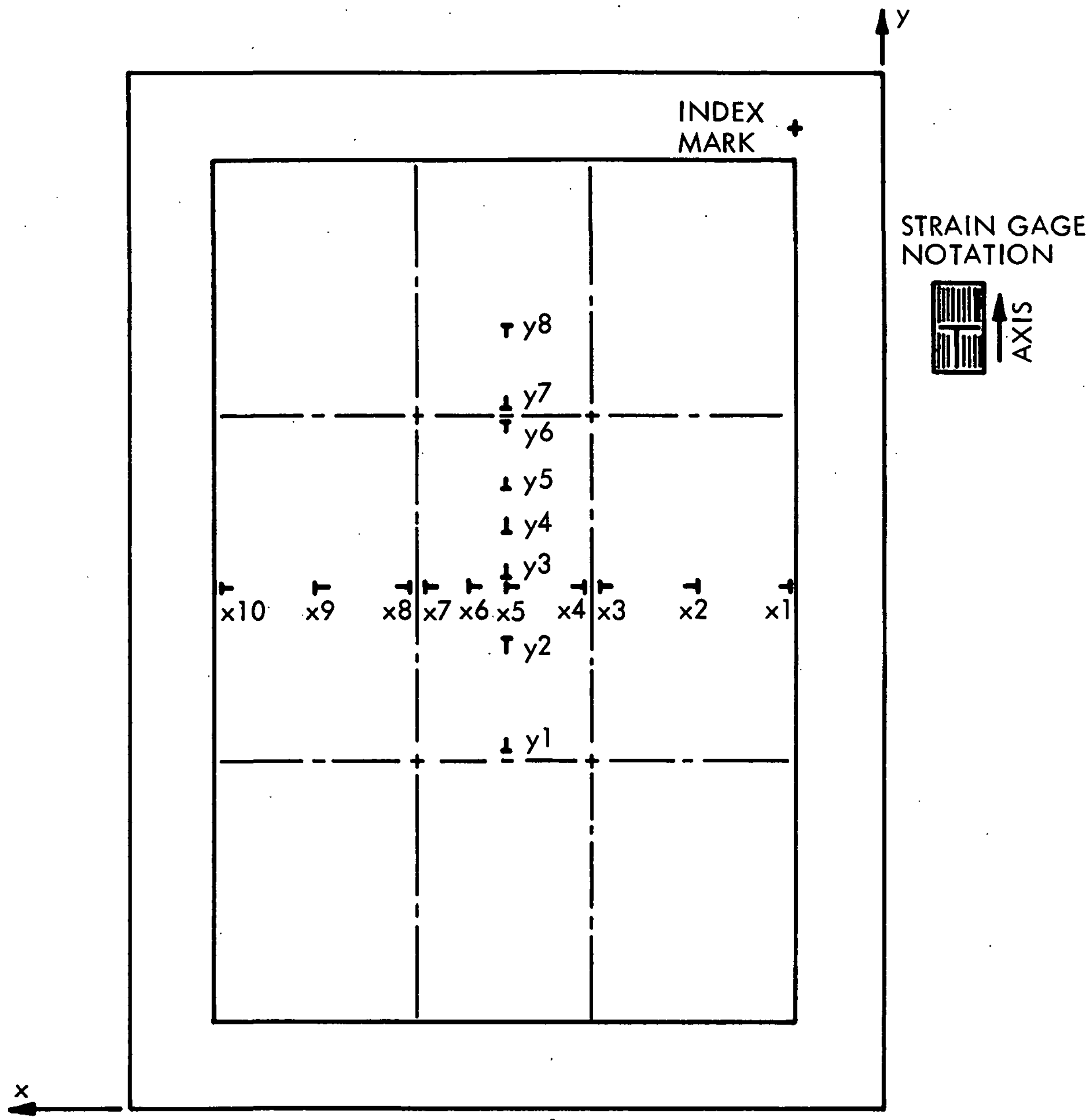
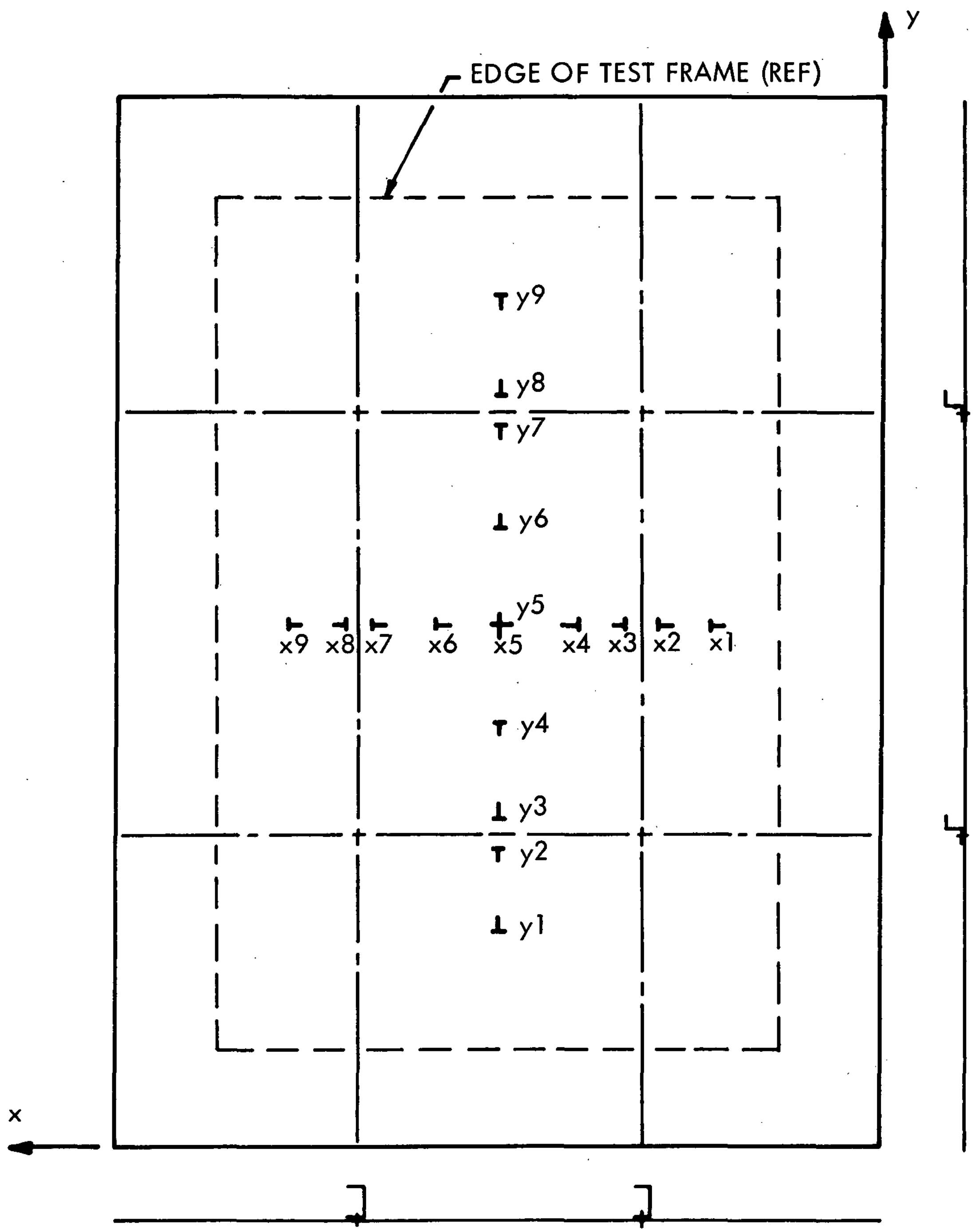


FIGURE 6. ACCELEROMETER LOCATION FOR NINE-BAY MACHINED PANEL SPECIMENS



SCALE: 1/60

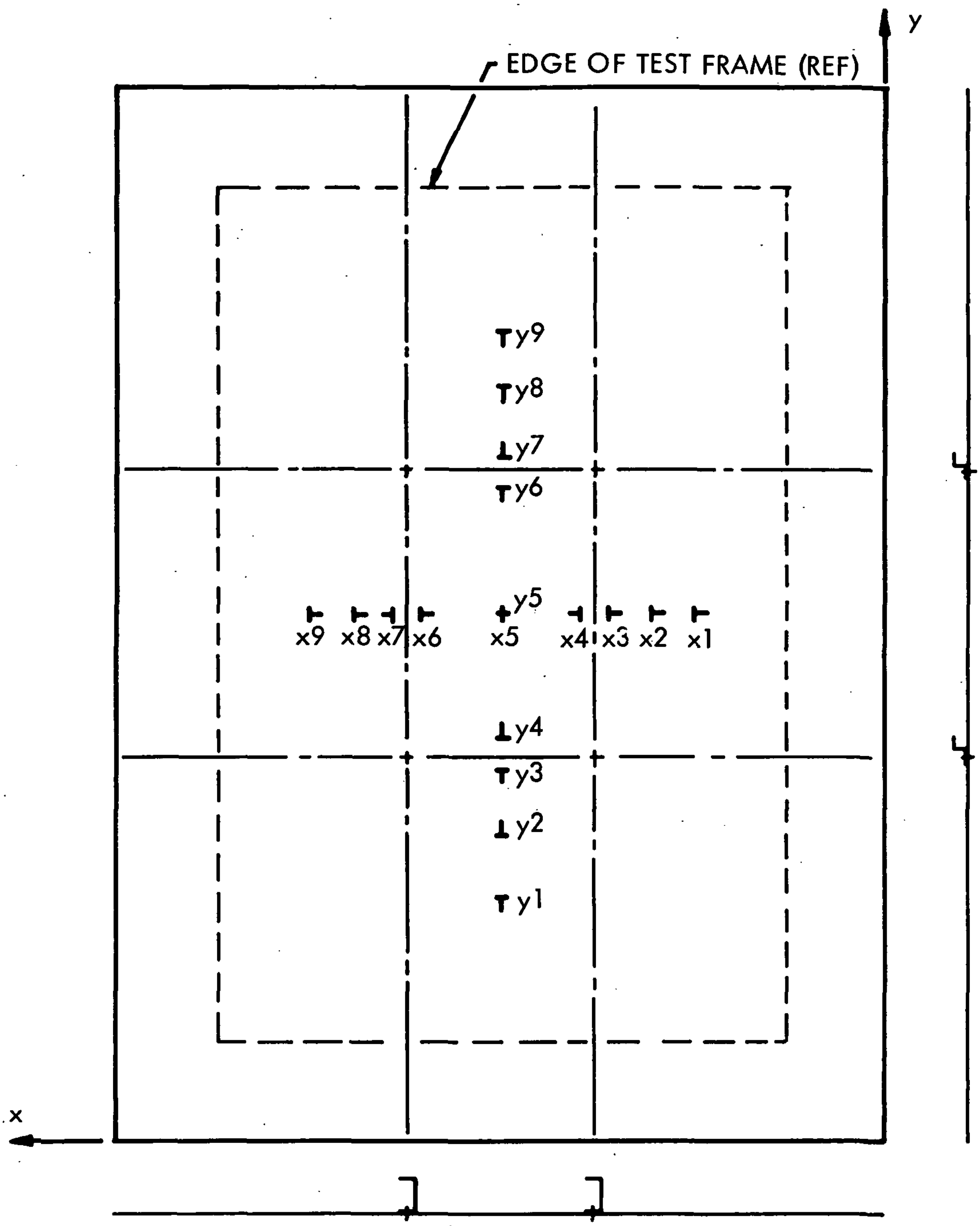
FIGURE 7. STRAIN GAGE LOCATION FOR MACHINED PANEL SPECIMENS (SEE TABLE 18)



SCALE = 1/60

STIFFENERS NOT SHOWN IN PLANVIEW FOR CLARITY

FIGURE 8. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-1
(SEE TABLE 18)



SCALE = 1/60

STIFFENERS NOT SHOWN IN PLANVIEW FOR CLARITY

FIGURE 9. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-2 (SEE TABLE 18)

TABLE 1

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-1	SPI-1	SPI-1	SPI-1	SPI-1	SPI-1
Frequency	82 Hz	106 Hz	119 Hz	126 Hz	108 Hz	127 Hz
Speaker Cond.	A	A	A	B	A	B
Position 1	0	0	0.20*	0	-	-
2	0.75	0.70	0.25*	-0.50	-	-
3	0.25	0	0.15*	0	-	-
4	-0.05	0	0.40	-0.24	0.25	-0.18
5	0	0.95	1.00	-1.00	1.00	-1.00
6	-0.10	0	0.43	0.10*	0.55	-0.40
7	0.25	0	0.63	0.19*	0.20	-0.30
8	0.75	0.61	1.00	0.27*	0.21*	-0.17
9	0.25	0	0.60	0.29*	0.25	-0.15
10	-0.10	0	0.42	0.35*	0.65	-0.20
11	0	1.00	0.90	0.81	1.00	0.43
12	-0.10	0	0.35	0.35	0.35	0
13	0	0	0.45	0.31	-	-
14	1.00	0.94	0.50	0.50	-	-
Position 15	0	0	0.05	0	-	-

*90° Phase shift to reference

TABLE 2

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-2-1	SPI-2-1	SPI-2-1	SPI-2-1	SPI-2-1	SPI-2-1	SPI-2-1
Frequency	88 Hz	92 Hz	103 Hz	113 Hz	120 Hz	91 Hz	109 Hz
Speaker Cond.	A	A	B	A	A	A	A
Position 1	0.01	-0.24	0.09	0.05	0.05	-	-
2	0.04	-0.24	0.21	0.01	-0.11	-	-
3	0.03	-0.43	-0.93	0.03	-0.27	-	-
4	0.03	-0.46	-0.75	0.01	-0.26	-	-
5	0.04	-0.37	-0.54	0.02	-0.13	-	-
6	0.03	-0.24	0.22	0.08	-0.11	-	-
7	-0.02	-0.30	0.22	0.14	-0.10	0.10	0
8	-0.08	0.63	0.23	0.26	-0.10	0.26	0.57*
9	-0.40	0.22	0.23	0.42	-0.24	0.50	0.59
10	-0.67	0.21	0.23	0.47	-0.53	0.60	0.69
11	-0.50	0.28	0.25	0.35	-0.44	0.69	0.69
12	-0.13	0.81	0.24	0.25	-0.20	0.40	0.42*
13	-0.01	-0.35	0.20	0.25	0.19*	0.33	0.11*
14	0.01	-0.01	0.10	0.26	0.28	0.54	0.14
15	0.18	0.07	0.05	0.28	0.36	0.82	0.36
16	0.20	0.15	0	0.26	0.36	1.00	0.46
17	0.18	0.12	0.05	0.21	0.30	0.74	0.36
18	0.11	-0.10	0.10	0.24	0.22	0.54	0.18
19	-0.01	-0.35	0.19	0.26	0.24	0.33	0.11*
20	-0.16	0.96	0.20	0.33	0.80	0.40	0.46*
21	-0.70	0.37	0.24	0.63	1.00	0.60	0.91
22	-1.00	0.36	0.21	1.00	0.85	0.60	1.00
23	-0.60	0.39	0.34	0.79	0.48	0.50	0.91
24	-0.14	1.00	0.19	0.40	0.48	0.28	0.50
25	-0.02	-0.30	0.26	0.12	0.31	0.14	0
26	0.05	-0.07	0.16	0.10	0.29	-	-
27	0.10	-0.03	-0.56	0.07	0.40	-	-
28	0.106	-0.04	-0.75	0.07	0.49	-	-
29	0.110	-0.11	-1.00	0.08	0.54	-	-
30	0.09	-0.11	0.34	0.08	0.58	-	-
Position 31	0.02	-0.08	0.20	0.09	0.14	-	-

*90° Phase shift to reference.

TABLE 3

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-2-1D	SPI-2-1D	SPI-2-1D	SPI-2-1D	SPI-2-1D	SPI-2-1D	SPI-2-1D
Frequency	80 Hz	88 Hz	111 Hz	128 Hz	94 Hz	108 Hz	134 Hz
Speaker Cond.	A	A	A	B	A	B	B
Position 1	0	0	0.09	-0.01	-	-	-
2	-0.01	0.32	0.24	0.40	-	-	-
3	-0.09	0.77	0.28	0.58	-	-	-
4	-0.09	1.00	0.29	0.70	-	-	-
5	-0.08	0.82	0.25	0.48	-	-	-
6	-0.01	0.27	0.21	0.25	-	-	-
7	-0.06	0.30*	0.29	0.25	-0.06	0.05*	0.22*
8	-0.14	-0.30	0.44	0.38	-0.14	0.12*	0.44*
9	-0.33	-0.68	0.73	0.60	-0.28	0.28*	0.78*
10	-0.40	-0.30	1.00	0.70	-0.40	-0.44	0.96*
11	-0.35	-0.93	0.77	0.60	-0.40	-0.44	0.85*
12	-0.16	-0.24	0.44	0.38	-0.20	0.12*	0.47*
13	-0.08	-0.25	0.43	0.15	0.07	0.25	0.25*
14	0.06	0.17	0.52	0.01*	0.40	0.53	0.31
15	0.13	0.34	0.63	0.15*	0.80	1.00	0.53
16	0.18	0.27	0.69	0.15*	1.00	1.00	0.53
17	0.06	0.15	0.63	0.21*	0.80	0.89	0.47
18	0.06	0.09	0.49	0.15*	0.58	0.50	0.25
19	-0.06	0.09	0.44	0.18*	0.16	0.40	0.22*
20	-0.20	0.16	0.61	0.45	-0.40	0.40	0.44*
21	-0.62	0.30	0.94	0.84	-0.46	0.60	0.85*
22	-0.98	0.43	1.00	0.84	-0.46	0.90	1.00*
23	-0.62	0.35	0.88	0.72	-0.40	0.80	0.78*
24	-0.20	0.26	0.55	0.45	-0.28	0.50	0.41*
25	-0.09	-	0.39	0.30	-0.10	0.24	0.28*
26	-0.02	-0.32	0.28	0.42	-	-	-
27	-0.47	-0.54	0.38	0.95	-	-	-
28	-0.59	-0.63	0.39	1.00	-	-	-
29	-0.59	-0.58	0.36	0.92	-	-	-
30	-0.16	-0.12	0.32	0.60	-	-	-
Position 31	-0.02	0.09	0.15	0.20	-	-	-

*90° Phase shift to reference.

TABLE 4

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-2-2	SPI-2-2	SPI-2-2	SPI-2-2	SPI-2-2	SPI-2-2
Frequency	57 Hz	61 Hz	68 Hz	51 Hz	61 Hz	67 Hz
Speaker Cond.	A	A	A	A	A	A
Position 1	0.03	0.05	0.05	-	-	-
2	0.08	0.13	0.10	-	-	-
3	0.16	0.15	0.15	-	-	-
4	0.16	0.17	0.18	-	-	-
5	0.12	0.15	0.17	-	-	-
6	0.04*	0.09	-0.10	0.04*	0.07	-0.11
7	-0.18	-0.23	-0.37	-0.11	-0.17	-0.38
8	-0.36	-0.43	-0.79	-0.22	-0.37	-0.81
9	-0.40	-0.63	-1.00	-0.36	-0.54	-1.00
10	-0.40	-0.61	-1.00	-0.36	-0.52	-1.00
11	-0.24	-0.30	-0.47	-0.22	-0.29	-0.56
12	-0.04	0.07	-0.13	0.11	-0.07	-0.14
13	0.27	0.29	0.30	0.49	0.29	0.31
14	0.63	0.67	0.67	0.69	0.67	0.67
15	0.74	0.92	0.87	0.95	0.83	0.93
16	1.00	1.00	1.00	1.00	1.00	1.00
17	0.91	0.92	0.93	1.00	0.83	0.93
18	0.70	0.69	0.73	0.78	0.60	0.67
19	0.40	0.36	0.33	0.39	0.40	0.33
20	0.06	0.07	0.05	0.09	0.08*	-0.10
21	-0.20	-0.29	-0.37	-0.15	-0.30	-0.47
22	-0.36	-0.43	-0.63	-0.28	-0.50	-0.87
23	-0.40	-0.54	-0.73	-0.28	-0.60	-1.00
24	-0.36	-0.46	-0.60	-0.19	-0.54	-0.87
25	-0.16	-0.21	-0.33	-0.12	-0.27	-0.47
26	-0.06	-0.09	-0.11	0.02	-0.10	-0.14
27	0.07	0.17	0.08	-	-	-
28	0.18	0.18	0.13	-	-	-
29	0.18	0.17	0.17	-	-	-
30	0.08	0.13	0.12	-	-	-
Position 31	0.05	0.08	0.05	-	-	-

*90° Phase shift to reference.

TABLE 5

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-2-2D	SPI-2-2D	SPI-2-2D	SPI-2-2D	SPI-2-2D
Frequency	55 Hz	59 Hz	68 Hz	96 Hz	64 Hz
Speaker Cond.	A	C	D	B	A
Position 1	0.09 T	0	0.05	0.04	-
2	0.14	0	0.20	-0.04	-
3	0.19	0	0.35	-0.08	-
4	0.19	0	0.36	-0.07	-
5	0.13	0	0.16	-0.04	-
6	0.07 T	0	0.06	0.14	0
7	-0.13	-0.21	-0.14	0.44	0
8	-0.19	-0.29	-0.36	0.77	-0.06
9	-0.25	-0.35	-0.40	1.00	-0.11
10	-0.23	-0.29	-0.36	0.77	-0.17
11	-0.15	-0.23	-0.20	0.44	-0.17
12	0.06 T	0	-0.06	0.22	-0.11
13	-0.32	0.38	0.22	-0.11	0.07
14	-0.50	0.44	0.89	-0.16	0.27
15	-1.00	0.50	1.00	-0.18	0.56
16	-1.00	1.00	1.00	0.16*	0.89
17	-0.63	0.50	1.00	0.22	1.00
18	-0.45	0.38	0.70	0.22	0.82
19	-0.25	0.21	0.22	0.18	0.45
20	0.11 T	0.12	-0.14	0.13*	0.18
21	0.15 T	-0.18	-0.28	0.16*	0.11
22	0.20 T	-0.29	-0.60	0.18*	0.06*
23	0.23 T	-0.29	-0.80	0.20*	0.08*
24	0.20 T	-0.29	-0.70	0.20*	0.08*
25	0.10 T	-0.15	-0.24	0.16*	0.08*
26	0.06 T	0	-0.10	0.06*	0
27	0.10 T	0.12	0.10	0.06	-
28	0.13 T	0.12	0.20	0.11	-
29	0.13 T	0.12	0.20	0.11	-
30	0.10 T	0	0.10	0.07	-
Position 31	0.06 T	0	0.04	0.03	-

*90° Phase shift to reference.

T response at twice frequency of reference.

TABLE 6

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

Panel	SPI-3-1	SPI-3-1	SPI-3-1	SPI-3-1	SPI-3-1	SPI-3-2	SPI-3-2
Frequency	80 Hz	88 Hz	107 Hz	117 Hz	101 Hz	62 Hz	68 Hz
Speaker Cond.	A	B	A	B	A	A	A
Position 1	0.00	-	-	-	-	-	-
2	0.10	-	-	-	-	-	-
3	0.20	-	-	-	-	-	-
4	0.30	0.60	1.00	0.77	-	0.00	-
5	0.38	-	-	-	-	-	-
6	0.20	-	-	-	-	-	-
7	0.00	-	-	-	-	-	-
8	-0.40	-	-	-	-	-	-
9	-0.83	-	-	-	-	0.20	0.00
10	-1.00	-0.60	0.28	0.42	0.40	-	-
11	-0.80	-	-	-	-	-	0.00
12	-0.35	-	-	-	-	-	-
13	-0.06	-	-	-	-	-	0.25
14	0.10	-	-	-	-	-	-
15	0.30	-	-	-	-	-	-
16	0.39	-0.15	-0.18	0.00	1.00	1.00	1.00
17	0.24	-	-	-	-	-	-
18	0.12	-	-	-	-	-	-
19	-0.15	-	-	-	-	-	0.20
20	-0.40	-	-	-	-	-	-
21	-0.70	-	-	-	-	-	0.00
22	-0.80	1.00	0.30	0.50	0.28	-	-
23	-0.68	-	-	-	-	0.58	0.00
24	-0.40	-	-	-	-	-	-
25	-0.03	-	-	-	-	-	-
26	0.00	-	-	-	-	-	-
27	0.10	-	-	-	-	-	-
28	0.18	-0.32	0.82	1.00	-	0.00	-
29	0.10	-	-	-	-	-	-
30	0.00	-	-	-	-	-	-
Position 31	0.00	-	-	-	-	-	-

TABLE 7

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS: ONE-DIMENSIONAL PANELS

Panel	SPI-3-1D	SPI-3-1D	SPI-3-1D	SPI-3-1D	SPI-3-1D	SPI-3-1D	SPI-3-1D
Frequency	105 Hz	105 Hz	109 Hz	127 Hz	134 Hz	106 Hz	139 Hz
Speaker Cond.	A	D	B	A	B	A	B
Position 1	0.09	0.15	0.01	0.13	0.12	-	-
2	0.15	0.18	0.08	0.36	0.61	-	-
3	0.56 T	0.28	0.20	0.31	0.81	-	-
4	0.20 T	0.25	0.35	0.27	0.91	-	-
5	0.22 T	0.23	0.27	0.30	0.76	-	-
6	0.25 T	0.20	0.15	0.36	0.44	-	-
7	0.35 T	0.43	-0.04	0.16	0.30	0.26	0.09
8	0.74	0.75	-0.30	0.26	0.44	0.63	0.25
9	0.87	1.00	1.00	0.36	0.36	1.00	0.62
10	0.94	1.00	0.59	0.38	0.96	1.00	0.50
11	1.00	1.00	0.63	0.38	0.96	1.00	0.49
12	0.81	0.85	-0.43	0.31	0.57	0.69	0.35
13	0.56	0.55	-0.07	0.27	0.52	0.47	0.12
14	0.22	0.30	0.71	-0.36	-0.09	0.40	0.08
15	0.17 T	0.15	0.25	-0.24	-0.21	0.60	0.09
16	0.17 T	0.15	0.25	-0.24	-0.18	0.74	0.12
17	0.17 T	0.15	0.25	-0.24	-0.12	0.60	0.13
18	0.22	0.25	0.11	-0.36	-0.12	0.33	0.08
19	0.47	0.55	-0.10	0.50	-0.27	0.33	-0.21
20	0.70	0.70	-0.33	0.37	-0.51	0.20	-0.44
21	0.88	0.80	-	0.67	-0.91	0.74	-0.80
22	0.92	0.75	-	0.74	-1.00	0.87	-1.00
23	0.87	0.80	0.20	0.61	-0.88	0.67	-0.78
24	0.67	0.75	0.11	0.49	-0.52	0.33	-0.35
25	0.15	0.20	0.20	0.25	-0.43	-	-
27	0.10 T	0.20	0.32	1.00	-0.64	-	-
28	0.10 T	0.25	0.38	0.30	-0.76	-	-
29	0.10 T	0.25	0.28	0.43	-0.67	-	-
30	0.10 T	0.25	0.13	0.25	-0.55	-	-
Position 31	0.10	0.15	0.03	0.10*	-0.15	-	-

T response at twice frequency of reference.

TABLE 8

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS: ONE-DIMENSIONAL PANELS

Panel	SPI-3-2D	SPI-3-2D	SPI-3-2D	SPI-3-2D	SPI-3-2D
Frequency	63 Hz	74 Hz	107 Hz	65 Hz	71 Hz
Speaker Cond.	A	A	B	A	D
Position 1	0.13 T	0.10 T	-0.08	-	-
2	0.10 T	0.16 T	-0.39	-	-
3	0.10 T	0.16 T	-0.69	-	-
4	0.10 T	0.10 T	-0.54	-	-
5	0.15 T	-0.13	-0.23	-	-
6	0.45 T	-0.31	0.19	-	-
7	0.50 *	-0.57	0.50	0.07	0.19 T
8	1.00	-0.72	0.85	0.07 T	-0.38
9	0.75	-0.61	1.00	0.10 T	-0.50
10	0.75	-0.36	1.00	-0.10	-0.50
11	0.35	-0.14	0.42	-0.10	-0.30
12	0.12	0.30	0.23	0.07	0.09 T
13	-0.10	0.68	0.31 *	0.25	0.33
14	-0.20	0.85	0.39 *	0.72	0.67
15	-0.25	1.00	0.39 *	1.00	0.50
16	-0.25	1.00	0.62	1.00	1.00
17	-0.30	0.82	0.58	1.00	0.50
18	-0.22	0.33	0.39	0.80	0.40
19	0.12 T	0.27	0.27	0.42	0.25
20	0.13	-0.10	0.31	0.17	0.08 T
21	0.36	-0.31	0.39 *	-0.17	-0.29
22	0.55	-0.63	0.58 *	-0.33	-0.50
23	0.63	-0.63	0.69 *	-0.33	-0.63
24	0.55	-0.56	0.69	-0.25	-0.48
25	0.30	-0.31	0.39 *	0.12 T	-0.25
26	0.13	-0.10	0.08 *	-	-
27	0.05 T	-0.06	0.12 *	-	-
28	0.08	-0.08	0.23 *	-	-
29	0.10	-0.10	0.31 *	-	-
30	0.08	0.06	0.15 *	-	-
Position 31	0.03	0.06	0	-	-

*90° Phase shift to reference.

T response at twice frequency of reference.

TABLE 9

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in
SPECIMEN SPI-1

Configuration	5 Bay	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay	3 Bay
Frequency, Hz	82	106	119	126	108	115	127
Strain Gage 1	0.00	0.00	0.00	0.00	-	-	-
2	1.00	0.26	-0.50	0.40	-	-	-
3	-0.87	-0.40	0.61	-1.00	-	-	-
4	-0.93	-0.40	0.56	-0.73	-0.56	-0.43	-0.20
5	0.00	0.40	0.28*	0.73	1.00	0.60	0.38
6	-0.80	-0.58	0.84	-0.77	-0.83	-0.50	-0.60
7	-0.67	-0.45	0.56	-0.77	-0.83	-0.50	-0.56
8	0.67	-0.40	-1.00	0.25	0.00	-1.00	0.40
9	-0.67	-0.32	0.70	0.50	-0.56	-0.63	0.56
10	-0.80	-0.32	0.70	0.40	-0.67	-0.68	0.46
11	0.00	-0.84	-0.42	-1.00	0.95	0.50	-1.00
12	-0.67	-0.47	0.20	0.94	-0.67	-0.38	0.60
13	-0.67	-0.40	0.20	0.94	-	-	-
14	0.67	1.00	-0.28	-0.67	-	-	-
Strain Gage 15	0.60	-0.13	0.00	0.11T	-	-	-
$\bar{\epsilon}$, μ in/in	63	158	150	250	75	168	208

*90° Phase shift to reference.

T response at twice reference frequency.

TABLE 10

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in

SPECIMEN SPI-2-1

Configuration	5 Bay	5 Bay	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay
Frequency, Hz	88	92	103	113	120	91	109
Strain Gage 1	0.00	0.00	0.00	0.00	0.00	-	-
2	0.80	0.28	-0.40	1.00*	0.70	-	-
3	-0.27	-1.00	0.45	-0.89	-1.00	-	-
4	-0.13	-0.83	0.30	-0.72	-1.00	0.54	-0.36
5	-1.00	1.00	1.00	0.54	0.60	-0.54	0.36
6	-0.27	-0.95	-0.70	0.79	-0.80	-0.77	-0.29
7	-0.27	-0.83	-0.63	-0.54	-0.80	-0.77	-0.29
8	1.00	0.27	0.00	0.79	0.25	0.77	0.36
9	-0.40	-0.45	0.18	-0.64	0.20	-0.93	-0.72
10	-0.40	-0.56	0.20	-0.64	0.35	-1.00	-1.00
11	-0.40	0.25	-0.40	0.47	-0.75	-0.77	0.89
12	-0.27	-0.89	0.15	-0.54	1.00	0.62	-0.72
13	-0.27	-0.56	-0.20	-0.47	0.75	-	-
14	0.54	0.55	0.60	0.82	-0.75	-	-
Strain Gage 15	0.00	0.00	0.00	0.00	0.00	-	-
$\bar{\epsilon}$, μ in/in	312	75	83	117	83	54	100

*90° Phase shift to reference.

TABLE 11

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in

SPECIMEN SPI-2-1D

Configuration		5 Bay	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay	3 Bay
Frequency, Hz		80	88	111	128	94	108	134
Strain Gage	1	-0.32	0.00	0.33	0.00	-	-	-
	2	0.80	0.73	-0.67	0.55	-	-	-
	3	-0.60	0.00	-0.33	-0.55	-	-	-
	4	-0.52	0.00	-0.33	-0.55	0.50	-0.56	0.84
	5	0.40	-1.00	0.33	0.91	-0.57	0.63	-1.00
	6	-0.32	0.33	-0.60	-0.46	0.33	-0.63	0.67
	7	-0.28	0.33T	-0.74	-0.46	0.33	-0.63	0.56
	8	0.40	0.67	1.00	0.00	0.50*	1.00	0.56
	9	-0.44	-0.67	-0.60	0.55	0.33	-0.63	-0.45
	10	-0.60	-0.67	-0.47	0.55	0.67	-0.63	-0.67
	11	1.00	0.87	0.40	-1.00	-1.00	0.31	1.00
	12	-0.60	0.33	-0.40	0.82	0.83	-0.38	-0.56
	13	-0.56	0.47	-0.47	0.82	-	-	-
	14	0.28	-0.80	-0.67	-0.73	-	-	-
Strain Gage	15	0.28	0.47	0.27	0.00	-	-	-
$\bar{\epsilon}$, μ in/in		105	125	312	92	125	67	75

*90° Phase shift to reference.

T Response at twice reference frequency.

TABLE 12

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in
SPECIMEN SPI-2-2

Configuration	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay	3 Bay
Frequency, Hz	57	61	68	61	51	67
Strain Gage 1	-0.13	-0.27	0.0	-	-	-
2	0.20	0.31	0.17	-	-	-
3	0.16	0.31	0.27	-	-	-
4	0.27	0.50	0.37	0.70	0.33	0.85
5	-0.55	-0.69	-0.50	-0.80	-0.33	-1.0
6	-0.36	-0.19	0.17	-0.30	-0.40	0.50
7	-0.65	-0.54	-0.20	-0.50	-0.80	-0.25
8	1.00	1.00	1.00	1.0	1.00	1.00
9	-0.69	-0.58	-0.27	-0.60	-0.83	-0.35
10	-0.44	-0.27	0.17	0.25*	-0.47	0.40
11	-0.44	-0.54	-0.37	-0.65	-0.33	-0.75
12	0.25	0.35	0.27	0.60	0.40	0.75
13	0.18	0.35	0.20	-	-	-
14	0.20	0.23	0.13	-	-	-
Strain Gage 15	-0.09	0.15	0.0	-	-	-
$\bar{\epsilon}$, μ in/in	230	108	125	83	125	167

*90° Phase shift to reference.

TABLE 13

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in
SPECIMEN SPI-2-2-D

Configuration	5 Bay	5 Bay	5 Bay	3 Bay
Frequency, Hz	55	68	96	64
Strain Gage 1	0.5	0.0	0.0	-
2	0.7	0.0	0.0	-
3	-0.5	0.0	0.40	-
4	-0.5	0.0	0.55	0.0
5	0.7	-0.83	-0.75	-0.6
6	-0.5	-1.0	0.40	-1.0
7	-0.5	-1.0	0.40	-1.0
8	1.0	1.0	0.50	-0.8
9	-0.6	-0.83	-0.75	-1.0
10	-0.8	-0.83	-0.75	-1.0
11	1.0	-0.83	1.00	-1.0
12	-0.5	0.0	-0.75	0.5
13	-0.5	0.0	-0.50	-
14	0.0	0.0	0.0	-
Strain Gage 15	0.0	0.0	0.0	-
$\bar{\epsilon}$, μ in/in	45	25	83	42

TABLE 14

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

$\bar{\varepsilon}$ = NORMALIZING STRAIN, μ in/in

SPECIMEN SPI-3-1

Configuration	5 Bay	5 Bay	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay
Frequency, Hz	80	88	92-93	107	117	90	101
Strain Gage 1	0.13	0.0	-0.38	-0.25	-0.19	-	-
2	0.36*	0.35	0.94	1.00	0.75	-	-
3	0.36*	0.0	-1.00	-0.45	-0.93	-	-
4	-0.39	0.25	-0.94	-0.42	-0.93	-0.83	-0.72
5	0.71	-0.75	0.56	0.50	1.00	1.00	1.00
6	0.21*	0.50	-0.31	0.33	-0.55	-0.63	-0.43
7	0.27*	0.40	-0.31	0.50	-0.44	-0.21	0.43
8	-0.71	0.50	0.0	-1.00	0.15	-0.42	-0.86
9	0.21*	-0.75	-0.47	0.67	0.37	0.0	0.50
10	-0.64	-1.00	-0.63	0.50	0.37	-0.42	-0.36
11	1.00	1.00	1.00	0.33	-0.74	1.00	0.79
12	-0.50	-0.50	-0.78	-0.67	0.74	-0.63	-0.64
13	0.27*	0.75	-0.78	-0.67	0.74	-	-
14	-0.72	-1.00	0.47	0.83	-0.55	-	-
Strain Gage 15	0.30	0.50	0.0	0.0	0.0	-	-
$\bar{\varepsilon}$, μ in/in	232	83	133	250	225	100	290

*90° Phase shift to reference.

TABLE 15

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

$\bar{\varepsilon}$ = NORMALIZING STRAIN, μ in/in

SPECIMEN SPI-3-2

Configuration	5 Bay	5 Bay	3 Bay	3 Bay	3 Bay
Frequency, Hz	54	62	62	68	101
Strain Gage 1	0.0	0.0	-	-	-
2	0.0	0.0	-	-	-
3	0.0	0.0	-	-	-
4	0.0	0.13	0.0	0.18	0.61
5	0.0	-0.50	0.0	-0.21	-0.89
6	-0.62	-0.30	-0.42	-0.36	0.33
7	-1.00	-0.85	-0.84	-0.89	-0.89
8	1.00	0.85	1.00	1.00	1.00
9	-0.93	-0.50	-0.88	-0.89	-1.00
10	-0.54	-0.40	-0.50	-0.36	0.28
11	0.0	-1.00	-0.21	-0.27	-0.56
12	0.0	0.50	0.0	0.18	0.45
13	0.0	0.65	-	-	-
14	0.0	0.30	-	-	-
Strain Gage 15	0.0	0.0	-	-	-
$\bar{\varepsilon}$, μ in/in	54	167	100	233	75

TABLE 16

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in

SPECIMENS SPI-3-1D AND SPI-3-2D

	SPI-3-1D				SPI-3-2D		
Configuration	5 Bay	5 Bay	5 Bay	5 Bay	5 Bay	3 Bay	3 Bay
Frequency, Hz	105	115	127	74	107	65	71
Strain Gage 1	0.18*	0.17*	0.25	0.33	-	-	-
2	0.42	0.83	-0.63	-0.47	-	-	-
3	-0.58	-0.63	0.42*	-0.60	-0.60	-	-
4	-0.79	-1.00	0.42*	-0.67	-0.80	0.50	0.50
5	1.00	0.83	0.42	1.00	0.67	-0.25	-1.00
6	-0.66	-0.42	-0.63	0.67	-0.87	-0.90	1.00T
7	-0.53	-0.33	-0.63	0.53	-0.67	0.0	0.60
8	0.50	-0.17	1.00	-1.00	0.67	1.00	0.90
9	-0.58	-0.63	-0.84	0.53	-0.67	-0.65	-0.50
10	-0.63	0.58	-0.75	0.67	-0.80	-0.90	-0.50
11	0.79	-0.75	0.57	0.87	1.00	0.40	0.40T
12	-0.66	0.83	-0.50	-0.80	-0.53	0.0	0.40
13	-0.53	0.79	0.42*	-0.67	-0.47	-	-
14	0.58	-0.63	-0.75	-0.47	-0.80	-	-
Strain Gage 15	-0.36	0.33	0.42	0.47*	0.40	-	-
$\bar{\epsilon}$, μ in/in	158	200	100	63	63	83	83

*90° Phase shift to reference.

T Response at twice frequency of reference.

TABLE 17

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS
NINE-BAY MACHINED PANEL SPECIMEN
(See Figure 6)

Frequency, Hz	88	94	148	175	188
Position 1	0.008	0.004	0.014	0.021	0.028
2	0.005	0.006	0.030	0.050	0.065
3	0.015	0.020	0.052	0.067	0.102
4	0.028	0.038	0.074	0.100	0.185
5	0.045	0.064	0.100	0.133	0.296
6	0.055	0.150	0.104	0.150	0.296
7	0.070	0.180	0.111	0.150	0.352
8	0.088	0.200	0.111	0.133	0.407
9	0.125	0.170	0.100	0.217	0.444
10	0.163	0.280	0.100	0.183	0.537
11	0.188	0.310	0.082	0.217	0.537
12	0.219	0.270	0.067	0.250	0.556
13	0.263	0.370	0.044	0.233	0.593
14	0.288	0.410	0.022*	0.333	0.593
15	0.300	0.420	-0.030	0.383	0.593
16	0.300	0.420	-0.044	0.433	0.593
17	0.275	0.390	-0.044	0.433	0.593
18	0.238	0.360	-0.044	0.433	0.574
19	0.200	0.320	-0.041	0.433	0.556
20	0.163	0.270	-0.032	0.399	0.482
21	0.125	0.230	-0.044	0.367	0.463
22	0.100	0.170	-0.026	0.367	0.407
23	0.075	0.120	-0.024	0.317	0.389
24	0.063	0.092	-0.022	0.283	0.352
25	0.050	0.068	-0.020	0.233	0.278
26	0.025	0.040	-0.018	0.158	0.204
27	0.013	0.024	-0.013	0.108	0.120
28	0.005	0.008	-0.007	0.049	0.065
Position 29	0.008	0.004	-	0.037	0.028

*90° Phase shift to reference.

TABLE 17
(CONTINUED)

Frequency, Hz	88	94	148	175	188
Position 30	0.008	0.060*	0.011	0.167	-0.092
31	0.050	0.080	0.556	-0.108	-0.278
32	0.088	0.096	0.815	-0.108	-0.130
33	0.125	0.128	0.593	-0.733	-0.074
34	0.150	0.144	0.593	-0.733	0.093*
35	0.163	0.160	0.815	-0.750	0.148
36	0.163	0.160	0.704	0.517	0.315
37	0.150	0.160	0.269	0.383	0.482
38	0.150	0.220	0.133	0.267	0.482
39	0.225	0.290	0.222	0.517*	0.556
40	0.375	0.440	0.315	-0.800	0.407
41	0.500	0.600	0.296	-0.450	0.259
42	0.725	0.740	0.052*	-0.450	0.148
43	0.925	0.860	-0.185	-0.617	-0.667
44	1.000	1.000	-0.241	-0.750	-1.000
45	0.950	0.900	-0.370	0.750*	-0.482
46	0.800	0.900	-0.704	0.300	-0.259
47	0.550	0.780	-1.000	0.500	0.185*
48	0.300	0.560	-0.324	0.708	0.482
49	0.175	0.300	-0.185	1.000	0.704
50	0.158	0.260	-0.048	0.917	0.482
51	0.113	0.200	0.030	0.583	0.556
52	0.138	0.200	0.048	0.250	0.519
53	0.125	0.200	0.048	0.083*	0.250
54	0.113	0.160	0.052	-0.100	0.093
55	0.088	0.100	0.052	-0.217	-0.185
56	0.063	0.080	0.052	-0.333	-0.463
57	0.038	0.080*	0.059	-0.333	-0.648
Position 58	0.008	0.020*	0.044	-0.125	-0.222

*90° Phase shift to reference.

TABLE 17
(CONTINUED)

Frequency, Hz	88	94	148	175	188
Position 59	0.010	0.004	0.013	0.021	0.028
60	0.005	0.006	0.037	0.067	0.074
61	0.008	0.018	0.059	0.083	0.111
62	0.023	0.040	0.085	0.100	0.185
63	0.033	0.060	0.104	0.133	0.241
64	0.050	0.100	0.119	0.167	0.296
65	0.065	0.140	0.126	0.167	0.333
66	0.088	0.180	0.133	0.150	0.370
67	0.125	0.200	0.133	0.250	0.444
68	0.163	0.300	0.133	0.200	0.482
69	0.200	0.340	0.133	0.217	0.519
70	0.238	0.380	0.126	0.225	0.519
71	0.275	0.430	0.096	0.225	0.574
72	0.300	0.440	0.082	0.225	0.611
73	0.313	0.460	0.044	0.267	0.630
74	0.300	0.460	0.022	0.283	0.630
75	0.275	0.420	-0.030	0.299	0.630
76	0.250	0.400	-0.030	0.317	0.593
77	0.188	0.350	-0.030	0.333	0.574
78	0.163	0.300	-0.028	0.333	0.555
79	0.125	0.220	-0.037	0.267	0.463
80	0.100	0.180	-0.026	0.367	0.444
81	0.075	0.120	-0.022	0.333	0.407
82	0.063	0.086	-0.022	0.317	0.370
83	0.050	0.064	-0.020	0.300	0.333
84	0.025	0.040	-0.016	0.200	0.250
85	0.013	0.020	-0.011	0.138	0.120
86	0.005	0.008	-0.007	0.071	0.111
Position 87	0.008	0.004	-	0.042	0.046

TABLE 17
(CONTINUED)

Frequency, Hz	88	94	148	175	188
Position 88	0.003	0.014	0.007	0.033	0.080
89	0.013	0.038	0.019	0.054	0.135
90	0.045	0.080	0.032	0.071	0.185
91	0.063	0.110	0.048	0.104	0.259
92	0.088	0.140	0.061	0.150	0.324
93	0.108	0.180	0.089	0.200	0.370
9	0.125	0.190	0.100	0.217	0.444
94	0.138	0.200	0.119	0.250	0.444
95	0.145	0.220	0.122	0.267	0.463
38	0.150	0.220	0.133	0.267	0.482
96	0.150	0.220	0.141	0.267	0.482
97	0.150	0.200	0.141	0.250	0.444
67	0.125	0.200	0.133	0.250	0.444
98	0.100	0.190	0.111	0.200	0.370
99	0.095	0.150	0.104	0.183	0.296
100	0.063	0.110	0.082	0.150	0.222
101	0.1575	0.070	0.048	0.100	0.185
102	0.025	0.036	0.032	0.058	0.148
103	0.003	0.016	0.017	0.042	0.074
104	0.069	0.112*	-0.082	-0.050	-0.185
105	0.250	0.030	-0.163	-0.200	-0.426
106	0.438	0.480	-0.178	-0.250	-0.370
107	0.500	0.560	-0.178	-0.283	-0.241
108	0.425	0.500	-0.148	0.217*	0.148*
109	0.313	0.380	-0.089	0.200	0.630
15	0.300	0.420	-0.030	0.433	0.593
110	0.500	0.520	-0.010	-0.383	-
111	1.000	0.780	-0.222	-0.667	-0.741
44	1.000	1.000	-0.241	-0.750	-1.000
112	0.925	0.780	-0.222	-0.683	-0.704
113	0.500	0.520	-0.089	-0.150	0.093
73	0.625	0.460	0.044	0.283	0.630
114	0.375	0.400	0.704	0.400	0.556
115	0.50	0.520	0.370	0.217	0.185
116	0.625	0.620	0.444	0.133*	-0.185
117	0.525	0.520	0.444	0.167*	-0.370
118	0.325	0.520	0.741	-0.167	-0.407
Position 119	0.125	0.100	0.185	0.042*	-0.167

*90° Phase shift to reference.

TABLE 17
(CONTINUED)

Frequency, Hz	88	94	148	175	188
Position 120	0.003	0.016	-0.007	0.050	0.074
121	0.013	0.042	-0.009	0.104	0.111
122	0.045	0.080	-0.015	0.129	0.167
123	0.063	0.120	-0.022	0.183	0.222
124	0.088	0.160	-0.011	0.275	0.296
125	0.108	0.190	-0.037	0.308	0.333
21	0.125	0.230	-0.044	0.317	0.407
126	0.138	0.250	-0.044	0.333	0.444
127	0.145	0.260	-0.044	0.350	0.462
50	0.158	0.260	-0.048	0.367	0.482
128	0.158	0.260	-0.044	0.350	0.462
129	0.150	0.250	-0.037	0.267	0.444
79	0.125	0.220	-0.037	0.267	0.407
130	0.108	0.200	-0.030	0.183*	0.370
131	0.083	0.160	-0.026	0.167*	0.333
132	0.063	0.130	-0.015	0.117*	0.259
133	0.045	0.090	-0.013	0.100	0.185
134	0.025	0.048	-0.005	0.067	0.158
Position 135	0.003	0.020	-0.007	0.042	0.074

*90° Phase shift to reference.

TABLE 18

STRAIN GAGE LOCATIONS
NINE-BAY PANEL SPECIMENS

Machines Panel Specimen
(See Figure 7)

SG	(x, y)	SG	(x, y)
X1	(3.25,18.0)	Y1	(13.0,12.35)
X2	(6.40,18.0)	Y2	(13.0,16.25)
X3	(9.75,18.0)	Y3	(13.0,18.3)
X4	(10.25,18.0)	Y4	(13.0,19.85)
X5	(13.00,18.0)	Y5	(13.0,21.85)
X6	(14.25,18.0)	Y6	(13.0,23.75)
X7	(15.75,18.0)	Y7	(13.0,24.25)
X8	(16.25,18.0)	Y8	(13.0,27.10)
X9	(19.60,18.0)		
X10	(22.80,18.0)		

SPII-1
(See Figure 8)

SG	(x, y)	SG	(x, y)
X1	(6.0 ,18.5)	Y1	(13.5, 7.50)
X2	(8.0 ,18.5)	Y2	(13.5,10.50)
X3	(9.0 ,18.5)	Y3	(13.5,11.50)
X4	(10.75,18.5)	Y4	(13.5,14.90)
X5	(13.5 ,18.5)	Y5	(13.5,18.50)
X6	(15.75,18.5)	Y6	(13.5,21.90)
X7	(18.0 ,18.5)	Y7	(13.5,25.50)
X8	(19.0 ,18.5)	Y8	(13.5,26.50)
X9	(21.0 ,18.5)	Y9	(13.5,30.00)

SPII-2
(See Figure 9)

SG	(x, y)	SG	(x, y)
X1	(6.7 ,18.5)	Y1	(13.5, 8.5)
X2	(8.2 ,18.5)	Y2	(13.5,10.75)
X3	(9.7 ,18.5)	Y3	(13.5,13.00)
X4	(10.7 ,18.5)	Y4	(13.5,14.10)
X5	(13.5 ,18.5)	Y5	(13.5,18.5)
X6	(16.3 ,18.5)	Y6	(13.5,23.0)
X7	(17.2 ,18.5)	Y7	(13.5,24.0)
X8	(18.6 ,18.5)	Y8	(13.5,26.25)
X9	(20.1 ,18.5)	Y9	(13.5,28.50)

TABLE 19

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS
NINE-BAY PANEL SPECIMENS SPII-1 AND SPII-2

Specimen SPII-1

Frequency, Hz	90	97	101	107	112	134	144	168
Bay Number 1	-	0.20	0.23	-0.23	-0.38	-	-0.40	0.70
2	-0.25	0.33*	0.30*	-0.27	-0.62	1.00	-0.27	0.50
3	-	0.20	0.30	-0.19	-0.38	-	0.27	1.00
4	-1.00	-0.27	0.33	-0.23	-0.38	0.25	0.67	0.65
5	0.19	1.00	1.00	1.00	1.00	0.70	-	0.85
6	-0.25	-0.20	-0.27	-0.31	-0.54	-0.65	0.27	0.45
7	-	0.23	0.30	0.23	0.38	-	-1.00	-1.00
8	-0.85	-0.23	0.30	0.27	0.31	-0.30	-0.33	-1.00
Bay Number 9	-	0.20	0.27	0.15	0.38	-	0.40	-0.70

Specimen SPII-2

Frequency, Hz	74	77	82	110	112	126
Bay Number 1	-	-	-	-	0.15T	-
2	-	-	-0.57	-1.00	-1.00	0.86
3	-	-	-	-	-	-
4	-	-	-0.57	-0.19	-	-
5	1.00	1.00	1.00	0.27	0.35	1.00
6	-	-	-0.71	-0.27	-	-
7	-	-	-	-	-	-
8	-	0.20	-0.74	-0.27	-	-0.37
Bay Number 9	-	-	-	-	-	-

Note: Measurements taken at center of each panel bay.

*90° Phase shift to reference.

TABLE 20

NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION

$\bar{\varepsilon}$ = NORMALIZING STRAIN, μ in/in

NINE BAY MACHINED PANEL SPECIMEN

(See Table 18 and Figure 7)

Strain Gage	Frequency, Hz/Speaker Phase Condition					
	88/A	94/A	123/A	148/A	170/A	188/A
X1	-0.79	-0.80	0.09	0.76	0.00	-0.40
X2	0.48	0.40	-0.09	0.00	0.00	0.32
X3	-0.79	-0.80	0.09	0.51	0.00	-0.40
X4	-1.00	-1.00	-0.86	-0.51	-0.61	-1.00
X5	0.79	0.80	0.86	0.51	0.72	1.00
X6	0.31	0.36	0.57	0.25	0.40	0.00
X7	0.79	-0.80	-0.86	-0.51	1.00	-1.00
X8	0.00	-0.60	0.57	-0.25	-0.40	-0.40
X9	-0.63	0.50	-0.57	0.25	0.28	0.28
X10	-0.79	-0.60	1.00	-0.51	0.00	-0.61
Y1	-0.48	-0.50	-0.57	-1.00	0.80	-0.61
Y2	0.22	0.10	0.29	0.51	-0.40	0.61
Y3	0.16	0.30	0.46	0.25	0.61	0.20
Y4	0.00	0.00	0.29	-0.25	0.40	-0.20
Y5	0.00	-0.10	0.00	-0.25	0.00	-0.20
Y6	-0.16	-0.40	-0.43	0.25	-0.61	0.00
Y7	0.00	-0.10	0.00	1.00	-0.21	0.00
Y8	0.00	0.10	0.00	-0.51	0.00	0.00
$\bar{\varepsilon}$	132	208	146	83	104	104

TABLE 21

NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION
$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in
NINE BAY PANEL SPECIMEN SPII-1

(See Table 18 and Figure 8)

Strain Gage	Frequency, Hz/Speaker Phase Condition					
	90/A	97/A	112/B	134/B	144/B	168/B
X1	0.14	0.16	0.00	-0.51	0.84	0.79
X2	0.12	-0.16	-0.17	-0.35	0.66	0.33
X3	-0.24	-0.37	-0.34	0.35	-1.00	-1.00
X4	-0.26	-0.95	-0.86	-0.76	-0.42	-1.00
X5	0.22	0.95	0.74	0.76	0.00	0.67
X6	-0.38	-1.00	-1.00	-1.00	-0.34	-0.92
X7	-0.76	-0.39	-0.43	-0.60	0.00	-0.46
X8	0.28	-0.47	-0.17	-0.25	0.00	-0.33
X9	0.86	-0.37	0.17	0.35	0.00	0.33
Y1	0.34	0.27	0.00	0.00	-0.42	0.21
Y2	0.65	-0.40	0.20	0.00	-0.58	0.46
Y3	-1.00	0.63	-0.34	-0.25	0.76	-0.40
Y4	-0.17	-0.68	-0.83	-0.60	0.34	-0.52
Y5	0.12	0.58	0.46	0.40	0.00	0.46
Y6	-0.09	-0.53	-0.66	-0.40	0.00	-0.33
Y7	-0.14	0.00	-0.34	-0.35	-0.58	0.67
Y8	0.14	0.00	0.34	-0.25	0.42	-0.46
Y9	0.14	0.00	0.17	-0.25	0.42	-0.46
$\bar{\epsilon}$	242	158	125	83	50	63

TABLE 22

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\bar{\epsilon}$ = NORMALIZING STRAIN, μ in/in
NINE BAY PANEL SPECIMEN SPII-2
(See Table 18 and Figure 9)

Strain Gage	Frequency, Hz/Speaker Phase Condition							
	74/A	77/B	77/C	81/D	82/A	110/A	112/D	126/B
X1	0.00	0.00	0.00	0.00	-0.25	0.50	0.00	0.00
X2	-0.50	-0.52	-0.50	0.00	-0.39	0.00	0.00	0.00
X3	-1.00	-0.76	-0.79	-0.72	-0.75	-0.69	0.00	-0.46
X4	0.50	0.39	0.50	0.72T	0.45	0.40	0.64	0.46
X5	1.00	1.00	1.00	0.72	1.00	1.00	1.00	0.46
X6	0.50	0.52	0.50	0.72T	0.50	0.48	0.64	0.33
X7	-1.00	-1.00	-0.79	-1.00	-1.00	-0.60	-0.52	-0.33
X8	0.57	-0.64	-0.50	0.00	-0.39	0.00	0.00	0.00
X9	0.00	0.00	0.00	0.00	-0.42	-0.50	-0.52	0.00
Y1	0.00	0.00	0.00	0.00	-0.39	-0.36	-0.52	1.00
Y2	0.00	0.00	0.00	0.00	0.25	0.36	0.52	-0.86
Y3	-0.72	-0.76	-0.60	0.00	-0.60	0.00	0.64	0.46
Y4	0.50	0.00	0.50	0.00	0.35	0.50	0.64	-0.67
Y5	0.50	0.76	0.60	0.72	0.50	0.50	0.64	0.46
Y6	0.36	0.00	0.40	0.00	0.20	-0.50	-0.64	0.67
Y7	-1.00	-0.76	-0.60	0.00	-0.55	0.50	-0.64	-0.67
Y8	0.00	0.00	-0.50	0.00	0.20	0.50	0.64	0.33
Y9	0.00	0.00	-0.69	0.00	-0.25	-0.69	-0.76	-0.46
$\bar{\epsilon}$	58	33	42	29	84	42	33	63

TABLE 23

DAMPING RATIOS (PERCENT OF CRITICAL DAMPING)
ONE-DIMENSIONAL PANELS

Specimen	Number of Bays	Frequency Hz	Strain Gage No.	Damping Ratio (percent)
SPI-1	5	82	X10	1.1
SPI-1	5	119	X11	1.3
SPI-1	5	126	X10	1.3
SPI-1	3	108	X5/X11	3.0/1.6
SPI-1	3	127	X11	2.0
SPI-2-1	5	88	X8	1.6
SPI-2-1	5	103	X5	2.7
SPI-2-1	5	120	X5	2.0
SPI-2-1	3	91	X8	3.0
SPI-2-1D	5	88	X5	1.5
SPI-2-1D	5	111	X8	2.0
SPI-2-2	5	57	X8	2.0
SPI-2-2	5	61	X8	1.5
SPI-2-2	3	51	X8	2.7
SPI-2-2	3	61	X8	1.5
SPI-2-1D	5	68	X8	1.5
SPI-3-1	5	80	X5	1.0
SPI-3-1	5	88	X5	2.9
SPI-3-1	5	107	X8	2.0
SPI-3-1	5	117	X5	1.0
SPI-3-1	3	101	X8	2.0
SPI-3-2	5	62	X11	1.8
SPI-3-2	3	68	X8	1.6
SPI-3-2D	5	74	X8	1.6
SPI-3-2D	3	71	X8	1.5

APPENDIX A

STIFFNESS AND CONSISTENT MASS MATRIX FOR A THIN-WALLED OPEN-SECTION BEAM

The stiffness and consistent mass matrices presented here are in the form of a composite array with logic numbers (α_x, α_y) defining terms relating to the orientation of the beam element. Subscripts 1 and 2 in the loading and displacement vectors refer to ends 1 and 2 on the element. End 2 is always in the positive direction of the element axis from end 1. Subscripts x and y in the expressions in the matrices refer to the x-axis and the y-axis, respectively. The cross-section nomenclature and coordinate directions are defined in figures 3 and 4 of reference 1.

For stiffener elements conforming to the edge rotations of the plate element described in Appendix B, the loading and displacement coordinates at station i of the element are defined as

$$\{\bar{P}\}_i = \begin{Bmatrix} P \\ M_x \\ M_y \\ M_{xy} \end{Bmatrix}_i = \begin{Bmatrix} \text{shear in the z direction} \\ \text{bending moment about the x-axis} \\ \text{bending moment about the y-axis} \\ \text{twisting moment} \end{Bmatrix}_i$$

$$\{\bar{d}\}_i = \begin{Bmatrix} d \\ \theta_x \\ \theta_y \\ \theta_{xy} \end{Bmatrix}_i = \begin{Bmatrix} \text{displacement in the z direction} \\ \text{rotation about the x-axis} \\ \text{rotation about the y-axis} \\ \text{twist} \end{Bmatrix}_i$$

The composite beam stiffness matrix has the form

$$\{\bar{P}\}_1 = [K_{11}]\{\bar{d}\}_1 + [K_{12}]\{\bar{d}\}_2$$

$$\{\bar{P}\}_2 = [K_{12}]^T\{\bar{d}\}_1 + [K_{22}]\{\bar{d}\}_2$$

where, for ribs parallel to the x-axis ($\alpha_x=1;\ \alpha_y=0$) and for ribs parallel to the y-axis ($\alpha_x=0;\ \alpha_y=1$)

$$[K_{ij}] = \alpha_x [K_{ij}]_x + \alpha_y [K_{ij}]_y$$

$$[K_{11}]_x = \begin{bmatrix} 12\beta_{yy} & -12R_y & -6\beta_{yy}L_x & -6r_yL_x \\ & 12\tau_1 & 6R_yL_x & 6\tau_2 \\ & & 4\beta_{yy}L_x^2 & 4r_yL^2 \\ \text{(symmetric)} & & & 4\gamma_3 \end{bmatrix}$$

$$[K_{12}]_x = \begin{bmatrix} -12\beta_{yy} & 12R_y & -6\beta_{yy}L_x & -6r_yL \\ 12R_y & -12\tau_1 & 6R_yL_x & 6\tau_2 \\ 6\beta_{yy}L_x & -6R_yL_x & 2\beta_{yy}L_x^2 & 2r_yL_x^2 \\ 6r_yL_x & -6\tau_2 & 2r_yL^2 & 2\gamma_4 \end{bmatrix}$$

$$[K_{22}]_x = \begin{bmatrix} 12\beta_{yy} & -12R_y & 6\beta_{yy}L_x & 6r_yL_x \\ & 12\tau_1 & -6R_yL_x & -6\tau_2 \\ & & 4\beta_{yy}L_x^2 & 4r_yL^2 \\ \text{(symmetric)} & & & 4\gamma_3 \end{bmatrix}$$

$$[K_{11}]_y = \begin{bmatrix} 12\beta_{xx} & 6\beta_{xx}L_y & 12R_x & 6r_xL_y \\ & 4\beta_{xx}L_y^2 & 6R_xL_y & 4r_xL_y^2 \\ & & 12\tau_1 & -6\tau_2 \\ \text{(symmetric)} & & & 4\gamma_3 \end{bmatrix}$$

$$[K_{12}]_y = \begin{bmatrix} -12\beta_{xx} & 6\beta_{xx}L_y & -12R_x & 6r_xL_y \\ -6\beta_{xx}L_y & 2\beta_{xx}L_y^2 & -6R_xL_y & 2r_xL_y^2 \\ -12R_x & 6R_xL_y & -12\tau_1 & -6\tau_2 \\ -6r_xL_y & 2r_xL^2 & 6\tau_2 & 2\gamma_4 \end{bmatrix}$$

$$[K_{22}]_y = \begin{bmatrix} 12\beta_{xx} & -6\beta_{xx}L_y & 12R_x & -6r_xL_y \\ & 4\beta_{xx}L_y^2 & -6R_xL & 4r_xL_y^2 \\ & & 12\tau_1 & 6\tau_{2y} \\ \text{(symmetric)} & & & 4\gamma_3 \end{bmatrix}$$

$$\beta_{ij} = EI_{ij}/L^3 \qquad R_x = S_x\beta_{xx} - S_z\beta_{xz} - r_x$$

$$r_i = ER_{ei}/L^3 \qquad R_y = S_y\beta_{yy} - S_z\beta_{yz} + r_y$$

$$\gamma_1 = E\Gamma/L^3 + GJ/10L \qquad \gamma_3 = E\Gamma/L + GJL/30$$

$$\gamma_2 = E\Gamma/L^2 + GJ/60 \qquad \gamma_4 = E\Gamma/L - GJL/60$$

for ribs parallel to the x-axis

$$\tau_1 = \gamma_1 + S_z^2\beta_{zz} - 2S_yS_z\beta_{yz} + S_y^2\beta_{yy} - 2(S_zr_z - S_yr_y)$$

$$\tau_2 = \gamma_2 - (S_zr_z - S_yr_y)L$$

for ribs parallel to the y-axis

$$\tau_1 = \gamma_1 + S_z^2\beta_{zz} - 2S_xS_z\beta_{xz} + S_x^2\beta_{xx} - 2(S_xr_x - S_zr_z)$$

$$\tau_2 = \gamma_2 - (S_xr_x - S_zr_z)L$$

The composite beam mass matrix has the form

$$\{\overline{P}\}_1 = [M_{11}]\{\ddot{\overline{d}}\} + [M_{12}]\{\ddot{\overline{d}}\}_2$$

$$\{\bar{P}\}_2 = [M_{12}]^T\{\ddot{d}\}_1 + [M_{22}]\{\ddot{d}\}_2$$

where $[M_{ij}] = \alpha_x[K_{ij}]_x + \alpha_y[K_{ij}]_y$

$$[M_{11}]_x = M\begin{bmatrix} 13/35 & 13e_y/35 & -11L_x/210 & 0 \\ & 13L_x^2I_p/35 & -11e_yL_x/210 & 11L_x^3I_p^*/210 \\ & & L_x^2/105 & 0 \\ \text{(symmetric)} & & & L_x^4I_p^*/105 \end{bmatrix}$$

$$[M_{12}]_x = M\begin{bmatrix} 9/70 & 9e_y/70 & 13L_x/420 & 0 \\ 9e_y/70 & 9L_x^2I_p/70 & 13e_yL_x/420 & -13L_x^3I_p^*/420 \\ -13L_x/420 & -13e_yL_x/420 & -L_x^2/140 & 0 \\ 0 & -13L_x^3I_p^*/420 & 0 & -L_x^4I_p^*/140 \end{bmatrix}$$

$$[M_{22}]_x = M\begin{bmatrix} 13/35 & 13e_y/35 & 11L_x/210 & 0 \\ & 13L_x^2I_p/35 & 11e_yL_x/210 & -11L_x^3I_p^*/210 \\ & & L_x^2/105 & 0 \\ \text{(symmetric)} & & & L_x^4I_p^*/105 \end{bmatrix}$$

$$[M_{11}]_y = M\begin{bmatrix} 13/35 & 11L_y/210 & -13e_x/35 & 0 \\ & L_y^2/105 & -11e_xL_y/210 & 0 \\ & & 13L_y^2I_p/35 & -11L_y^3I_p^*/210 \\ \text{(symmetric)} & & & L_y^4I_p^*/105 \end{bmatrix}$$

$$[M_{12}]_y = M \begin{bmatrix} 9/70 & -13L_y/420 & -9e_x/70 & 0 \\ 13L_y/420 & -L_y^2/140 & -13e_xL_y/420 & 0 \\ -9e_x/70 & 13e_xL_y/420 & 9L_y^2I_p/70 & 13L_y^3I_p^*/420 \\ 0 & 0 & -13L_y^3I_p^*/420 & -L_y^4I_p^*/140 \end{bmatrix}$$

$$[M_{22}]_y = M \begin{bmatrix} 13/35 & -11L_y/210 & -13e_x/35 & 0 \\ & L_y^2/105 & 11e_xL_y/210 & 0 \\ & & 13L_y^2I_p/35 & 11L_y^3I_p^*/210 \\ \text{(symmetric)} & & & L_y^4I_p^*/105 \end{bmatrix}$$

For ribs parallel to the x-axis

$$M = \rho A_xL_x \qquad e_y = C_y - S_y \qquad e_z = C_z - S_z$$

$$r^2 = (e_y^2 + e_z^2)/L_x^2$$

$$I_p^* = (I_{yy} + I_{zz})/(A_xL_x^2)$$

$$I_p = r^2 + I_p^*$$

and for ribs parallel to the y-axis

$$M = \rho A_yL_y \qquad e_x = C_x - S_x \qquad e_z = C_z - S_z$$

$$r^2 = (e_x^2 + e_z^2)/L_y^2$$

$$I_p^* = (I_{xx} + I_{zz})/(A_yL_y^2)$$

$$I_p = r^2 + I_p^*$$

APPENDIX B

STIFFNESS AND CONSISTENT MASS MATRIX FOR INCLUDING THE FUNDAMENTAL INTERIOR MODE FOR A RECTANGULAR PLATE BENDING ELEMENT

The stiffness and consistent mass matrix presented here are based upon equations (26) and (27) as described in the main text. The basic stiffness matrix is a sixteen-degree-of-freedom element as referenced in the main text, and the modifying interior mode functions are taken as the eigenfunctions for a clamped-clamped beam. The positive coordinate directions for this element are given in figure 9.

At each corner of the element, the loading and displacement coordinates for the i^{th} corner are

$$\{\bar{P}\}_i = \begin{Bmatrix} P \\ M_x \\ M_y \\ M_{xy} \end{Bmatrix}_i = \begin{Bmatrix} \text{shear in the z direction} \\ \text{bending moment about x-axis} \\ \text{bending moment about y-axis} \\ \text{twisting moment} \end{Bmatrix}_i$$

$$\{\bar{d}\}_i = \begin{Bmatrix} d \\ \theta_x \\ \theta_y \\ \theta_{xy} \end{Bmatrix}_i = \begin{Bmatrix} \text{displacement in the z direction} \\ \text{rotation about x-axis} \\ \text{rotation about y-axis} \\ \text{twist} \end{Bmatrix}_i \qquad (i=1,2,3,4)$$

From equation (26), the stiffness matrix has the form

$$\begin{Bmatrix} \bar{P}_i \\ \hline P_o \end{Bmatrix} = \frac{D}{ab} \left[\begin{array}{c|c} [K_{ij}] + [\bar{K}_{ij}] & K_{ci} \\ \hline K_{ci}^T & k \end{array} \right] \begin{Bmatrix} \bar{d}_i \\ \hline W_o \end{Bmatrix} \qquad D = \frac{Eh^3}{12(1-\nu^2)}$$

where P_o is the generalized force in the W_o direction. The matrix $[\bar{K}_{ij}]$ has the form

$$[\bar{K}_{ij}] = \begin{bmatrix} \bar{K}_{11} & \bar{K}_{12} & \bar{K}_{13} & \bar{K}_{14} \\ & \bar{K}_{22} & \bar{K}_{23} & \bar{K}_{24} \\ & & \bar{K}_{33} & \bar{K}_{34} \\ \text{(symmetric)} & & & \bar{K}_{44} \end{bmatrix}$$

where

$$[\bar{K}_{11}] = \begin{bmatrix} k/16 & kb/64 & -ka/64 & 8k_1ab \\ & kb^2/256 & -kab/256 & 2k_1ab^2 \\ & & ka^2/256 & -2k_1a^2b \\ \text{(symmetric)} & & & k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{12}] = \begin{bmatrix} k/16 & kb/64 & ka/64 & -8k_1ab \\ kb/64 & kb^2/256 & kab/256 & -2k_1ab^2 \\ -ka/64 & -kab/256 & -ka^2/256 & 2k_1a^2b \\ 8k_1ab & 2k_1ab^2 & 2k_1a^2b & -k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{13}] = \begin{bmatrix} k/16 & -kb/64 & -ka/64 & -8k_1ab \\ kb/64 & -kb^2/256 & -kab/256 & -2k_1ab^2 \\ -ka/64 & kab/256 & ka^2/256 & 2k_1a^2b \\ 8k_1ab & -2k_1ab^2 & -2k_1a^2b & -k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{14}] = \begin{bmatrix} k/16 & -kb/64 & ka/64 & 8k_1ab \\ kb/64 & -kb^2/256 & kab/256 & 2k_1ab^2 \\ -ka/64 & kab/256 & -ka^2/256 & -2k_1a^2b \\ 8k_1ab & -2k_1ab^2 & 2k_1a^2b & k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{22}] = \begin{bmatrix} k/16 & kb/64 & ka/64 & -8k_1ab \\ & kb^2/256 & kab/256 & -2k_1ab^2 \\ & & ka^2/256 & -2k_1a^2b \\ \text{(symmetric)} & & & k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{23}] = \begin{bmatrix} k/16 & -kb/64 & -ka/64 & -8k_1ab \\ kb/64 & -kb^2/256 & -kab/256 & -2k_1ab^2 \\ ka/64 & -kab/256 & -ka^2/256 & -2k_1a^2b \\ -8k_1ab & 2k_1ab^2 & 2k_1a^2b & k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{24}] = \begin{bmatrix} k/16 & -kb/64 & ka/64 & 8k_1ab \\ kb/64 & -kb^2/256 & kab/256 & 2k_1a^2b \\ ka/64 & -kab/256 & ka^2/256 & 2k_1ab^2 \\ -8k_1ab & 2k_1ab^2 & -2k_1a^2b & -k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{33}] = \begin{bmatrix} k/16 & -kb/64 & -ka/64 & -8k_1ab \\ & kb^2/256 & kab/256 & 2k_1ab^2 \\ & & ka^2/256 & 2k_1a^2b \\ \text{(symmetric)} & & & k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{34}] = \begin{bmatrix} k/16 & -kb/64 & ka/64 & 8k_1ab \\ -kb/64 & kb^2/256 & -kab/256 & -2k_1ab^2 \\ -ka/64 & kab/256 & -ka^2/256 & -2k_1a^2b \\ -8k_1ab & 2k_1ab^2 & -2k_1a^2b & -k_2a^2b^2 \end{bmatrix}$$

$$[\bar{K}_{44}] = \begin{bmatrix} k/16 & -kb/64 & ka/64 & 8k_1ab \\ & kb^2/256 & -kab/256 & -2k_1ab^2 \\ & & ka^2/256 & 2k_1a^2b \\ \text{(symmetric)} & & & k_2a^2b^2 \end{bmatrix}$$

$$k = \frac{C_o^2}{C_{11}^2}\left[(b/a)^2 + (a/b)^2 + 2C_{11}^2(C_{31} - 2)^2\right]$$

$$k_1 = k/2048 - C_o C_{11}^2 \qquad k_2 = k/4096 - C_o C_{11}^2$$

$$C_o = 1/(1.58815)^2 \qquad \alpha_1 = 0.98250222$$

$$C_{11} = \alpha_1/(\beta_1 L) \qquad \beta_1 L = 4.7300408$$

$$C_{31} = \alpha_1 \beta_1 L$$

The coupling stiffness matrix, $\{K_{ci}\}$, has the form

$$\{K_{ci}\} = \left\{\begin{array}{c} K_{c1} \\ \hline K_{c2} \\ \hline K_{c3} \\ \hline K_{c4} \end{array}\right\}$$

where

$$\{K_{c1}\} = \begin{Bmatrix} -k/4 \\ -kb/16 \\ ka/16 \\ -32k_1ab \end{Bmatrix} \quad ; \quad \{K_{c2}\} = \begin{Bmatrix} -k/4 \\ -kb/16 \\ -ka/16 \\ 32k_1ab \end{Bmatrix}$$

$$\{K_{c3}\} = \begin{Bmatrix} -k/4 \\ kb/16 \\ ka/16 \\ 32k_1ab \end{Bmatrix} \quad ; \quad \{K_{c4}\} = \begin{Bmatrix} -k/4 \\ kb/16 \\ -ka/16 \\ -32k_1ab \end{Bmatrix}$$

From equation (27), the consistent mass matrix has the form

$$\left\{\begin{array}{c} \overline{P}_i \\ \hline \overline{P}_o \end{array}\right\} = \overline{\rho}hab \left[\begin{array}{c|c} [M_{ij}] + [\overline{M}_{ij}] & M_{ci} \\ \hline M_{ci}^T & C_o^2 \end{array}\right] \left\{\begin{array}{c} \ddot{d}_j \\ \hline \ddot{\overline{W}}_o \end{array}\right\}$$

The matrix $[\bar{M}_{ij}]$ has the form

$$[\bar{M}_{ij}] = \begin{bmatrix} \bar{M}_{11} & \bar{M}_{12} & \bar{M}_{13} & \bar{M}_{14} \\ & \bar{M}_{22} & \bar{M}_{23} & \bar{M}_{24} \\ & & \bar{M}_{33} & \bar{M}_{34} \\ \text{symmetric} & & & \bar{M}_{44} \end{bmatrix}$$

where

$$[\bar{M}_{11}] = \begin{bmatrix} r_1 & r_2 b & -r_2 a & r_4 ab \\ & r_3 b^2 & -r_3 ab & r_5 ab^2 \\ & & r_3 a^2 & -r_5 a^2 b \\ \text{(symmetric)} & & & r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{12}] = \begin{bmatrix} r_1 & r_2 b & r_2 a & -r_4 ab \\ r_2 b & r_3 b^2 & r_3 ab & -r_5 ab^3 \\ -r_2 a & -r_3 ab & -r_3 a^2 & r_5 a^2 b \\ r_4 ab & r_5 ab^2 & r_5 a^2 b & -r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{13}] = \begin{bmatrix} r_1 & -r_2 b & -r_2 a & -r_4 ab \\ r_2 b & -r_3 b^2 & -r_3 ab & -r_5 ab^2 \\ -r_2 a & r_3 ab & r_3 a^2 & r_5 a^2 b \\ r_4 ab & -r_5 ab^2 & -r_5 a^2 b & -r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{14}] = \begin{bmatrix} r_1 & -r_2 b & r_2 a & r_4 ab \\ r_2 b & -r_3 b^2 & r_3 ab & r_5 ab^2 \\ -r_2 a & r_3 ab & -r_3 a^2 & -r_5 a^2 b \\ r_4 ab & -r_5 ab^2 & r_5 a^2 b & r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{22}] = \begin{bmatrix} r_1 & r_2 b & r_2 a & -r_4 ab \\ & r_3 b^2 & r_3 ab & -r_5 ab^2 \\ & & r_3 a^2 & -r_5 a^2 b \\ \text{(symmetric)} & & & r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{23}] = \begin{bmatrix} r_1 & -r_2 b & -r_2 a & -r_4 ab \\ r_2 b & -r_3 b^2 & -r_3 ab & -r_5 ab^2 \\ r_2 a & -r_3 ab & -r_3 a^2 & -r_5 a^2 b \\ -r_4 ab & r_5 ab^2 & r_5 a^2 b & r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{24}] = \begin{bmatrix} r_1 & -r_2 b & r_2 a & r_4 ab \\ r_2 b & -r_3 b^2 & r_3 ab & r_5 ab^2 \\ r_2 a & -r_3 ab & r_3 a^2 & r_5 a^2 b \\ -r_4 ab & r_5 ab^2 & -r_5 a^2 b & -r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{33}] = \begin{bmatrix} r_1 & -r_2 b & -r_2 a & -r_4 ab \\ & r_3 b^2 & r_3 ab & r_5 ab^2 \\ & & r_3 a^2 & r_5 a^2 b \\ \text{(symmetric)} & & & r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{34}] = \begin{bmatrix} r_1 & -r_2 b & r_2 a & r_4 ab \\ -r_2 b & r_3 b^2 & -r_3 ab & -r_5 ab^2 \\ -r_2 a & r_3 ab & -r_3 a^2 & -r_5 a^2 b \\ -r_4 ab & r_5 ab^2 & -r_5 a^2 b & -r_6 a^2 b^2 \end{bmatrix}$$

$$[\bar{M}_{44}] = \begin{bmatrix} r_1 & -r_2 b & r_2 a & r_4 ab \\ & r_3 b^2 & -r_3 ab & -r_5 ab^2 \\ & & r_3 a^2 & r_5 a^2 b \\ \text{(symmetric)} & & & r_6 a^2 b^2 \end{bmatrix}$$

$$\begin{aligned} r_1 &= C_o\left(C_o/16 - 2C_{11}^2\right) \\ r_2 &= C_o\left(C_o/64 - C_{11}(C_{21} + C_{11}/4)\right) \\ r_3 &= C_o\left(C_o/128 - C_{11}C_{21}\right)/2 \\ r_4 &= C_o\left(C_o/256 - C_{21}^2 - C_{11}^2/16\right) \\ r_5 &= C_o\left(C_o/256 - C_{21}^2 - C_{21}C_{11}/4\right)/4 \\ r_6 &= C_o\left(C_o/512 - C_{21}^2\right)/8 \\ C_{21} &= C_{11}/C_{31} \end{aligned}$$

The coupling matrix, $\{M_{ci}\}$, has the form

$$\{M_{ci}\} = \left\{ \begin{array}{c} M_{c1} \\ \hdashline M_{c2} \\ \hdashline M_{c3} \\ \hdashline M_{c4} \end{array} \right\}$$

where

$$\{M_{c1}\} = \begin{Bmatrix} -r_7 \\ -r_8 b \\ r_8 a \\ -r_9 ab \end{Bmatrix} \qquad \{M_{c2}\} = \begin{Bmatrix} -r_7 \\ -r_8 b \\ -r_8 a \\ r_9 ab \end{Bmatrix}$$

$$\{M_{c3}\} = \begin{Bmatrix} -r_7 \\ r_8 b \\ r_8 a \\ r_9 ab \end{Bmatrix} \qquad \{M_{c4}\} = \begin{Bmatrix} -r_7 \\ r_8 b \\ -r_8 a \\ -r_9 ab \end{Bmatrix}$$

$$r_7 = 2C_o(C_o/16 - C_{11}^2)$$

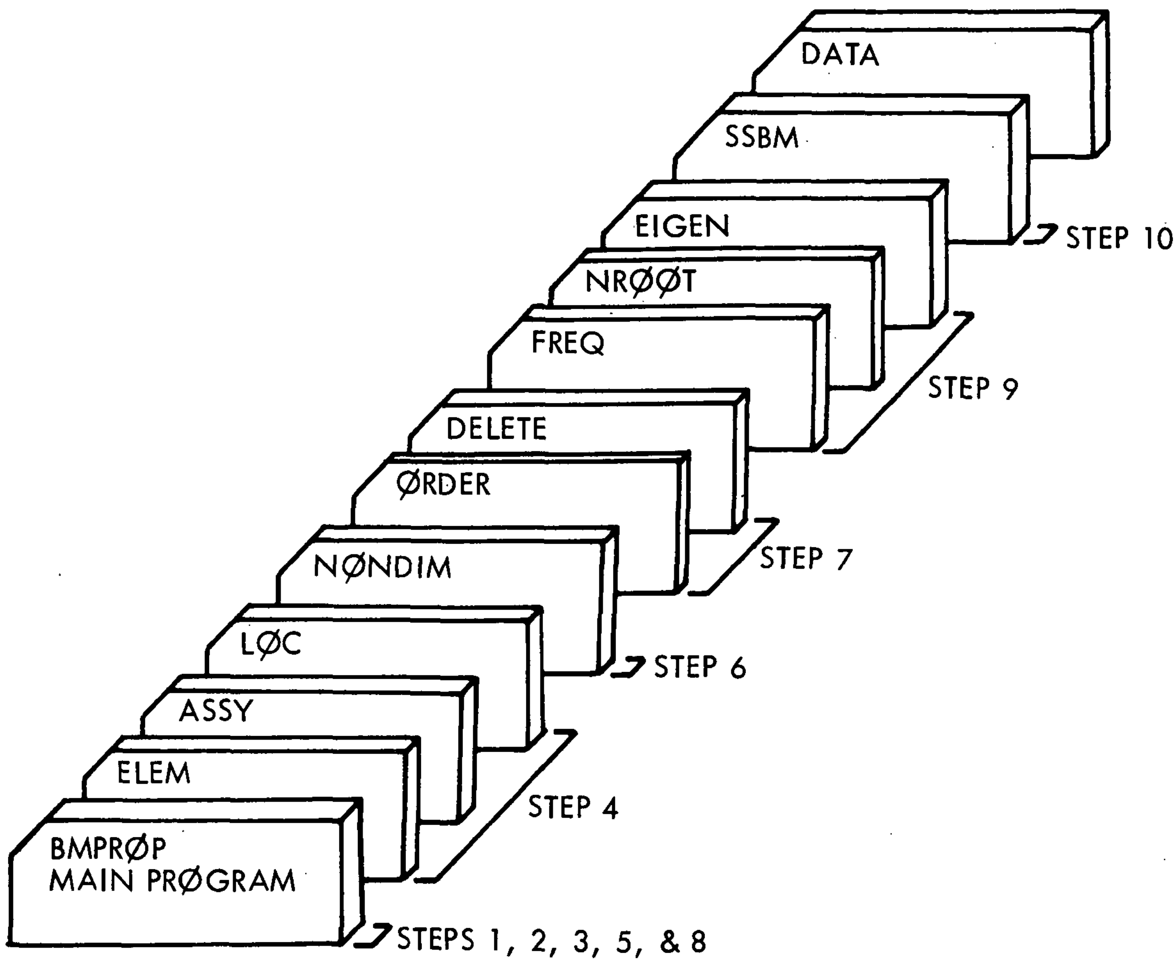
$$r_8 = 2C_o(C_o/64 - C_{11}C_{21})$$

$$r_9 = 2C_o(C_o/256 - C_{21}^2)$$

APPENDIX C

COMPUTER PROGRAM DESCRIPTIONS, FLOW CHARTS, AND CARD IMAGE LISTINGS

This appendix contains the computer program descriptions, flow charts, and listings for the one-dimensional panel and the two-dimensional panel modal analyses. The program descriptions list the purpose of the program or subprogram, the subprograms required, definition of primary variables, restrictions, accuracy (when applicable), and compiled size (octal) of the program for the NASA Langley CDC 6600 computer.



ONE-DIMENSIONAL PANEL ANALYSIS: MAIN PROGRAM AND SUBPROGRAMS IN ORDER OF APPEARANCE

PROGRAM BMPROP (MAIN)
(See Figure 1 for Flow Chart)

PURPOSE: Main program for computing natural frequencies, normal mode shapes, modal shear distribution, and modal bending moment distribution along the centerline of a one-dimensional panel array undergoing cylindrical bending (beam analogy). A fundamental clamped-clamped mode across the panel width is assumed. Elastic supports are introduced as lumped spring-mass constants and lumped masses are introduced as a support with zero stiffness. Clamped or elastic supports can be introduced at either end of the structure.

SUBPROGRAMS REQUIRED: ELEM, ASSY, LOC, NONDIM, ORDER, DELETE, FREQ, NROOT, EIGEN, SSBM

INPUT DATA: See Appendix D for description -
NCASE, NDATA, NBAY, NSUP, IOUT, IBL, IBR, NINT, BW, PR, NEL(I), EI(I), WB(I), BL(I), NCP(I), SL(I), SC(I), SR(I), RL(I), RC(I), PR(I)

VARIABLES: NDEL(N) - Constraint vector for an N degree-of-freedom system. If NDEL(J) = 0, the J^{th} coordinate is unconstrained; if NDEL(J) = 1, the J^{th} coordinate is constrained (deleted from the equations of motion).

R(N) - Consistent mass matrix - dimension $N(N + 1)/2$ for N degree-of-freedom system.

S(N) - Stiffness matrix - dimension $N(N + 1)/2$ for N degree-of-freedom system.

S1(4), S2(4), S3(4) - Dummy arrays for assembling the element stiffness in matrix S(N) and the element mass in matrix R(N).

DUM3(2293) - Dummy array for eigenvalue calculation.

RESTRICTIONS: For the declared size of the arrays
$2(\Sigma NEL(I) + 1) \leq 38$, NBAY $\leq$ 5.

SIZE: 005152_8

```
      PROGRAM BMPROP (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION BL(5),NEL(5),NDEL(38),R(741),S(741)
      DIMENSION SL(6),SC(6),SR(6),RL(6),RC(6),RR(6)
      DIMENSION S1(4),S2(4),S3(4),NCP(6)
      DIMENSION EI(5),WB(5),BLMT(5),DUM3(2293)
      COMMON R,S
      COMMON EI,WB,BLMT,BW,PR
      COMMON TL,SL,SC,SR,RL,RC,RR,NEL,NCP
      COMMON BL,S1,S2,S3,NDEL,DUM3
      IN=5
      IO=6
      ICASE=1
      READ(IN,120) NCASE
  100 READ(IN,120) NDATA,NBAY,NSUP,IOUT,IBL,IBR,NINT
      READ(IN,125) BW,PR
      READ(IN,130) (NEL(I),EI(I),WB(I),BL(I),I=1,NBAY)
      IF(NSUP) 110,110,105
  105 DO 110 I=1,NSUP
      READ(IN,130) NCP(I),SL(I),SC(I),SR(I)
      READ(IN,140) RL(I),RC(I),RR(I)
  110 CONTINUE
      WRITE(IO,145)
      WRITE(IO,150) NDATA
      WRITE(IO,155) NBAY,NSUP
      WRITE(IO,160) BW,PR
      WRITE(IO,165)
      WRITE(IO,170)
      DO 175 I=1,NBAY
      WRITE(IO,180) I,NEL(I),EI(I),WB(I),BL(I)
  175 CONTINUE
      DO 181 I=1,NSUP
      WRITE(IO,182) I,NCP(I)
      WRITE(IO,183) SL(I),SC(I),SR(I)
      WRITE(IO,184) RL(I),RC(I),RR(I)
  181 CONTINUE
      TL=0.0
      TK=0.0
      TM=0.0
      NCT=0
      DO 200 I=1,NBAY
      BLMT(I)=BL(I)/FLOAT(NEL(I))
      TL=TL+BL(I)
      NCT=NCT+NEL(I)
  200 CONTINUE
      NGP=NCT+1
      NCO=2*NGP
      NUP=NCO*(NCO+1)/2
      DO 240 IOP=1,2
      DO 210 I=1,NUP
      R(I)=0.0
  210 CONTINUE
      NUT=0
      DO 220 J=1,NBAY
      CALL ELEM(J,IOP,S1,S2,S3)
      NU=NEL(J)
      NUT=NUT+NU
      DO 220 I=1,NU
      ICN=2*(I+NUT-NU)-1
```

PROGRAM BMPROP: CARD IMAGE LISTING 1/3

```
      ICS=ICN+2
      CALL ASSY(NCO,ICN,ICS,R,S1,S2,S3,2)
  220 CONTINUE
      IF(IOP-1) 230,230,240
  230 DO 235 I=1,NUP
      S(I)=R(I)
  235 CONTINUE
  240 CONTINUE
      IF(NSUP) 250,250,245
  245 DO 250 I=1,NSUP
      J=NCP(I)
      K=J+1
      JJ=J+(J*J-J)/2
      JK=J+(K*K-K)/2
      KK=K+(K*K-K)/2
      S(JJ)=S(JJ)+SL(I)
      S(JK)=S(JK)+SC(I)
      S(KK)=S(KK)+SR(I)
      R(JJ)=R(JJ)+RL(I)/386.0
      R(JK)=R(JK)+RC(I)/386.0
      R(KK)=R(KK)+RR(I)/386.0
  250 CONTINUE
C     NONDIMENSIONALIZE STIFFNESS MATRIX
      DO 255 I=2,NCO,2
      II=I+(I*I-I)/2
      TK=TK+S(II)
      TM=TM+R(II)
  255 CONTINUE
      TL=TL/FLOAT(NCT)
      TK=TK/FLOAT(NCT)
      TM=TM/FLOAT(NCT)
      CALL NONDIM(S,NCO,TL,TK)
      CALL NONDIM(R,NCO,TL,TM)
C     APPLY CONSTRAINTS
      NDL=0
      DO 261 J=1,NCO
      NDEL(J)=0
  261 CONTINUE
      IF(IBL) 264,264,262
  262 NDEL(1)=1
      NDEL(2)=1
      DO 263 I=1,NSUP
      NCP(I)=NCP(I)-2
  263 CONTINUE
  264 IF(IBR) 270,270,265
  265 IC=NCO-1
      NDEL(IC)=1
      NDEL(NCO)=1
      CALL ORDER(S,NDEL,NGP,NDL)
      CALL ORDER(R,NDEL,NGP,NDL)
  270 NCO=NCO-NDL
      NUP=NCO*(NCO+1)/2
      IF(IOUT-1) 315,275,275
  275 WRITE(IO,280)
      WRITE(IO,285) NCO,TK,TL
      WRITE(IO,290) (S(I),I=1,NUP)
      WRITE(IO,300)
      WRITE(IO,305) NCO,TM,TL
      WRITE(IO,290) (R(I),I=1,NUP)
```

PROGRAM BMPROP: CARD IMAGE LISTING 2/3

```
C       COMPUTE EIGENVALUES AND EIGENVECTORS
  315 WRITE(IO,320) TL,TK,TM
      CALL FREQ(S,R,TL,TK,TM,NDATA,NCO)
      IF(IOUT-1) 100,100,260
  260 CALL SSBM(NCO,NBAY,NSUP,IBL,NINT,NDATA)
      ICASE=ICASE+1
      IF(NCASE-ICASE) 205,100,100
  205 CONTINUE
  120 FORMAT(I5,6I3)
  125 FORMAT(3X,2E12.5)
  130 FORMAT(I3,3E12.5)
  140 FORMAT(3X,3E12.5)
  145 FORMAT(1H1,7X,47HFREE VIBRATION OF A ONE DIMENSIONAL PANEL ARRAY)
  150 FORMAT(/,25X,9HDATA CASE,I4)
  155 FORMAT(/,4X,15HNUMBER OF BAYS=,I3,19X,19HNUMBER OF SUPPORTS=,I3)
  160 FORMAT(/,4X,12HPANEL WIDTH=,E12.5,7X,16HPOISSON'S RATIO=,E12.5)
  165 FORMAT(/,5X,3HBAY,5X,9HNUMBER OF,3X,7HBENDING,6X,10HWEIGHT PER,
     18X,3HBAY)
  170 FORMAT(4X,6HNUMBER,3X,8HELEMENTS,4X,8HRIGIDITY,5X,
     19HUNIT AREA,8X,6HLENGTH,/)
  180 FORMAT(/,5X,I3,7X,I3,5X,E12.5,1X,E12.5,3X,E12.5)
  182 FORMAT(/,4X,11HSUPPORT NO.,I3,25X,17HINPUT COORDINATE=,I3)
  183 FORMAT(4X,4HKZZ=,E12.5,2X,8HKZTHETA=,E12.5,2X,7HKTHETA=,E12.5)
  184 FORMAT(4X,4HIZZ=,E12.5,2X,8HIZTHETA=,E12.5,2X,7HITHETA=,E12.5)
  280 FORMAT(1H1,4X,16HSTIFFNESS MATRIX)
  285 FORMAT(/,5X,4HNCO=,I4,2X,3HTK=,E12.5,2X,3HTL=,E12.5,/)
  290 FORMAT(8E12.5)
  300 FORMAT(1H1,4X,11HMASS MATRIX)
  305 FORMAT(/,5X,4HNCO=,I4,2X,3HTM=,E12.5,2X,3HTL=,E12.5,/)
  310 FORMAT(6E11.4)
  320 FORMAT(3E12.5)
      END
```

PROGRAM BMPROP: CARD IMAGE LISTING 3/3

SUBROUTINE ELEM (I,IOP,S1,S2,S3)

PURPOSE: To compute the stiffness (IOP = 1) and the consistent mass matrix (IOP = 2) for a panel element in the I^{th} bay of the structure. The partitioned stiffness or mass matrix is assigned to the arrays S1,S2, S3 where S1 is the direct stiffness or mass term at end 1 of the element, S2 is the coupling term between ends 1 and 2, and S3 is the direct term at end 2 of the element.

SUBPROGRAMS REQUIRED: None

VARIABLES:

I - Panel Bay Number

IOP - Logic number: IOP = 1, stiffness matrix for element is calculated; IOP = 2, consistent mass matrix is calculated.

S1,S2,S3 - See 'Purpose' above

EI(I) - Bending rigidity of element

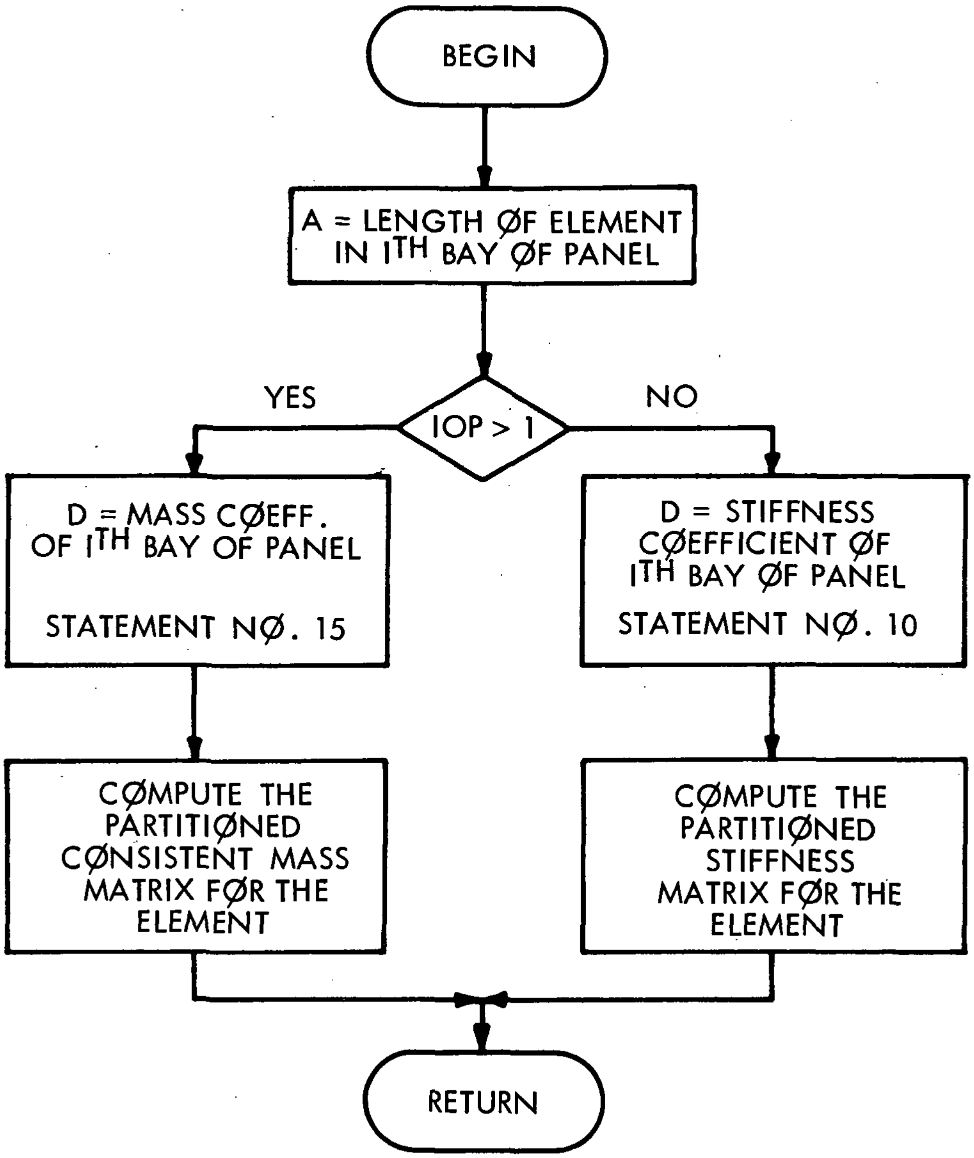
WB(I) - Weight percent length of element

BL(I) - Length of element

RESTRICTIONS: None

SIZE: 000152_8

REFERENCE: Reference 1, pp. 9 - 11.



FLOW CHART: SUBPROGRAM ELEM (I, IOP, S1, S2, S3)

```
      SUBROUTINE ELEM (I,IOP,S1,S2,S3)
      DIMENSION S1(1),S2(1),S3(1),DUM1(1482)
      DIMENSION EI(5),WB(5),BL(5)
      COMMON DUM1,EI,WB,BL,BW,PR
      A=BL(I)
      AS=A*A
      IF(IOP-1) 10,10,15
   10 D=EI(I)/(A*AS)
      S1(1)=12.0*D
      S1(2)=6.0*D*A
      S1(3)=4.0*D*AS
      S2(1)=-12.0*D
      S2(2)=-6.0*D*A
      S2(3)=6.0*D*A
      S2(4)=2.0*D*AS
      S3(1)=12.0*D
      S3(2)=-6.0*D*A
      S3(3)=4.0*D*AS
      RETURN
   15 D=WB(I)*A/386.0
      S1(1)=13.0*D/35.0
      S1(2)=11.0*D*A/210.0
      S1(3)=D*AS/105.0
      S2(1)=9.0*D/70.0
      S2(2)=13.0*D*A/420.0
      S2(3)=-13.0*D*A/420.0
      S2(4)=-D*A/140.0
      S3(1)=13.0*D/35.0
      S3(2)=-11.0*D*A/210.0
      S3(3)=D*AS/105.0
      RETURN
      END
```

SUBPROGRAM ELEM: CARD IMAGE LISTING

SUBROUTINE ASSY (N, ICN, ICS, A, E1, E2, E3, NLM)

PURPOSE: To assemble (add) the partitioned element stiffness or mass matrices (E1, E2, E3) in the appropriate location of the global stiffness or mass matrix A .

SUBPROGRAMS REQUIRED: LOC

VARIABLES:

N - Size of matrix A (See Subroutine LOC).

ICN - Initial coordinate for diagonal location of E1 in A.

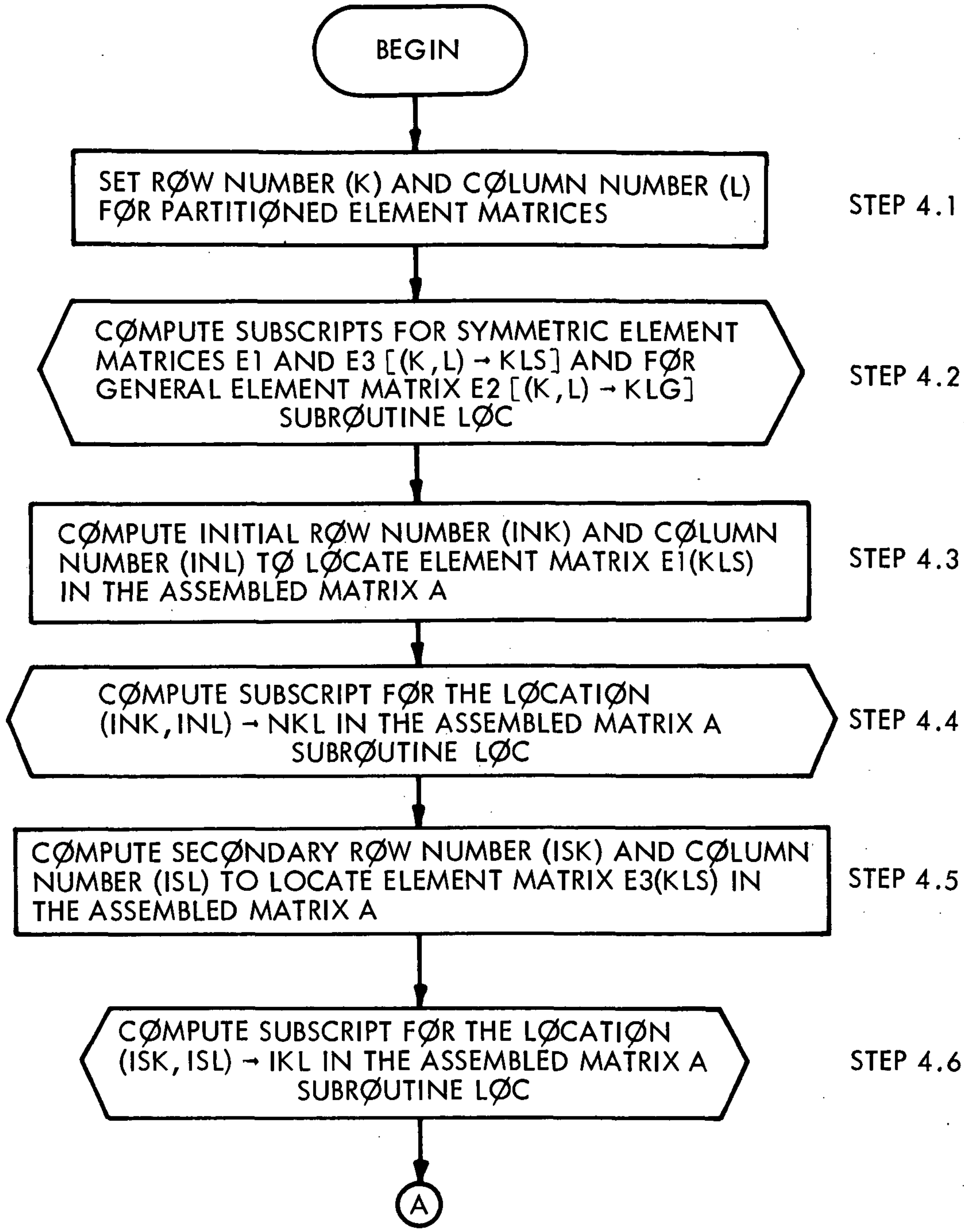
ICS - Initial coordinate for column location of E2 in A for row ICN.

NLM - The number of coordinates at each grid point for the element described by E1, E2, and E3. For the one-dimensional analysis NLM = 2.

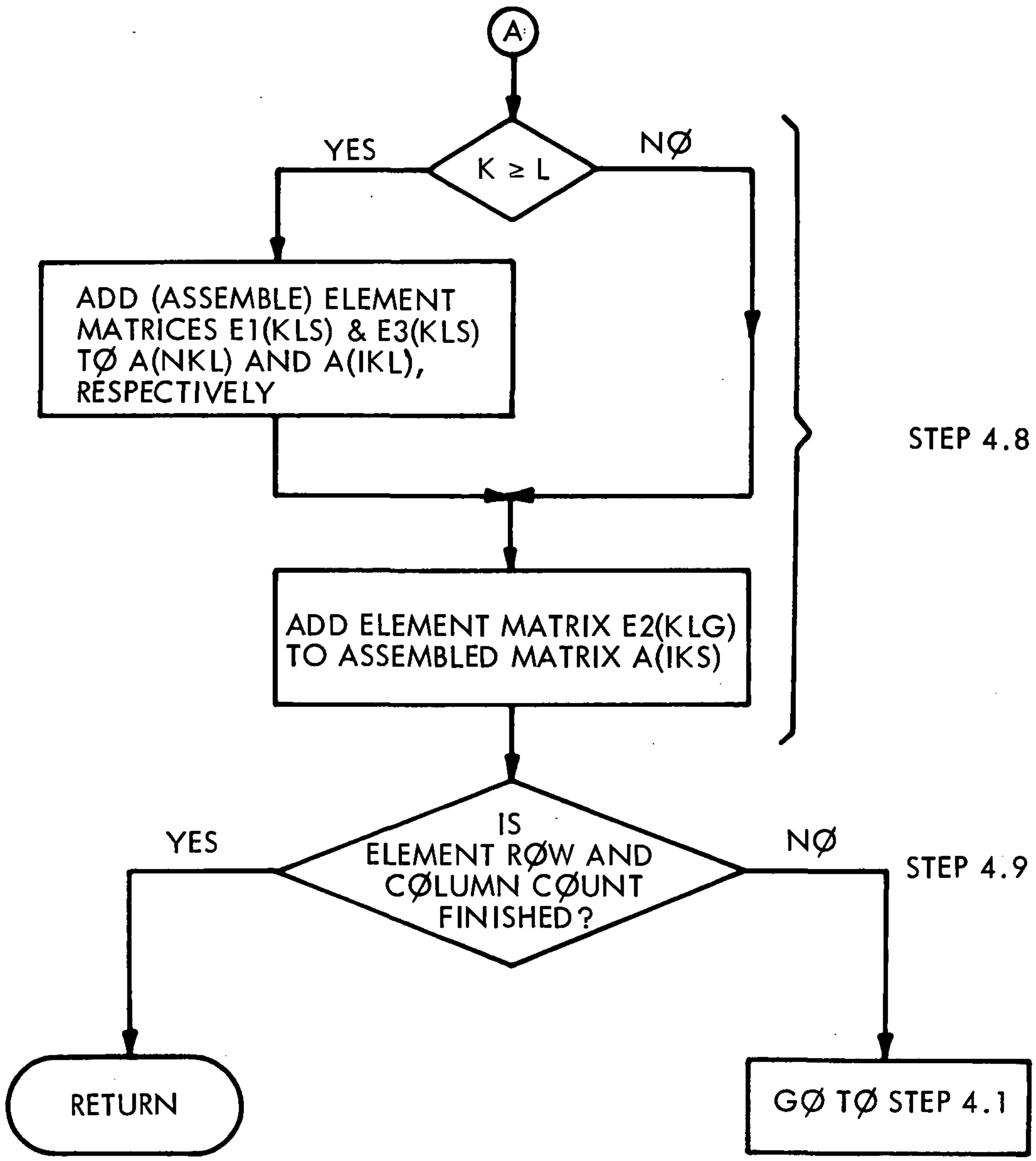
RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000143_8



FLØW CHART: SUBPRØGRAM ASSY (N, ICN, ICS, A,E1, E2, E3, NLM)



FLØW CHART: SUBPRØGRAM ASSY (N, ICN, ICS, A, E1, E2, E3, NLM)

```
      SUBROUTINE ASSY(N,ICN,ICS,A,E1,E2,E3,NLM)
      DIMENSION A(1),E1(1),E2(1),E3(1)
      DO 20 K=1,NLM
      DO 20 L=1,NLM
      CALL LOC(K,L,KLS,NLM,1)
      CALL LOC(K,L,KLG,NLM,0)
      INK=ICN+K-1
      INL=ICN+L-1
      CALL LOC(INK,INL,NKL,N,1)
      ISK=ICS+K-1
      ISL=ICS+L-1
      CALL LOC(ISK,ISL,IKL,N,1)
      CALL LOC(INK,ISL,IKS,N,1)
      IF(K-L) 15,10,10
   10 A(NKL)=A(NKL)+E1(KLS)
      A(IKL)=A(IKL)+E3(KLS)
   15 A(IKS)=A(IKS)+E2(KLG)
   20 CONTINUE
      RETURN
      END
```

SUBPROGRAM ASSY: CARD IMAGE LISTING

SUBROUTINE LOC (I,J,IR,N,MS)

PURPOSE: To calculate a single subscript, IR, for a double subscripted square array, A, of size NXN for a row-column location (I,J). MS is a logic number for calculating the subscript IR.

MS = 0, General Storage, array is assumed to be dimensioned as
A(R) R = NXN

MS = 1, Symmetric Storage, array is assumed to be dimensioned as
A(R) R = N (N + 1)/2

MS = 2, Diagonal Storage, array is assumed to be dimensioned as
A(R) R = N

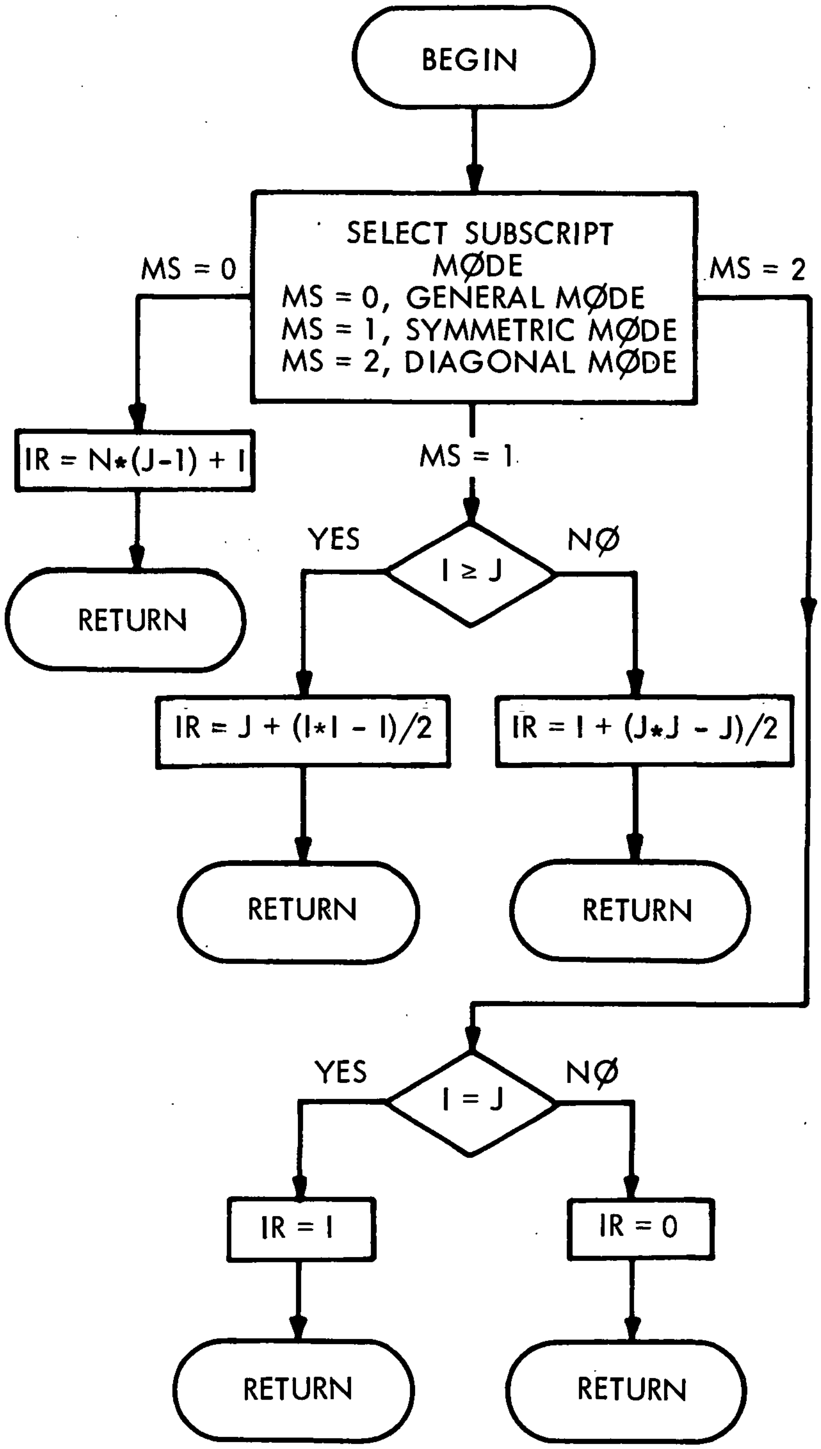
SUBPROGRAMS REQUIRED: None

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000057_8

REFERENCES: Reference 3



FLØW CHART: SUBPRØGRAM LØC(I, J, IR, N, MS)

```
      SUBROUTINE LOC(I,J,IR,N,MS)
C
C     THIS SUBROUTINE COMPRESSES A TWO DIMENSIONAL
C     ARRAY INTO A ONE DIMENSIONAL ARRAY
C     MS=0 IS FOR GENERAL STORAGE
C     MS=1 IS FOR SYMMETRIC STORAGE
C     MS=2 IS FOR DIAGONAL STORAGE
C
      IX=I
      JX=J
      IF(MS-1) 10,20,30
   10 IRX=N*(JX-1)+IX
      GO TO 36
   20 IF(IX-JX) 22,24,24
   22 IRX=IX+(JX*JX-JX)/2
      GO TO 36
   24 IRX=JX+(IX*IX-IX)/2
      GO TO 36
   30 IRX=0
      IF(IX-JX) 36,32,36
   32 IRX=IX
   36 IR=IRX
      RETURN
      END
```

SUBPROGRAM LOC: CARD IMAGE LISTING

SUBROUTINE NONDIM (A,N,TL,TIC)

PURPOSE: To nondimensionalize the free-free stiffness and mass matrix of the structure.

SUBPROGRAMS REQUIRED: LOC

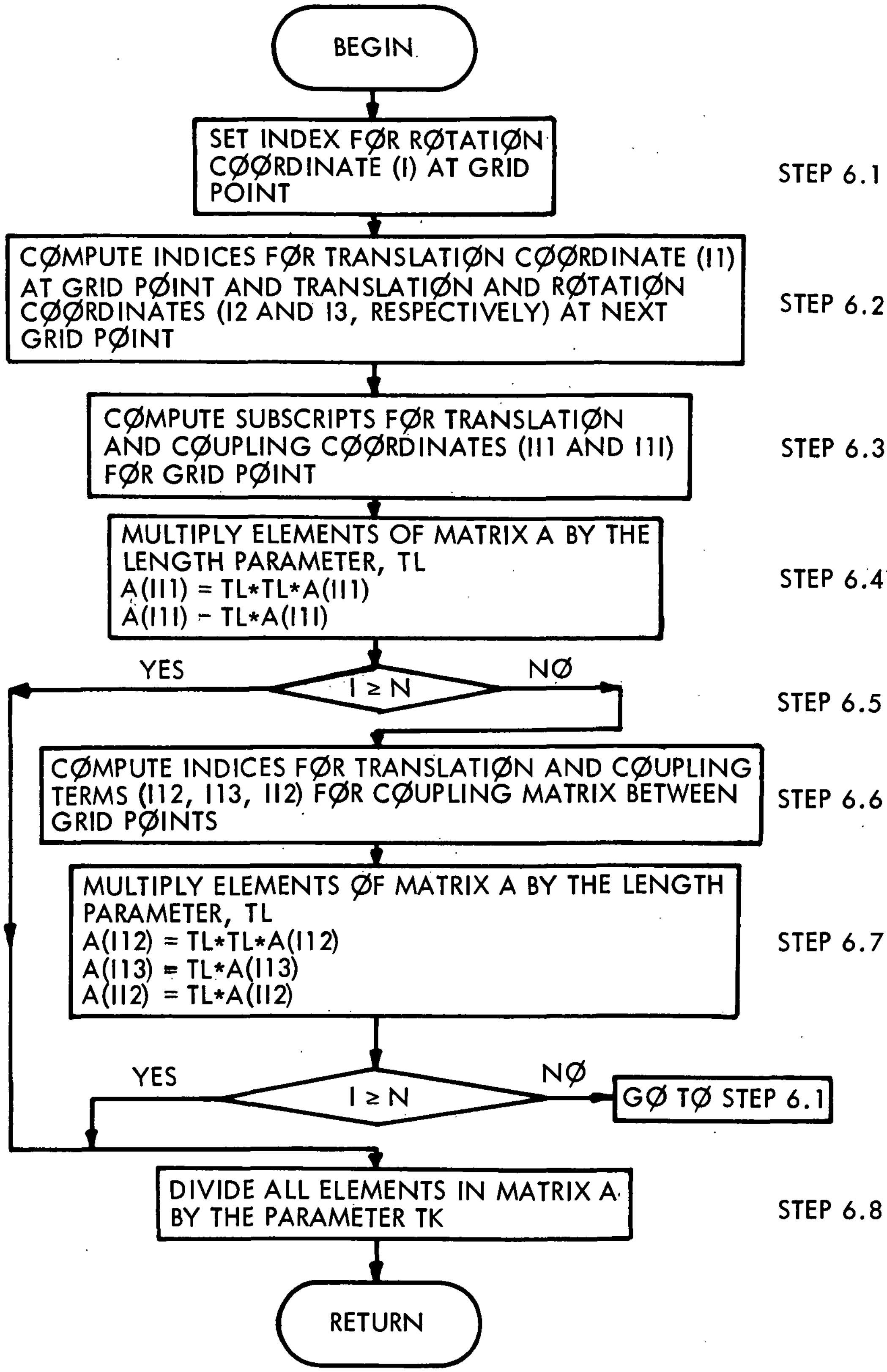
VARIABLES:

- A(N) - *Stiffness on mass matrix to be nondimensionalized*
- N - Size of array A (MS = 1 in LOC)
- TL - Arbitrary length parameter (taken as the average element length of the structural idealization)
- TK - Arbitrary stiffness parameter (taken as the average rotational stiffness of the structural idealization)

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000133_8



FLØW CHART: SUBPRØGRAM NØNDIM (A, N, TL, TK)

```
      SUBROUTINE NONDIM(A,N,TL,TK)
      DIMENSION A(1)
    1 DO 3 I=2,N,2
      I1=I-1
      I2=I+1
      I3=I+2
      II1=I1+(I1*I1-I1)/2
      I1I=I1+(I*I-I)/2
      A(II1)=TL*TL*A(II1)
      A(I1I)=TL*A(I1I)
      IF(I-N) 2,3,3
    2 I12=I1+(I2*I2-I2)/2
      I13=I1+(I3*I3-I3)/2
      II2=I+(I2*I2-I2)/2
      A(I12)=TL*TL*A(I12)
      A(I13)=TL*A(I13)
      A(II2)=TL*A(II2)
    3 CONTINUE
      DO 4 I=1,N
      DO 4 J=I,N
      CALL LOC(I,J,IJ,N,1)
      A(IJ)=A(IJ)/TK
    4 CONTINUE
      RETURN
      END
```

SUBPROGRAM NONDIM: CARD IMAGE LISTING

SUBROUTINE ORDER (A, NDEL, NGP, NDL)

PURPOSE: To remove (set to zero) specified (constrained) coordinates in array A, reorder the array A, and calculate the new size of array A.

SUBPROGRAMS REQUIRED: DELETE, LOC

VARIABLES:

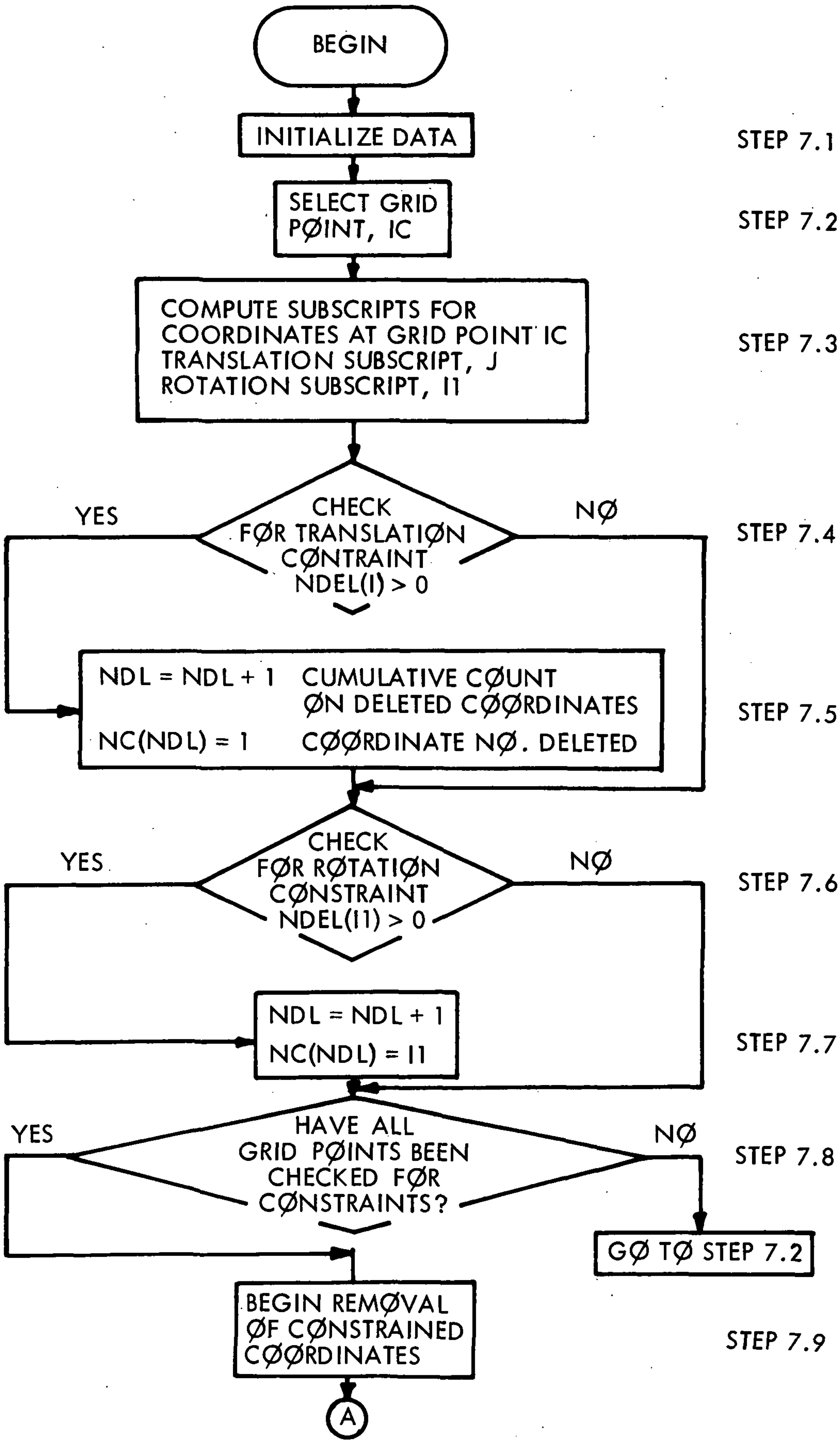
- A(I) - Stiffness or mass matrix of structural idealization (symmetric storage mode: LOC)
- NDEL(I) - Array of logic numbers: See BMPROP
- NGP - Number of grid points of the structure
- NDL - Number of coordinates removed by this subprogram
- NC(38) - Array of coordinate numbers for which NDEL(I) = 1

RESTRICTIONS: NGP is assumed to be equal to or less than 19.

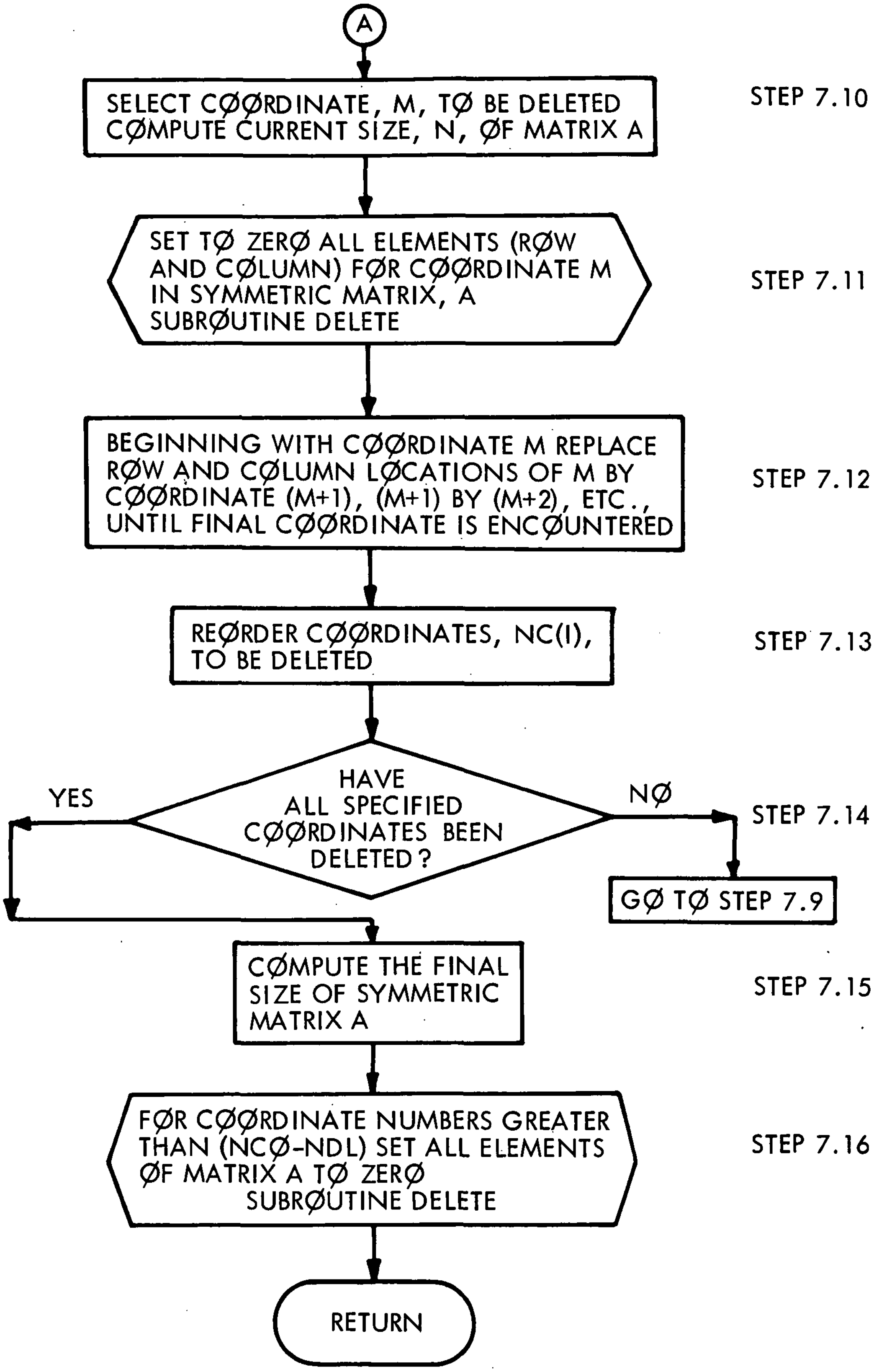
NC(I) must be dimensioned the same as NDEL(I) in program BMPROP

ACCURACY: Not Applicable

SIZE: 000244_8



FLØW CHART: SUBPRØGRAM ØRDER (A, NDEL, NGP, NDL)



FLØW CHART: SUBPRØGRAM ØRDER (A, NDEL, NGP, NDL)

SUBROUTINE DELETE (A,N,J)

PURPOSE: To delete (set to zero) all elements in the J^{th} row column of array A.

SUBPROGRAMS REQUIRED: LOC

VARIABLES:

A(N) - Single subscripted array (symmetric storage mode: LOC)

N - Size of array A

J - Row-column number of elements of A to be set to zero

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000034_8

```
      SUBROUTINE ORDER(A,NDEL,NGP,NDL)
      DIMENSION A(1),NDEL(1),NC(38)
      NDL=0
      NCO=2*NGP
      DO 1 I=1,NCO
      NC(I)=0
    1 CONTINUE
      DO 5 IC=1,NGP
      I=2*IC-1
      I1=2*IC
      IF(NDEL(I)) 3,3,2
    2 NDL=NDL+1
      NC(NDL)=I
    3 IF(NDEL(I1)) 5,5,4
    4 NDL=NDL+1
      NC(NDL)=I1
    5 CONTINUE
      DO 11 K=1,NDL
      M=NC(K)
      ML=NCO-K
      N=ML+1
      CALL DELETE(A,N,M)
      DO 9 I=M,ML
      I1=I+1
      DO 9 J=1,N
      CALL LOC(I,J,IJ,N,1)
      IF(I-J) 7,6,7
    6 J1=J+1
      CALL LOC(I1,J1,IJ1,N,1)
      GO TO 8
    7 CALL LOC(I1,J,IJ1,N,1)
    8 A(IJ)=A(IJ1)
    9 CONTINUE
      DO 11 I=1,NDL
      IF(NC(I)-M) 11,11,10
   10 NC(I)=NC(I)-1
   11 CONTINUE
      M=NCO-NDL+1
      DO 12 K=M,NCO
      CALL DELETE(A,NCO,K)
   12 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DELETE(A,N,J)
      DIMENSION A(1)
      DO 1 K=1,N
      CALL LOC(K,J,KJ,N,1)
      A(KJ)=0.0
    1 CONTINUE
      RETURN
      END
```

SUBPROGRAMS ORDER AND DELETE: CARD IMAGE LISTING

SUBROUTINE FREQ (SS,RR,TL,TK,TM,NCASE,N)

PURPOSE: To convert the stiffness, SS, and mass, RR, matrices (symmetric storage mode: LOC) to the stiffness, S, and mass, R, matrices (general storage mode: LOC); call for eigenvalue calculations, and write the eigenvalues (frequency) and eigenvectors.

SUBPROGRAMS REQUIRED: LOC, NROOT (NROOT requires EIGEN)

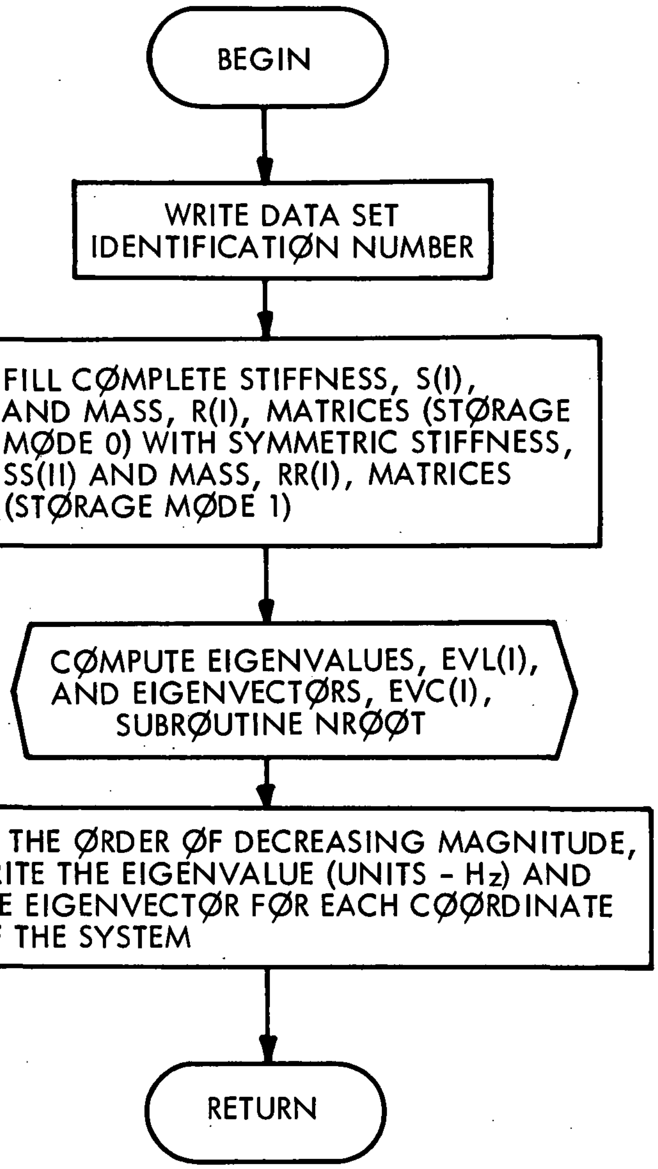
VARIABLES:

SS(NUP)	- Dimensionaless stiffness matrix
RR(NUP)	- Dimensionless mass matrix
TL	- Length parameter used in nondimensionalization
TK	- Stiffness parameter used in nondimensionalization
TM	- Mass parameter used in nondimensionalization
NCASE	- Data case identification number
N	- Number of coordinates

RESTRICTIONS: For the declared size of the arrays, $N \leqq 19$

ACCURACY: See NROOT and EIGEN

SIZE: 000256_8



FLØW CHART: SUBPRØGRAM FREQ (SS, RR, TL, TK, TM, NCASE, N)

```
      SUBROUTINE FREQ(SS,RR,TL,TK,TM,NCASE,N)
      DIMENSION SS(1),RR(1),EVL(38),EVC(1156)
      DIMENSION S(1156),R(1156),DUM1(342)
      DIMENSION IDUM1(11),DUM2(17)
      COMMON EVL,EVC,DUM1,IDUM1,DUM2,S,R
      IO=6
      NUP=N*(N+1)/2
      WRITE(IO,120)
      WRITE(IO,125) NCASE
  200 DO 205 I=1,N
      DO 205 J=1,N
      CALL LOC(I,J,IJ,N,0)
      CALL LOC(I,J,IJS,N,1)
      S(IJ)=SS(IJS)
      R(IJ)=RR(IJS)
  205 CONTINUE
      CALL NROOT (N,S,R,EVL,EVC)
      DO 220 I=1,N
      IF(EVL(I)) 210,215,215
  210 EVL(I)=ABS(EVL(I))
  215 EVL(I)=0.159155*SQRT(TK*EVL(I)/TM)
      WRITE(IO,225) EVL(I)
      WRITE(IO,230)
      IX=N*(I-1)+1
      IY=N*I
      WRITE(IO,235) (EVC(J),J=IX,IY)
  220 CONTINUE
      RETURN
  120 FORMAT(1H1,27X,24HFREE VIBRATION OF A ONE-,
     123HDIMENSIONAL PANEL ARRAY)
  125 FORMAT(/,44X,9HDATA CASE,I4,/)
  225 FORMAT(/,5X,10HFREQUENCY=,E12.5,1X,3HHZ.)
  230 FORMAT(/,5X,10HMODE SHAPE,/)
  235 FORMAT(5X,8E12.5)
  236 FORMAT(5E15.8)
      END
```

SUBPROGRAM FREQ: CARD IMAGE LISTING

SUBROUTINE NROOT (M,A,B,XL,X)

PURPOSE: To compute the eigenvalues and eigenvectors of a real symmetric matrix of the form B-inverse times A.

SUBPROGRAMS REQUIRED: EIGEN

VARIABLES:

M - Order of square matrices A, B, and X

A - Input matrix, MXM, (stiffness matrix)

B - Input matrix, MXM, (mass matrix)

XL - Output vector of length M containing eigenvalues of B-inverse times A

X - Output matrix, MXM, containing eigenvectors column wise

RESTRICTIONS: See EIGEN

ACCURACY: See EIGEN

SIZE: 000312_8

REFERENCES: References 3 and 4

```
      SUBROUTINE NROOT (M,A,B,XL,X)
      DIMENSION A(1),B(1),XL(1),X(1)
C     COMPUTE EIGENVALUES AND EIGENVECTORS OF B
      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     THE MATRIX B IS A REAL SYMMETRIC MATRIX
      MV=0
      CALL EIGEN(B,X,M,MV)
C     FORM RECIPROCALS OF SQUARE ROOT OF EIGENVALUES. THE RESULTS
C     ARE PREMULTIPLIED BY THE ASSOCIATED EIGENVECTORS.
      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     FORM (B**(-1/2))PRIME*A*(B**(-1/2))
      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     COMPUTE EIGENVALUES AND EIGENVECTORS OF MATRIX A.
      CALL EIGEN (A,X,M,MV)
      L=0
      DO 140 I=1,M
      L=L+I
  140 XL(I)=A(L)
C     COMPUTE NORMALIZED EIGENVECTORS
      DO 150 I=1,M
      N2=0
      DO 150 J=1,M
      N1=I-M
```

SUBPROGRAM NROOT: CARD IMAGE LISTING 1/2

```
      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
```

SUBPROGRAM NROOT: CARD IMAGE LISTING 2/2

SUBROUTINE EIGEN (A,R,N,MV)

PURPOSE: To compute eigenvalues and eigenvectors of a real symmetric matrix by the Jacobi method.

SUBPROGRAMS REQUIRED: None

VARIABLES:

A - Original matrix (symmetric storage mode: LOC), destroyed in computation. Resultant eigenvalues are developed in diagonal of matrix A in descending order.

R - Resultant matrix of eigenvectors (stored column wise, in same sequence as eigenvectors).

N - Order of matrices A and R

MV - Input option

0 Compute eigenvalues and eigenvectors

1 Compute eigenvalues only (R need not be dimensioned but must still appear in calling sequence)

RESTRICTIONS: The original matrix A must be real symmetric (storage mode 1: LOC). Matrix A cannot be in the same location as matrix R.

ACCURACY: At each step of the diagonalization a norm is calculated and the diagonalization continued with the magnitude of the off-diagonal term is sufficiently small to insure convergence.

SIZE: 000522_8

REFERENCES: References 3 and 4

```
      SUBROUTINE EIGEN(A,R,N,MV)
      DIMENSION A(1),R(1)
C     GENERATE IDENITY MATRIX
    5 RANGE=1.0E-6
      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     COMPUTE INITIAL AND FINAL NORMS (ANORM AND ANORMX)
   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*RANGE/FLOAT(N)
C     INITIALIZE INDICATORS AND COMPUTE THRESHOLD, THR
      IND=0
      THR=ANORM
   45 THR=THR/FLOAT(N)
   50 L=1
   55 M=L+1
C     COMPUTE SIN AND COS
   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)
      COSX2=COSX*COSX
      SINCS=SINX*COSX
C     ROTATE L AND M COLUMNS
      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
```

SUBPROGRAM EIGEN: CARD IMAGE LISTING 1/2

```
   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=X+A(LL)*SINX2+A(MM)*COSX2
      A(LM)=(A(LL)-A(MM))*SINCS+A(LM)*(COSX2-SINX2)
      A(LL)=Y
      A(MM)=X
C      TESTS FOR COMPLETION
C     TEST FOR M = LAST COLUMN
  130 IF(M-N) 135,140,135
  135 M=M+1
      GO TO 60
C     TEST FOR L = SECOND FROM LAST COLUMN
  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     COMPARE THRESHOLD WITH FINAL NORM
  160 IF(THR-ANRMX) 165,165,45
C     SORT EIGENVALUES AND EIGENVECTORS
  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
```

SUBPROGRAM EIGEN: CARD IMAGE LISTING 2/2

SUBROUTINE SSBM (NCO, NBAY, NSUP, IBL, NINT, NDATA)

PURPOSE: To compute the displacement, slope, shear, and bending moment distribution along the centerline of the panel row for the fifteen lower frequency modes of the structure. The displacement, slope, shear, and bending moment distribution are calculated at each element node point and at NINT points interior to the element. All values are normalized to the maximum value and printed.

SUBPROGRAMS REQUIRED: ELEM

VARIABLES:

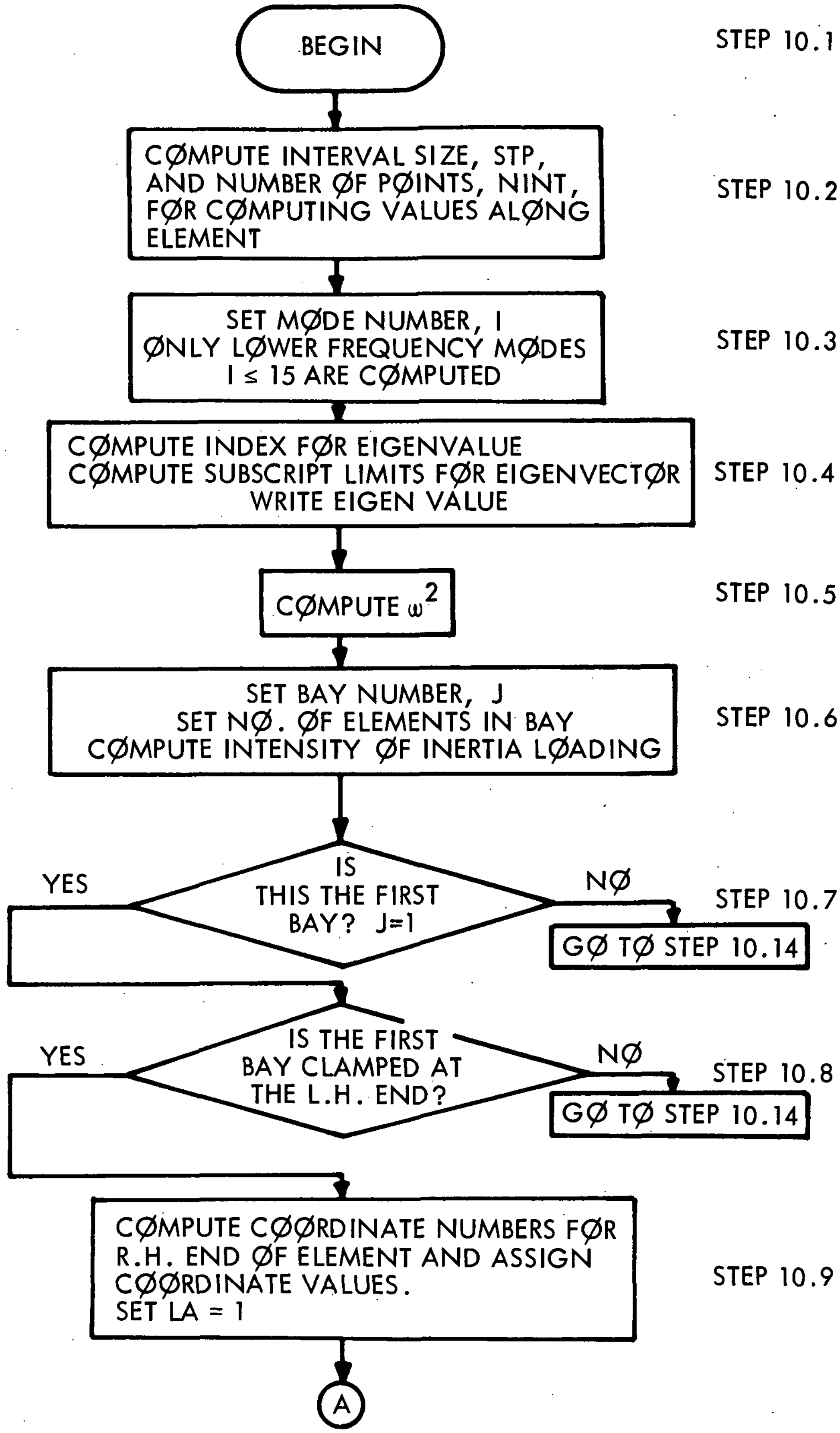
- NCO - Number of coordinates for the structural idealization
- NBAY - Number of panel bays of the structure
- NSUP - Number of elastic supports
- IBL - Logic number: IBL = 0, the left end of the structure is free or elastically supported; IBL = 1, the left end of the structure is clamped.
- NINT - Number of points interior to an element for which interpolated values of displacement, slope shear and bending moment are to be calculated.
- NDATA - Four digit data case identification number

RESTRICTIONS: For the declared size of the arrays: NCO $\leq$ 38, NBAY $\leq$ 5, NSUP $\leq$ 6, NINT $\leq$ 5.

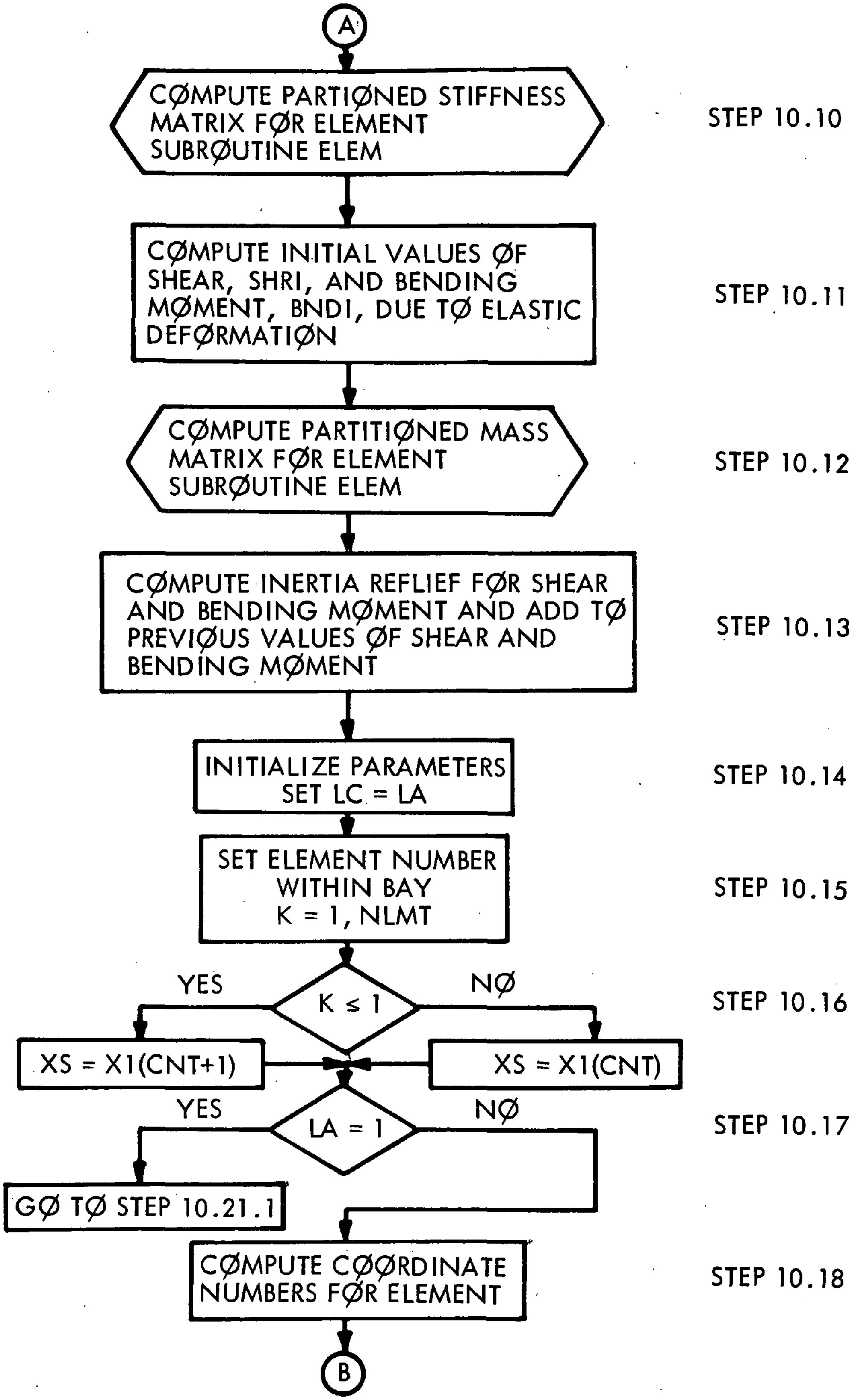
ACCURACY: (See NROOT and EIGEN)

SIZE: 001114_8

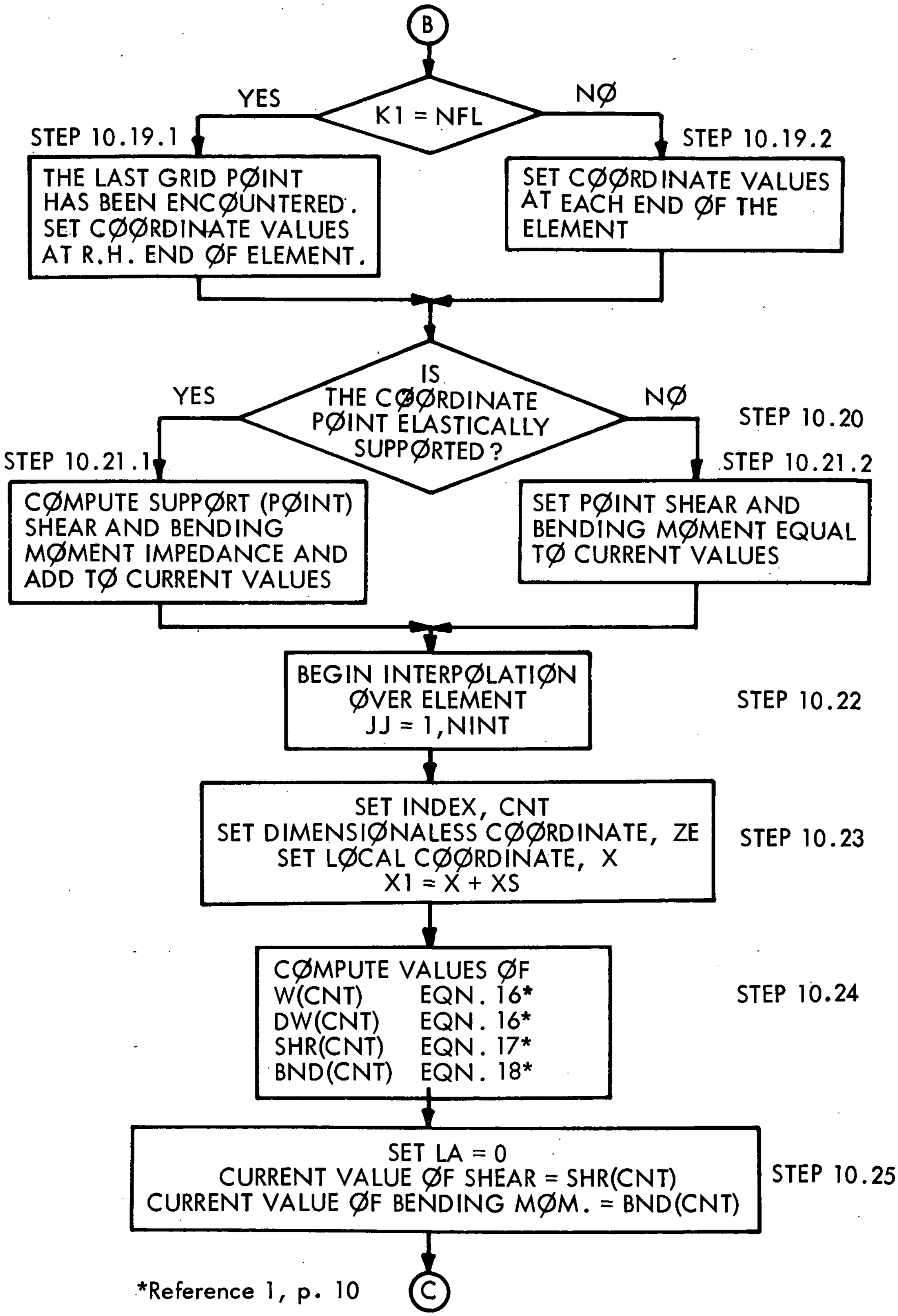
REFERENCE: Reference 1, pp. 9 - 11.



FLØW CHART: SUBPRØGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)

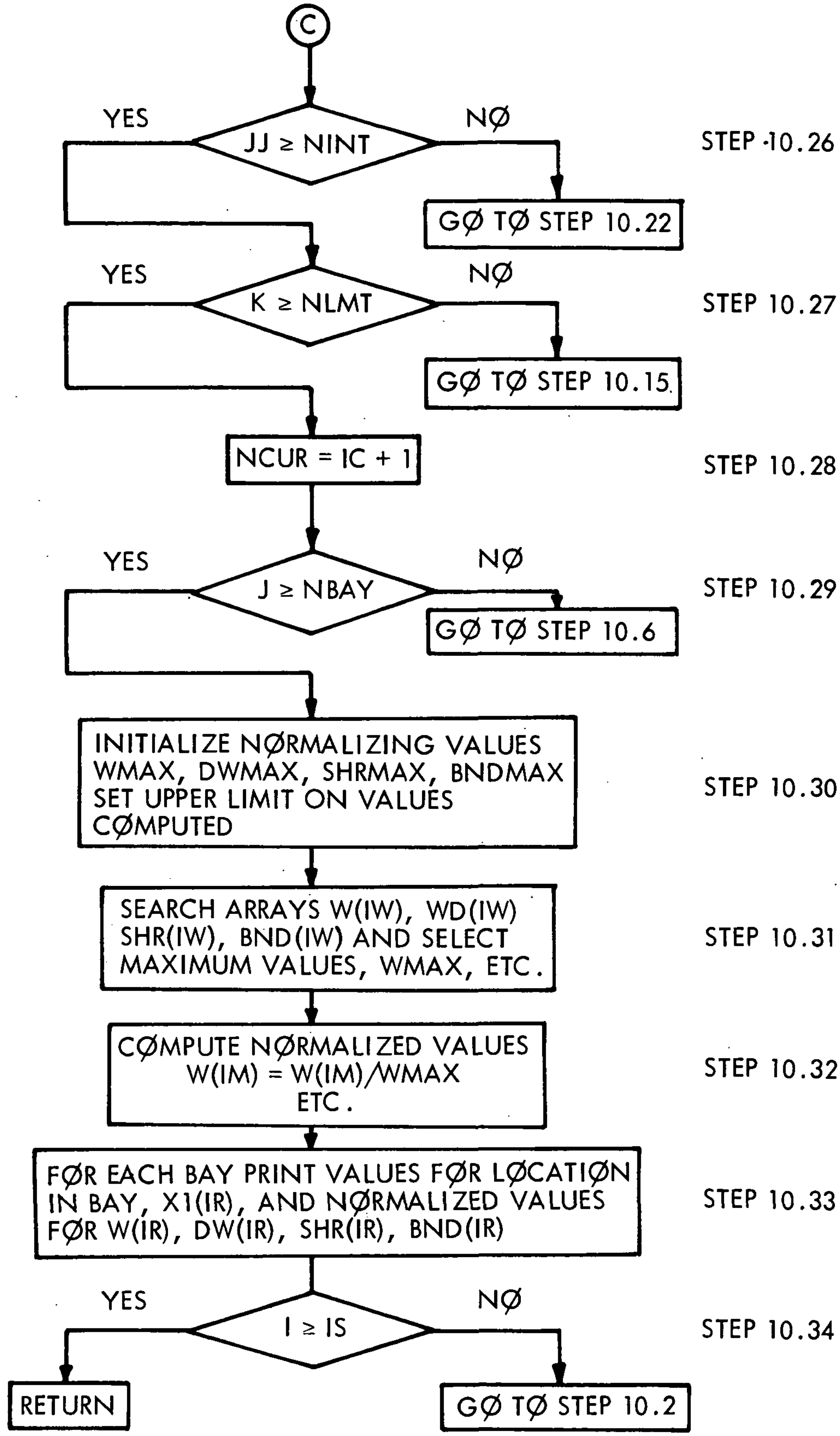


FLØW CHART: SUBPRØGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)



*Reference 1, p. 10

FLØW CHART: SUBPRØGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)



FLØW CHART: SUBPRØGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)

```
      SUBROUTINE SSBM(NCO,NBAY,NSUP,IBL,NINT,NDATA)
      DIMENSION EVL(38),EVC(1156),WB(5),BLMT(5)
      DIMENSION SL(6),SC(6),SR(6),RL(6),RC(6),RR(6)
      DIMENSION NEL(5),NCP(6),S1(4),S2(4),S3(4)
      DIMENSION DUM1(293),DUM3(5)
      DIMENSION X1(180),W(180),DW(180),SHR(180),BND(180)
      COMMON EVL,EVC,DUM1,WB,BLMT,BW,DUM2
      COMMON TL,SL,SC,SR,RL,RC,RR,NEL,NCP
      COMMON DUM3,S1,S2,S3,X1,W,DW,SHR,BND
      INTEGER CNT
      IO=6
      STP=1./FLOAT(NINT)
      NINT=NINT+1
      DO 929 I=1,15
      WRITE(IO,100)
      WRITE(IO,101) NDATA
      SHRI=0.
      BNDI=0.
      SHRP=0.
      BNDP=0.
      NLMAX=0
      CNT=0
      NN=NCO+1-I
      WRITE(IO,102) EVL(NN)
      NFL=NN*NCO-1
      OM=6.28318*EVL(NN)
      OMS=OM*OM
      NCUR=0
      LA=0
      DO 921 J=1,NBAY
      NLMT=NEL(J)
      NLMAX=NLMAX+NLMT
      BMM=OMS*WB(J)/386.
      IF(J-1) 901,901,907
  901 IF(IBL-1) 907,902,902
  902 K1=NCO*(NN-1)+1
      K2=K1+1
      D1=0.
      D2=0.
      D3=EVC(K1)
      D4=EVC(K2)
      LA=1
      CALL ELEM(J,1,S1,S2,S3)
      SHRI=S2(1)*TL*D3+S2(3)*D4
      BNDI=-S2(2)*TL*D3-S2(4)*D4
      CALL ELEM(J,2,S1,S2,S3)
      SHRI=SHRI-OMS*S2(1)*TL*D3-OMS*S2(3)*D4
      BNDI=BNDI+OMS*S2(2)*TL*D3+OMS*S2(4)*D4
  907 CONTINUE
      X1(CNT+1)=0.
      LC=LA
      DO 920 K=1,NLMT
      IF(K-1) 903,903,904
  903 XS=X1(CNT+1)
      GO TO 905
  904 XS=X1(CNT)
  905 IF(1-LA) 908,914,908
```

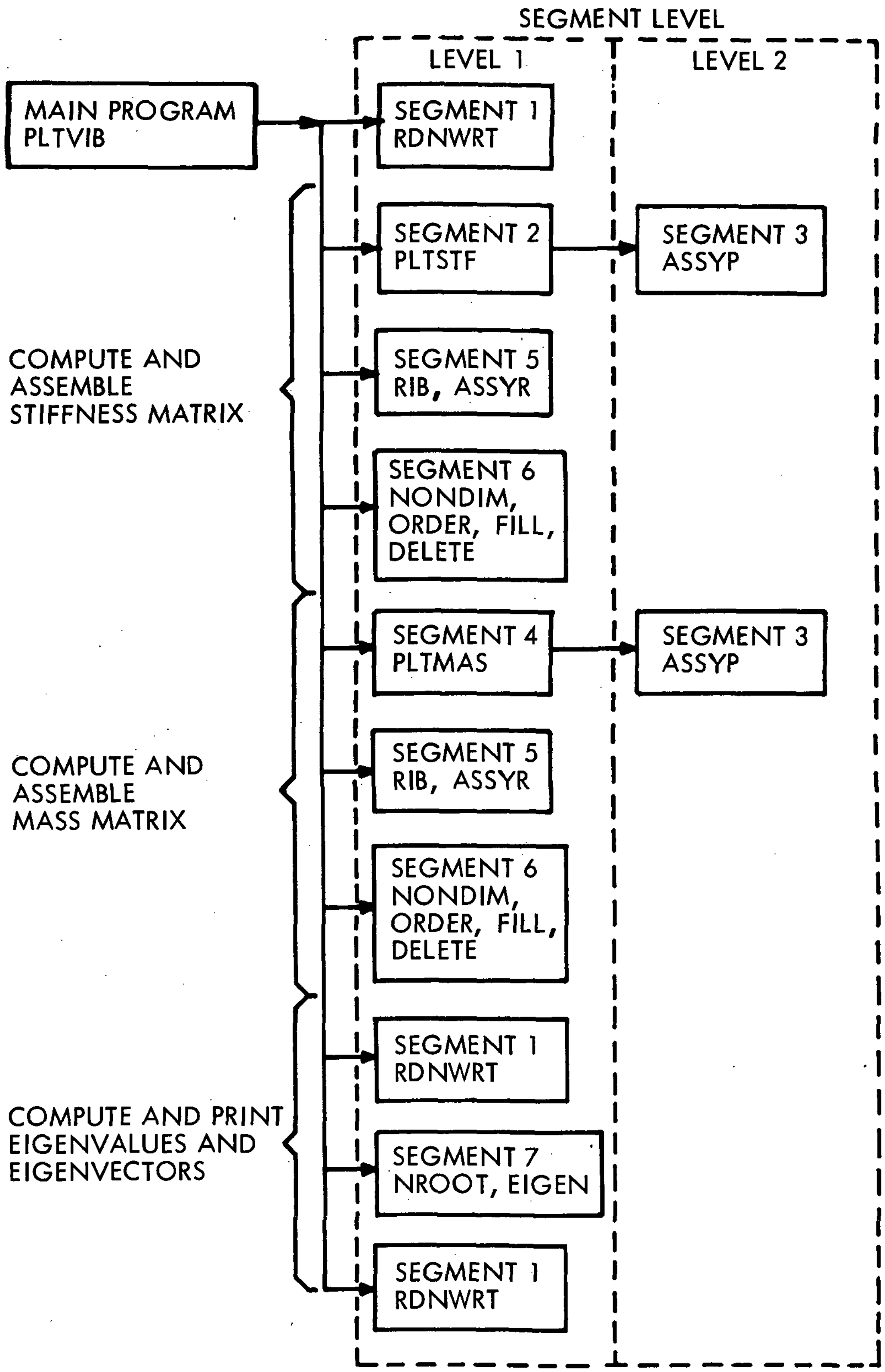
SUBPROGRAM SSBM: CARD IMAGE LISTING 1/3

```
  908 IC=NCUR+2*K-2*LC-1
      K1=NCO*(NN-1)+IC
      K2=K1+1
      K3=K1+2
      K4=K1+3
      IF(K1-NFL) 909,910,910
  909 D1=EVC(K1)
      D2=EVC(K2)
      D3=EVC(K3)
      D4=EVC(K4)
      GO TO 911
  910 D1=EVC(K1)
      D2=EVC(K2)
      D3=0.
      D4=0.
  911 DO 912 KK=1,NSUP
      IF(NCP(KK)-IC) 912,913,912
  912 CONTINUE
      GO TO 914
  913 SHRP=(OMS*RL(KK)/386.-SL(KK))*TL*D1+
     2(OMS*RC(KK)/386.-SC(KK))*D2+SHRI
      BNDP=(SC(KK)-OMS*RC(KK)/386.)*TL*D1+
     2(SR(KK)-OMS*RR(KK)/386.)*D2+BNDI
      GO TO 915
  914 SHRP=SHRI
      BNDP=BNDI
  915 CONTINUE
      DO 920 JJ=1,NINT
      CNT=CNT+1
      ZE=STP*FLOAT(JJ-1)
      X=ZE*BLMT(J)
      X1(CNT)=X+XS
      ZES=ZE*ZE
      ZEC=ZE*ZES
      W(CNT)=(2.*ZEC-3.*ZES+1.)*TL*D1+X*(ZES-2.*ZE+1.)*D2-
     2ZES*(2.*ZE-3.)*TL*D3+X*ZE*(ZE-1.)*D4
      DW(CNT)=6.*ZE*(ZE-1.)*TL*D1/BLMT(J)+(3.*ZES-4.*ZE+1.)*D2-
     26.*ZE*(ZE-1.)*TL*D3/BLMT(J)+ZE*(3.*ZES-2.)*D4
      SHR(CNT)=SHRP+BMM*X*(.5*ZEC-ZES+1.)*TL*D1+
     2BMM*X*X*(.25*ZES-2.*ZE/3.+.5)*D2-
     3BMM*X*ZES*(.5*ZE-1.)*TL*D3+
     4BMM*X*X*ZE*(.25*ZE-1./3.)*D4
      BND(CNT)=BNDP+SHRP*X+BMM*X*X*(.1*ZEC-.25*ZES+.5)*TL*D1+
     2BMM*X*X*X*(.05*ZES-ZE/6.+1./6.)*D2-
     3BMM*X*X*ZES*(.1*ZE-.25)*TL*D3+
     4BMM*X*X*X*ZE*(.05*ZE-1./12.)*D4
      LA=0
      SHRI=SHR(CNT)
      BNDI=BND(CNT)
  920 CONTINUE
      NCUR=IC+1
  921 CONTINUE
      WMAX=0.
      DWMAX=0.
      SHRMAX=0.
      BNDMAX=0.
      LIM=NLMAX*NINT
      DO 924 IW=1,LIM
      IF(ABS(W(IW))-WMAX) 916,916,917
```

SUBPROGRAM SSBM: CARD IMAGE LISTING 2/3

```
917 WMAX=ABS(W(IW))
916 IF(ABS(DW(IW))-DWMAX) 918,918,919
919 DWMAX=ABS(DW(IW))
918 IF(ABS(SHR(IW))-SHRMAX) 922,922,923
923 SHRMAX=ABS(SHR(IW))
922 IF(ABS(BND(IW))-BNDMAX) 924,924,925
925 BNDMAX=ABS(BND(IW))
924 CONTINUE
    DO 926 IM=1,LIM
    W(IM)=W(IM)/WMAX
    DW(IM)=DW(IM)/DWMAX
    SHR(IM)=SHR(IM)/SHRMAX
    BND(IM)=BND(IM)/BNDMAX
926 CONTINUE
    LIM=1
    DO 928 J=1,NBAY
    WRITE(IO,998)
    WRITE(IO,997) J
    LIMM=LIM+NINT*NEL(J)-1
    DO 927 IR=LIM,LIMM
    WRITE(IO,999) X1(IR),W(IR),DW(IR),SHR(IR),BND(IR)
927 CONTINUE
    LIM=LIM+NINT*NEL(J)
928 CONTINUE
929 CONTINUE
100 FORMAT(1H1)
101 FORMAT(25X,9HDATA CASE,I4)
102 FORMAT(/,5X,11HFREQUENCY =,E12.5,1X,3HHZ.)
997 FORMAT(/,29X,3HBAY,I2)
998 FORMAT(/,9X,1HX,10X,1HW,8X,5HDW/DX,9X,1HV,11X,1HM)
999 FORMAT(5X,F7.3,2X,4E12.5)
    RETURN
    END
```

SUBPROGRAM SSBM: CARD IMAGE LISTING 3/3



TWO-DIMENSIONAL PANEL ANALYSIS:
PROGRAM CORE-OVERLAY STRUCTURE

PROGRAM PLTVIB (MAIN)
(See Figure 2 for Flow Chart)

PURPOSE: Main program for computing the natural frequencies and normal mode shapes of a nine-bay orthogonally stiffened flat panel. The structure is assumed to have clamped edges along the edges and four orthogonal stiffeners dividing the uniform cover sheet into nine bays. The stiffeners are modeled with a finite element representation of a thin-walled open-section beam. The stiffener element deformation fully conforms to the plate element deformation along the edges of the plate element. The rectangular plate bending element used is based upon a sixteen degree-of-freedom element with an interior element mode in the form of a clamped-clamped beam fundamental mode.

SUBPROGRAMS REQUIRED: RDNWRT, PLTSTF, PLTMAS, RIB, NONDIM, ASSYR, ASSYP, FILL, ZERO, ORDER, DELETE*, LOC*, EIGEN*, NROOT*

INPUT DATA: See Appendix D for description -
NCASE, A(I), B(I), EP, HP, PR, RHOP, ER(I), GR(I), RHO(I),
SR2(I), C2(I), SR3(I), C3(I), AR(I),
A22(I), A23(I), A33(I), SJ(I), RE2(I)
RE3(I), GM(I)

VARIABLES: NDEL(D) - Constraint vector for an N degree-of-freedom system. If NDEL(R) = 1 the Rth coordinate is removed from the equations of motion. If NDEL(R) = 0, the Rth coordinate is ignored in subprogram ORDER.

S1(I), S2(I), S3(I) - The arrays represented the partitioned stiffness or mass matrices of the plate on rib element.

SC(D) - The coupling term between the edge displacements and the generalized coordinate for the plate stiffness and mass matrices.

SF(I), RF(I) - Structure stiffness and mass matrices
(symmetric storage mode: LOC)

EVL(I) - Array of eigenvalues

VARIABLES: (Continued)

EVC(I) - Array of eigenvectors

R(I) - Dummy array

M - Number of grid points in f-direction

N - Number of grid points in y-direction

RESTRICTIONS: For the declared size of the arrays: $M \leq 4$, $N \leq 4$

ACCURACY: Not Applicable

SIZE: 006371_8

REFERENCES: Reference 1, pp. 11 - 16

*Subroutine is identical to that described for the one-dimensional analysis.

```
      SEGZERO(SEG0,PLTVIB,LOC,ZERO)
      SEGMENT(SEG1,RDNWRT)
      SEGMENT(SEG2,PLTSTF)
      SEGMENT(SEG3,ASSYP)
      SEGMENT(SEG4,PLTMAS)
      SEGMENT(SEG5,RIB,ASSYR)
      SEGMENT(SEG6,NONDIM,ORDER,FILL,DELETE)
      SEGMENT(SEG7,NROOT,EIGEN)
      PROGRAM PLTVIB(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON ER(4),GR(4),RHO(4),SR2(4),C2(4),SR3(4),C3(4),
     1AR(4),A22(4),A23(4),A33(4),SJ(4),RE2(4),RE3(4),GM(4)
      COMMON R(2701),A(3),B(3)
      COMMON NCASE,EP,HP,PR,RHOP,DP,TL,TK,TM,NCO
      DIMENSION NDEL(73),S1(36),S2(64),S3(36),SC(17),
     1SE(625),RF(625),EVL(25),EVC(625),ANAME(2)
      EQUIVALENCE (R(326),RF(1)),(R(952),EVL(1)),(R(978),EVC(1))
      DATA LFILE/3HLGO/
      IDATA=1
 100  READ(5,105) NDATA
 105  FORMAT(5X,I3)
 110  M=4
      N=4
      NCP=4
      MBAY=M-1
      NBAY=N-1
      NGP=M*N
      NU1=NCP*NGP
      NCO=NU1+MBAY*NBAY
      ANAME(1)=4HSEG1
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      CALL RDNWRT(1)
C     INITIALIZE CONSTRAINT VECTOR
      DO 120 I=1,64
      IF(I-20) 115,115,111
 111  IF(I-29) 114,115,112
 112  IF(I-36) 115,115,113
 113  IF(I-45) 114,115,115
 114  NDEL(I)= 0
      GO TO 120
 115  NDEL(I)= 1
 120  CONTINUE
      TL= SQRT(A(2)*A(2)+B(2)*B(2))
      DP=EP*HP*HP*HP/(12.*(1.-PR*PR))
      CALL RDNWRT (2)
      RHOP=RHOP*HP/386.
      NU1=NCP*NGP
      DO 305 IOP=1,2
      NCO=NU1+MBAY*NBAY
      CALL ZERO(R,2701)
      IF(IOP-1) 200,200,210
C     COMPUTE AND ASSEMBLE FREE-FREE PLATE STIFFNESS MATRIX
 200  ANAME(1)=4HSEG2
      ANAME(2)=0
```

PROGRAM PLTVIB: CARD IMAGE LISTING 1/3

```
      CALL SEGMENT(LFILE,1,ANAME)
      ANAME(1)=4HSEG3
      ANAME(2)=0
      CALL SEGMENT(LFILE,2,ANAME)
      DO 205 J=1,NBAY
      DY=B(J)
      DO 205 I=1,MBAY
      DX=A(I)
      CALL PLTSTF(DX,DY,DP,PR,S1,S2,S3,SC)
      CALL ASSYP(R,S1,S2,S3,SC,I,M,J,N,NCP)
  205 CONTINUE
      GO TO 220
C     COMPUTE AND ASSEMBLE FREE-FREE PLATE MASS MATRIX
  210 ANAME(1)=4HSEG4
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      ANAME(1)=4HSEG3
      ANAME(2)=0
      CALL SEGMENT(LFILE,2,ANAME)
      DO 215 J=1,NBAY
      DY=B(J)
      DO 215 I=1,MBAY
      DX=A(I)
      CALL PLTMAS(DX,DY,RHOP,S1,S2,S3,SC)
      CALL ASSYP(R,S1,S2,S3,SC,I,M,J,N,NCP)
  215 CONTINUE
C     COMPUTE AND ASSEMBLE FREE-FREE RIB STIFFNESS AND MASS MATRICES
  220 ANAME(1)=4HSEG5
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      DO 270 IR=1,4
      GO TO (225,235,250,255),IR
  225 J=2
      GO TO 240
  235 J=3
  240 AX=1.0
      DO 245 I=1,MBAY
      DR=A(I)
      CALL RIB(IR,IOP,DR,S1,S2,S3)
      CALL ASSYR(R,S1,S2,S3,I,M,J,N,NCP,AX)
  245 CONTINUE
      GO TO 270
  250 I=2
      GO TO 260
  255 I=3
  260 AX=0.0
      DO 265 J=1,NBAY
      DR=B(I)
      CALL RIB(IR,IOP,DR,S1,S2,S3)
      CALL ASSYR(R,S1,S2,S3,I,M,J,N,NCP,AX)
  265 CONTINUE
  270 CONTINUE
C     NONDIMENSIONALIZE MATRICES
      TR=0.0
```

PROGRAM PLTVIB: CARD IMAGE LISTING 2/3

```
      DO 275 I=3,NU1,NCP
      I1=I-1
      II1=I1+(I1*I1-I1)/2
      II=I+(I*I-I)/2
      TR=TR+R(II1)+R(II)
 275  CONTINUE
      ANAME(1)=4HSEG6
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      IF(IOP-1) 280,280,285
 280  TK=TR/(FLOAT(M)*FLOAT(N))
      CALL NONDIM(R,M,N,TK,TL)
      GO TO 290
 285  TM=TR/(FLOAT(M)*FLOAT(N))
      CALL NONDIM(R,M,N,TM,TL)
 290  NDL=0
C     APPLY COORDINATE CONSTRAINTS
      CALL ORDER(R,NDEL,NCP,M,N,NDL)
      NCO=NCO-NDL
      IF(IOP-1) 295,295,300
 295  CALL FILL(SF,R,NCO,0)
      GO TO 305
 300  CALL FILL(RF,R,NCO,0)
 305  CONTINUE
C     COMPUTE EIGENVALUES AND EIGENVECTORS
      ANAME(1)=4HSEG1
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      CALL RDNWRT (3)
      ANAME(1)=4HSEG7
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      CALL NROOT(NCO,SF,RF,EVL,EVC)
      ANAME(1)=4HSEG1
      ANAME(2)=0
      CALL SEGMENT(LFILE,1,ANAME)
      CALL RDNWRT (4)
      IDATA=IDATA+1
      IF(NDATA-IDATA) 310,110,110
 310  CONTINUE
      END
```

PROGRAM PLTVIB: CARD IMAGE LISTING 3/3

SUBROUTINE RDNWRT (ITØ)

PURPOSE: This subprogram contains all input/output statements for program PLTVIB. Input data definition and format is described in Appendix D. An example of output format is also included.

SUBPROGRAMS REQUIRED: None

VARIABLES:

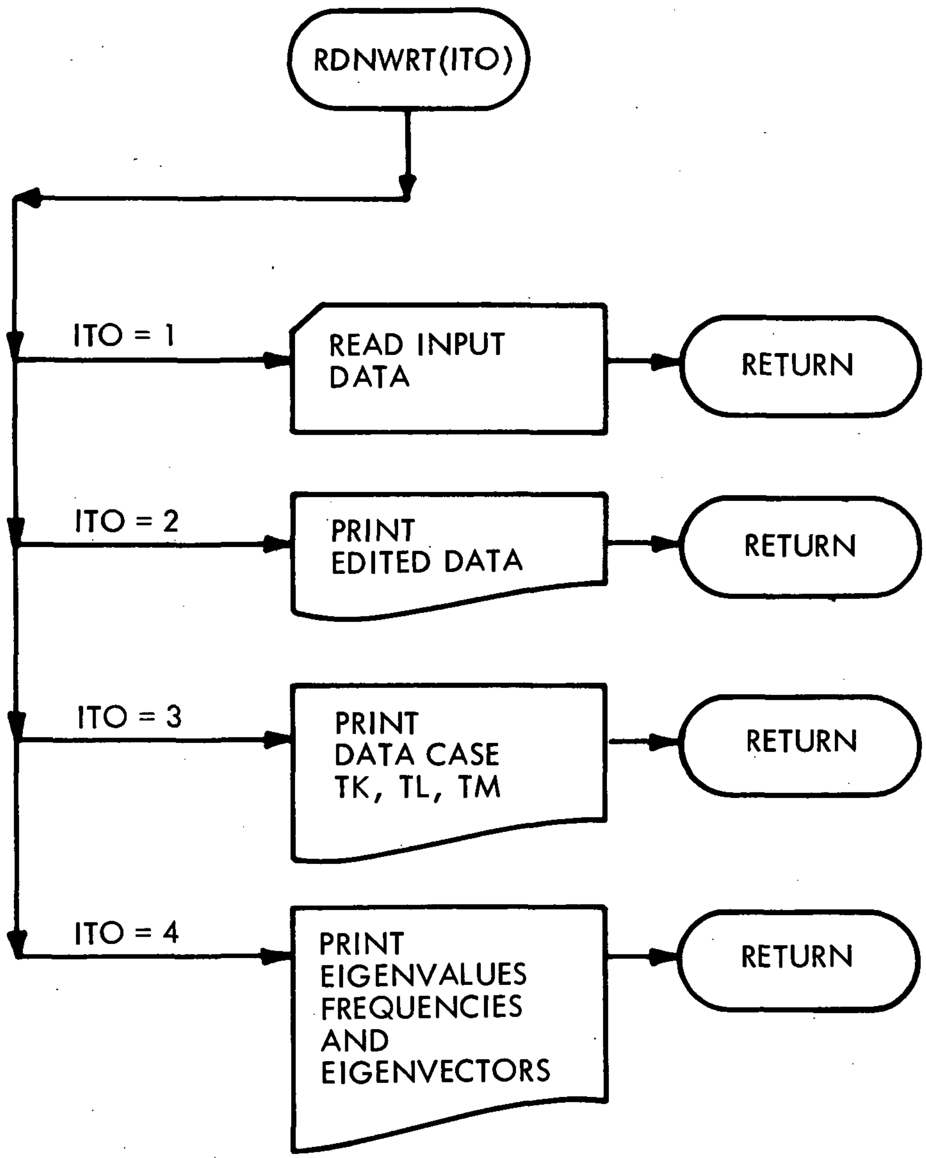
ITØ	= 1, input data read = 2, edited input data is printed = 3, NCASE, TK, TL, TM are printed = 4, eigenvalues and eigenvectors are printed
NCASE	Four digit data identification number
TK,TL,TM	Nondimensionalizing constants for force (stiffness), length, and mass, respectively

RESTRICTIONS: $1 \leq ITØ \leq 4$

ACCURACY: Not Applicable

SIZE: 001026_8

REFERENCES: None



FLOW CHART: SUBROUTINE RDNWRT(ITO)

```
      SUBROUTINE RDNWRT (ITO)
      COMMON ER(4),GR(4),RHO(4),SR2(4),C2(4),SR3(4),C3(4),
     1AR(4),A22(4),A23(4),A33(4),SJ(4),RE2(4),RE3(4),GM(4)
      COMMON R(2701),A(3),B(3)
      COMMON NCASE,EP,HP,PR,RHOP,DP,TL,TK,TM,NCO
      DIMENSION EVL(25),EVC(625),RF(625)
      EQUIVALENCE (R(326),RF(1)),(R(952),EVL(1)),(R(978),EVC(1))
      IN=5
      IO=6
      GO TO (100,200,400,500),ITO
  100 READ(IN,600) NCASE
      READ(IN,605) A(1),A(2),A(3)
      READ(IN,605) B(1),B(2),B(3)
      READ(IN,610) EP,HP,PR,RHOP
      DO 105 I=1,4
      READ(IN,610) ER(I),GR(I),RHO(I)
      READ(IN,610) SR2(I),C2(I),SR3(I),C3(I)
      READ(IN,610) AR(I),A22(I),A23(I),A33(I)
      READ(IN,610) SJ(I),RE2(I),RE3(I),GM(I)
  105 CONTINUE
      RETURN
  200 WRITE(IO,620) NCASE
      WRITE(IO,625)
      WRITE(IO,630) A(1),A(2),A(3)
      WRITE(IO,635) B(1),B(2),B(3)
      WRITE(IO,640)
      WRITE(IO,645) EP,PR,HP,RHOP,DP
      WRITE(IO,650)
      DO 140 I=1,4
      GO TO (130,130,135,135),I
  130 WRITE(IO,655)
      WRITE(IO,660) I,ER(I),GR(I),RHO(I)
      WRITE(IO,665) SR2(I),C2(I),SR3(I),C3(I)
      WRITE(IO,670) AR(I),A22(I),A23(I),A33(I)
      WRITE(IO,675) SJ(I),RE2(I),RE3(I),GM(I)
      GO TO 140
  135 WRITE(IO,680)
      WRITE(IO,660) I,ER(I),GR(I),RHO(I)
      WRITE(IO,685) SR2(I),C2(I),SR3(I),C3(I)
      WRITE(IO,690) AR(I),A22(I),A23(I),A33(I)
      WRITE(IO,695) SJ(I),RE2(I),RE3(I),GM(I)
  140 CONTINUE
      RETURN
  400 WRITE(IO,620) NCASE
      WRITE(IO,700)
      WRITE(IO,705) TK,TL,TM
      RETURN
  500 DO 415 I=1,NCO
      IF(EVL(I)) 405,410,410
  405 EVL(I)= ABS(EVL(I))
  410 FREQ= 0.159155*SQRT(TK*EVL(I)/TM)
      WRITE(IO,710) EVL(I),FREQ
      WRITE(IO,715)
      IX=NCO*(I-1)+1
      IY=NCO*I
      WRITE(IO,720) (EVC(J),J=IX,IY)
  415 CONTINUE
  600 FORMAT(5X,I4)
```

SUBPROGRAM RDNWRT: CARD IMAGE LISTING 1/2

```
 605  FORMAT(4X,3E12.5)
 610  FORMAT(4X,4E12.5)
C615  FORMAT(4X,4I2)
 620  FORMAT(1H1,28X,9HDATA CASE,I5)
 625  FORMAT(/,28X,19HFREE VIBRATION OF A,/,19X,
     137HNINE BAY ORTHOGONALLY STIFFENED PANEL,//,28X,
     219HSTRUCTURAL GEOMETRY,/)
 630  FORMAT(15X,3HA1=,E12.5,2X,3HA2=,E12.5,2X,3HA3=,E12.5,/)
 635  FORMAT(15X,3HB1=,E12.5,2X,3HB2=,E12.5,2X,3HB3=,E12.5,//)
 640  FORMAT(30X,16HCOVER SHEET DATA,/)
 645  FORMAT(5X,16HYOUNG'S MODULUS=,E12.5,15X,16HPOISSON'S RATIO=,
     1E12.5,/,5X,16HTHICKNESS       =,E12.5,15X,16HWEIGHT/VOLUME  =,
     2E12.5,/,24X,17HBENDING RIGIDITY=,E12.5,//)
 650  FORMAT(31X,14HSTIFFENER DATA,/)
 655  FORMAT(24X,29HSTIFFENERS PARALLEL TO X-AXIS)
 660  FORMAT(5X,13HSTIFFENER NO.,I2,2X,4HE  =,E12.5,2X,4HG  =,E12.5,
     12X,6HRHO  =,E12.5)
 665  FORMAT(5X,3HSY=,E12.5,2X,4HCY =,E12.5,2X,4HSZ =,E12.5,2X,
     16HCZ   =,E12.5)
 670  FORMAT(5X,3HA =,E12.5,2X,4HIYY=,E12.5,2X,4HIYZ=,E12.5,2X,
     16HIZZ  =,E12.5)
 675  FORMAT(5X,3HJ =,E12.5,2X,4HREY=,E12.5,2X,4HREZ=,E12.5,2X,
     16HGAMMA=,E12.5,/)
 680  FORMAT(24X,29HSTIFFENERS PARALLEL TO Y-AXIS)
 685  FORMAT(5X,3HSX=,E12.5,2X,4HCX =,E12.5,2X,4HSZ =,E12.5,2X,
     16HCZ   =,E12.5)
 690  FORMAT(5X,3HA =,E12.5,2X,4HIXX=,E12.5,2X,4HIXZ=,E12.5,2X,
     16HIZZ  =,E12.5)
 695  FORMAT(5X,3HJ =,E12.5,2X,4HREX=,E12.5,2X,4HREZ=,E12.5,2X,
     16HGAMMA=,E12.5,/)
 700  FORMAT(/,23X,29HNONDIMENSIONALIZING CONSTANTS)
 705  FORMAT(13X,3HTK=,E12.5,2X,3HTL=,E12.5,2X,3HTM=,E12.5)
 710  FORMAT(/,5X,11HEIGENVALUE=,E12.5,19X,10HFREQUENCY=,E12.5,4H,HZ.)
 715  FORMAT(33X,11HEIGENVECTOR)
 720  FORMAT(4X,E12.5,2X,E12.5,2X,E12.5,2X,E12.5,2X,E12.5)
      RETURN
      END
```

SUBPROGRAM RDNWRT: CARD IMAGE LISTING 2/2

SUBROUTINE PLTSTF (A,B,D,P,S1,S2,S3,SC)

PURPOSE: To compute the stiffness matrix of the modified sixteen degree-of-freedom plate element described by Bogner, Fox, and Schmidt with an interior mode in the form of clamped-clamped beam functions.

SUBPROGRAMS REQUIRED: None

VARIABLES:

A - Dimension of the plate element in the x-direction

B - Dimension of the plate element in the y-direction

D - Bending rigidity of plate element (Reference 1)

P - Poisson's ratio for the plate element

S1,S2,S3,SC - Partitioned stiffness matrices for the plate element (see Flow Chart and Appendix B)

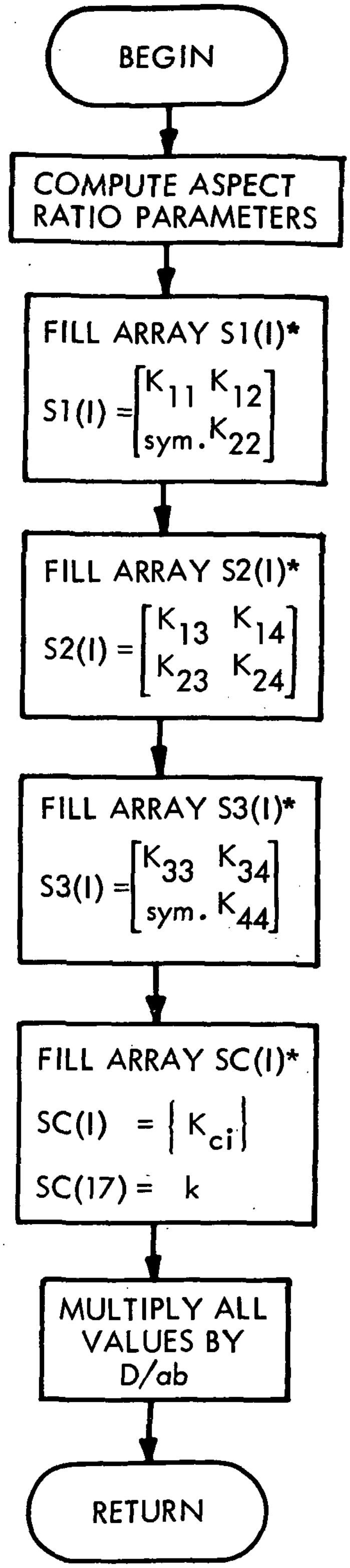
RESTRICTIONS: $A \neq 0$, $B \neq 0$

ACCURACY: See References below

SIZE: 002220_8

REFERENCES:

- Reference 1, pp. 12 - 15
- Bogner, F. K.; Fox, R. L.; and Schmidt, L. R., Jr.: Conference on Matrix Methods in Structural Mechanics, Wright-Patterson Air Force Base, Ohio. AFFDL-TR-66-80, 1966, pp. 391 - 443
- Mason, V.: Rectangular Finite Elements for Analysis of Plate Vibrations. J. Sound Vib., Vol. 7, No. 3, May 1968, pp. 437 - 448.



*SEE APPENDIX B

FLOW CHART: SUBROUTINE PLTSTF (A,B,D,P,S1,S2,S3,SC)

```
      SUBROUTINE PLTSTF(A,B,D,P,S1,S2,S3,SC)
      DIMENSION S1(2),S2(2),S3(2),SC(2)
      AB=A*B
      F= B*B/(A*A)
      G= A*A/(B*B)
      R= F+G
      C0=  .39647605
      C11= .20771538
      C21= .04469616
      C31=4.6472757
      PHI=R+2.*C11*C11*(C31-2.)*(C31-2.)
      SM= C0*C0*PHI/(C21*C21)
      SM1=SM/2048.-C0*C11*C11
      SM2=SM/4096.-C0*C11*C11
      S1(1)=  156.*R/35.+2.88+.0625*SM
      S1(2)=  ((22.*F+78.*G)/35.+1.2*(.2+P)+.015625*SM)*B
      S1(3)=  ((4.*F+52.*G)/35.+.32+.00390625*SM)*B*B
      S1(4)= -((78.*F+22.*G)/35.+1.2*(.2+P)+.015625*SM)*A
      S1(5)= -(11.*R/35.+.02+1.2*P+.00390625*SM)*AB
      S1(6)=  ((52.*F+4.*G)/35.+.32+.00390625*SM)*A*A
      S1(7)=  (11.*R/35.+.02+.2*P+8.*SM1)*AB
      S1(8)=  ((2.*F+22.*G/3.)/35.+2.*(.2+P)/15.+2.*SM1)*AB*B
      S1(9)= -((22.*F/3.+2.*G)/35.+2.*(.2+P)/15.+2.*SM1)*A*AB
      S1(10)= (4.*R/105.+8./225.+SM2)*AB*AB
      S1(11)=-(156.*F-54.*G)/35.-2.88+.0625*SM
      S1(12)=-((22.*F-27.*G)/35.+.24*(.2+P)-.015625*SM)*B
      S1(13)= ((78.*F-13.*G)/35.+.24-.015625*SM)*A
      S1(14)=-((11.*F-6.5*G)/35.+.1*(.2+P)-8.*SM1)*AB
      S1(15)= S1(1)
      S1(16)= S1(12)
      S1(17)=-((4.*F-18.*G)/35.+.32-.00390625*SM)*B*B
      S1(18)= ((11.*F-6.5*G)/35.+.1*(.2+P)-.00390625*SM)*AB
      S1(19)=-((2.*F-13.*G/3.)/35.+2./75.-2.*SM1)*AB*B
      S1(20)= S1(2)
      S1(21)= S1(3)
      S1(22)=-S1(13)
      S1(23)=-S1(18)
      S1(24)= ((26.*F-3.*G)/35.-.08-.00390625*SM)*A*A
      S1(25)=-((11.*F/3.-1.5*G)/35.-(.2+P)/30.-2.*SM1)*A*AB
      S1(26)=-S1(4)
      S1(27)=-S1(5)
      S1(28)= S1(6)
      S1(29)=-S1(14)
      S1(30)=-S1(19)
      S1(31)= S1(25)
      S1(32)= ((2.*F/3.-G)/35.-2./225.-SM2)*AB*AB
      S1(33)=-S1(7)
      S1(34)=-S1(8)
      S1(35)= S1(9)
      S1(36)= S1(10)
      S2(1)=  (54.*F-156.*G)/35.-2.88+.0625*SM
      S2(2)=  ((13.*F-78.*G)/35.-.24+.015625*SM)*B
      S2(3)= -((27.*F-22.*G)/35.-1.2*(.2+P)+.015625*SM)*A
      S2(4)=  ((6.5*F-11.*G)/35.-.1*(.2+P)+8.*SM1)*AB
      S2(5)= -54.*R/35.+2.88+.0625*SM
      S2(6)= -((13.*F+27.*G)/35.-.24-.015625*SM)*B
      S2(7)= -((27.*F+13.*G)/35.-.24-.015625*SM)*A
      S2(8)=  (6.5*R/35.-.02-8.*SM1)*AB
```

SUBPROGRAM PLTSTF: CARD IMAGE LISTING 1/3

```
S2(9)= -S2(2)
S2(10)=-((3.*F-26.*G)/35.+2./25.+.00390625*SM)*B*B
S2(11)= ((6.5*F-11.*G)/35.-.1*(.2+P)+.00390625*SM)*AB
S2(12)=-((1.5*F-11.*G/3.)/35.+(.2+P)/30.+2.*SM1)*AB*B
S2(13)=-S2(6)
S2(14)= ((3.*F+9.*G)/35.+.08-.00390625*SM)*B*B
S2(15)= (6.5*R/35.-.02-.00390625*SM)*AB
S2(16)=-((1.5*F+13.*G/6.)/35.+1./150.-2.*SM1)*AB*B
S2(17)= S2(3)
S2(18)=-S2(11)
S2(19)= ((18.*F-4.*G)/35.-.32+.00390625*SM)*A*A
S2(20)=-((13.*F/3.-2.*G)/35.-2./75.+2.*SM1)*A*AB
S2(21)=-S2(7)
S2(22)= S2(15)
S2(23)= ((9.*F+3.*G)/35.+.08-.00390625*SM)*A*A
S2(24)=-((13.*F/6.+1.5*G)/35.+1./150.-2.*SM1)*A*AB
S2(25)=-S2(4)
S2(26)= S2(12)
S2(27)=-S2(20)
S2(28)=-((F-2.*G/3.)/35.+2./225.+SM2)*AB*AB
S2(29)= S2(8)
S2(30)=-S2(16)
S2(31)=-S2(24)
S2(32)=-(R/70.-1./450.-SM2)*AB*AB
S2(33)= S2(5)
S2(34)= S2(6)
S2(35)=-S2(7)
S2(36)=-S2(8)
S2(37)= S2(1)
S2(38)= S2(2)
S2(39)=-S2(3)
S2(40)=-S2(4)
S2(41)= S2(13)
S2(42)= S2(14)
S2(43)=-S2(15)
S2(44)=-S2(16)
S2(45)= S2(9)
S2(46)= S2(10)
S2(47)=-S2(11)
S2(48)=-S2(12)
S2(49)=-S2(35)
S2(50)= S2(43)
S2(51)= S2(23)
S2(52)= S2(24)
S2(53)=-S2(17)
S2(54)=-S2(18)
S2(55)= S2(19)
S2(56)= S2(20)
S2(57)=-S2(29)
S2(58)=-S2(30)
S2(59)= S2(31)
S2(60)= S2(32)
S2(61)=-S2(25)
S2(62)=-S2(26)
S2(63)= S2(27)
S2(64)= S2(28)
S3(1)=  S1(1)
S3(2)= -S1(2)
S3(3)=  S1(3)
```

SUBPROGRAM PLTSTF: CARD IMAGE LISTING 2/3

```
      S3(4)=  S1(4)
      S3(5)= -S1(5)
      S3(6)=  S1(6)
      S3(7)= -S1(7)
      S3(8)=  S1(8)
      S3(9)= -S1(9)
      S3(10)= S1(10)
      S3(11)= S1(11)
      S3(12)=-S1(12)
      S3(13)= S1(13)
      S3(14)=-S1(14)
      S3(15)= S1(15)
      S3(16)=-S1(16)
      S3(17)= S1(17)
      S3(18)=-S1(18)
      S3(19)= S1(19)
      S3(20)=-S1(20)
      S3(21)= S1(21)
      S3(22)= S1(22)
      S3(23)=-S1(23)
      S3(24)= S1(24)
      S3(25)=-S1(25)
      S3(26)= S1(26)
      S3(27)=-S1(27)
      S3(28)= S1(28)
      S3(29)=-S1(29)
      S3(30)= S1(30)
      S3(31)=-S1(31)
      S3(32)= S1(32)
      S3(33)=-S1(33)
      S3(34)= S1(34)
      S3(35)=-S1(35)
      S3(36)= S1(36)
      SC(1)= -.25*SM
      SC(2)= -.0625*SM*B
      SC(3)=  .0625*SM*A
      SC(4)= -32.*SM1*AB
      SC(5)= -.25*SM
      SC(6)= -.0625*SM*B
      SC(7)=-SC(3)
      SC(8)=-SC(4)
      SC(9)= -.25*SM
      SC(10)=-SC(2)
      SC(11)= .0625*SM*A
      SC(12)= 32.*SM1*AB
      SC(13)=-.25*SM
      SC(14)= .0625*SM*B
      SC(15)=-.0625*SM*A
      SC(16)=-32.*SM1*AB
      SC(17)= SM
      DO 25 I=1,64
      IF(I-17) 5,5,10
 5    SC(I)= D*SC(I)/AB
 10   IF(I-36) 15,15,20
 15   S1(I)= D*S1(I)/AB
      S3(I)= D*S3(I)/AB
 20   S2(I)= D*S2(I)/AB
 25   CONTINUE
      RETURN
      END
```

SUBPROGRAM PLTSTF: CARD IMAGE LISTING 3/3

SUBROUTINE PLTMAS (A,B,R,S1,S2,S3,SC)

PURPOSE: To compute the consistent mass matrix of the modified sixteen degree-of-freedom plate element described by Bogner, Fox, and Schmidt with an interior mode in the form of clamped-clamped beam functions.

SUBPROGRAMS REQUIRED: None

VARIABLES:

A - Dimension of the plate element in the x-direction

B - Dimension of the plate element in the y-direction

R - Mass per unit area of plate element

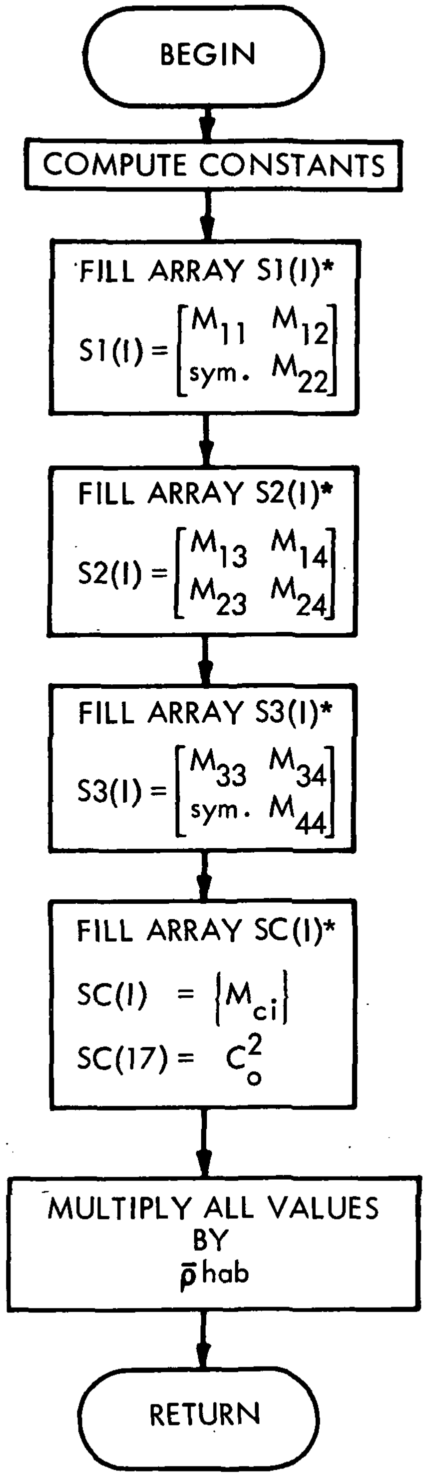
S1,S2,S3,SC - Partitioned mass matrices for the plate element (see Flow Chart and Appendix B)

RESTRICTIONS: None

ACCURACY: See References below

SIZE: 001520_8

REFERENCES: See References for subroutine PLTSTF



*SEE APPENDIX B

FLOW CHART: SUBROUTINE PLTMAS (A, B, R, S1, S2, S3, SC)

```
      SUBROUTINE PLTMAS(A,B,R,S1,S2,S3,SC)
      DIMENSION S1(2),S2(2),S3(2),SC(2)
      AB=A*B
      C1= 13./35.
      C2= 11./210.
      C3=  1./105.
      C4=  9./70.
      C5= 13./420.
      C6=  1./140.
      C0= 0.39647605
      C11= .20771538
      C21= .04469616
      C31=4.6472757
      R1= C0*(.0625*C0-2.*C11*C11)
      R2= C0*(.015625*C0-C11*(C21+.25*C11))
      R3= C0*(.00390625*C0-.5*C11*C21)
      R4= C0*(.00390625*C0-C21*C21-.0625*C11*C11)
      R5= C0*(C0/1024.-.25*C21*(C21+.25*C11))
      R6= C0*(C0/4096.-.125*C21*C21)
      R7= C0*(.25*C0-4.*C11*C11)
      R8= C0*(.0625*C0-4.*C11*C21)
      R9= C0*(.015625*C0-4.*C21*C21)
      S1(1)=  C1*C1+R1
      S1(2)=  (C1*C2+R2)*B
      S1(3)=  (C1*C3+R3)*B*B
      S1(4)= -(C1*C2+R2)*A
      S1(5)= -(C2*C2+R3)*AB
      S1(6)=  (C1*C3+R3)*A*A
      S1(7)=  (C2*C2+R4)*AB
      S1(8)=  (C2*C3+R5)*AB*B
      S1(9)= -(C2*C3+R5)*A*AB
      S1(10)= (C3*C3+R6)*AB*AB
      S1(11)=  C1*C4+R1
      S1(12)= (C2*C4+R2)*B
      S1(13)=-(C1*C5+R2)*A
      S1(14)= (C2*C5+R4)*AB
      S1(15)= S1(1)
      S1(16)= S1(12)
      S1(17)= (C3*C4+R3)*B*B
      S1(18)=-(C2*C5+R3)*AB
      S1(19)= (C3*C5+R5)*AB*B
      S1(20)= S1(2)
      S1(21)= S1(3)
      S1(22)=-S1(13)
      S1(23)=-S1(18)
      S1(24)=-(C1*C6+R3)*A*A
      S1(25)= (C2*C6+R5)*A*AB
      S1(26)=-S1(4)
      S1(27)=-S1(5)
      S1(28)= S1(6)
      S1(29)=-S1(14)
      S1(30)=-S1(19)
      S1(31)= S1(25)
      S1(32)=-(C3*C6+R6)*AB*AB
      S1(33)=-S1(7)
      S1(34)=-S1(8)
      S1(35)= S1(9)
      S1(36)= S1(10)
```

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 1/4

```
S2(1)=  C1*C4+R1
S2(2)=  (C1*C5+R2)*B
S2(3)= -(C2*C4+R2)*A
S2(4)=  (C2*C5+R4)*AB
S2(5)=  C4*C4+R1
S2(6)=  (C4*C5+R2)*B
S2(7)=  (C4*C5+R2)*A
S2(8)= -(C5*C5+R4)*AB
S2(9)= -S2(2)
S2(10)=-(C1*C6+R3)*B*B
S2(11)= (C2*C5+R3)*AB
S2(12)=-(C2*C6+R5)*AB*B
S2(13)=-S2(6)
S2(14)=-(C4*C6+R3)*B*B
S2(15)=-(C5*C5+R3)*AB
S2(16)= (C5*C6+R5)*AB*B
S2(17)= S2(3)
S2(18)=-S2(11)
S2(19)= (C3*C4+R3)*A*A
S2(20)=-(C3*C5+R5)*A*AB
S2(21)=-S2(7)
S2(22)= S2(15)
S2(23)=-(C4*C6+R3)*A*A
S2(24)= (C5*C6+R5)*A*AB
S2(25)=-S2(4)
S2(26)= S2(12)
S2(27)=-S2(20)
S2(28)=-(C3*C6+R6)*AB*AB
S2(29)= S2(8)
S2(30)=-S2(16)
S2(31)=-S2(24)
S2(32)= (C6*C6+R6)*AB*AB
S2(33)= S2(5)
S2(34)= S2(6)
S2(35)=-S2(7)
S2(36)=-S2(8)
S2(37)= S2(1)
S2(38)= S2(2)
S2(39)=-S2(3)
S2(40)=-S2(4)
S2(41)= S2(13)
S2(42)= S2(14)
S2(43)=-S2(15)
S2(44)=-S2(16)
S2(45)= S2(9)
S2(46)= S2(10)
S2(47)=-S2(11)
S2(48)=-S2(12)
S2(49)=-S2(21)
S2(50)=-S2(22)
S2(51)= S2(23)
S2(52)= S2(24)
S2(53)=-S2(17)
S2(54)=-S2(18)
S2(55)= S2(19)
S2(56)= S2(20)
S2(57)=-S2(29)
S2(58)=-S2(30)
S2(59)= S2(31)
```

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 2/4

```
S2(60)= S2(32)
S2(61)=-S2(25)
S2(62)=-S2(26)
S2(63)= S2(27)
S2(64)= S2(28)
S3(1)=  S1(1)
S3(2)= -S1(2)
S3(3)=  S1(3)
S3(4)=  S1(4)
S3(5)= -S1(5)
S3(6)=  S1(6)
S3(7)= -S1(7)
S3(8)=  S1(8)
S3(9)= -S1(9)
S3(10)= S1(10)
S3(11)= S1(11)
S3(12)=-S1(12)
S3(13)= S1(13)
S3(14)=-S1(14)
S3(15)= S1(15)
S3(16)=-S1(16)
S3(17)= S1(17)
S3(18)=-S1(18)
S3(19)= S1(19)
S3(20)=-S1(20)
S3(21)= S1(21)
S3(22)= S1(22)
S3(23)=-S1(23)
S3(24)= S1(24)
S3(25)=-S1(25)
S3(26)= S1(26)
S3(27)=-S1(27)
S3(28)= S1(28)
S3(29)=-S1(29)
S3(30)= S1(30)
S3(31)=-S1(31)
S3(32)= S1(32)
S3(33)=-S1(33)
S3(34)= S1(34)
S3(35)=-S1(35)
S3(36)= S1(36)
SC(1)= -R7
SC(2)= -R8*B
SC(3)= R8*A
SC(4)= -R9*AB
SC(5)= -R7
SC(6)= -R8*B
SC(7)=-SC(3)
SC(8)=-SC(4)
SC(9)= -R7
SC(10)=-SC(2)
SC(11)= R8*A
SC(12)= R9*AB
SC(13)=-R7
SC(14)= R8*B
SC(15)=-R8*A
SC(16)=-R9*AB
SC(17)= C0*C0
DO 25 I=1,64
```

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 3/4

```
      IF(I-17) 5,5,10
 5    SC(I)= R*SC(I)*AB
 10   IF(I-36) 15,15,20
 15   S1(I)= R*S1(I)*AB
      S3(I)= R*S3(I)*AB
 20   S2(I)= R*S2(I)*AB
 25   CONTINUE
      RETURN
      END
```

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 4/4

SUBROUTINE ASSYP (A, S1, S2, S3, SC, I, M, J, N, NCP)

PURPOSE: To assemble (add) the plate element stiffness or mass matrices (S1, S2, S3, SC) in the appropriate location in the system free-free stiffness or mass matrix (A).

SUBPROGRAMS REQUIRED: LOC

VARIABLES:

A - System free-free stiffness or mass matrices

S1, S2, S3, SC - Partitioned element stiffness or mass matrix (see Subroutines PLTSTF and PLTMAS)

I - Index for bay number in x-direction

M - Number of grid points in x-direction

J - Index for bay number in y-direction

N - Number of grid points in y-direction

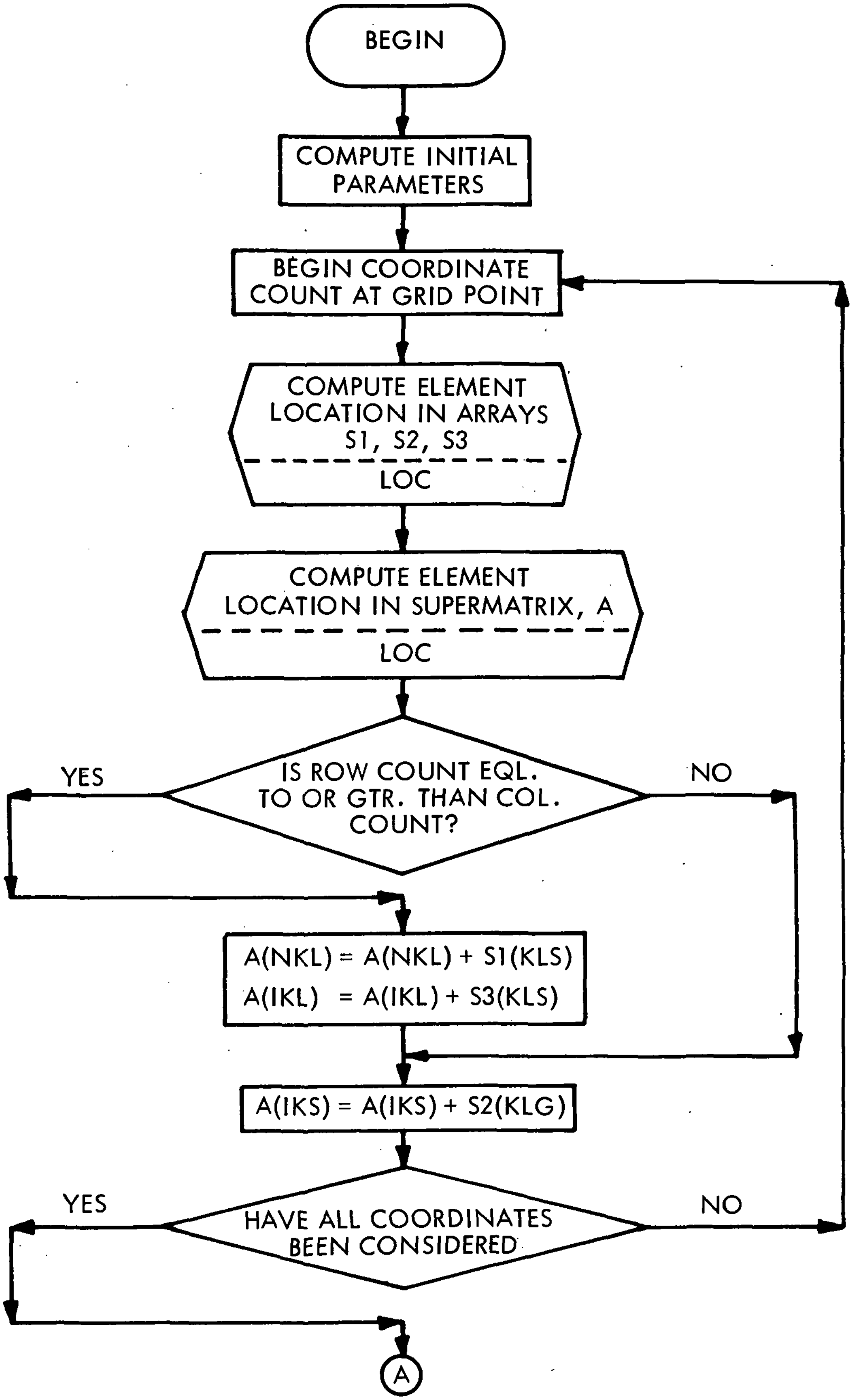
NCP - Number of coordinates per grid point

RESTRICTIONS: None

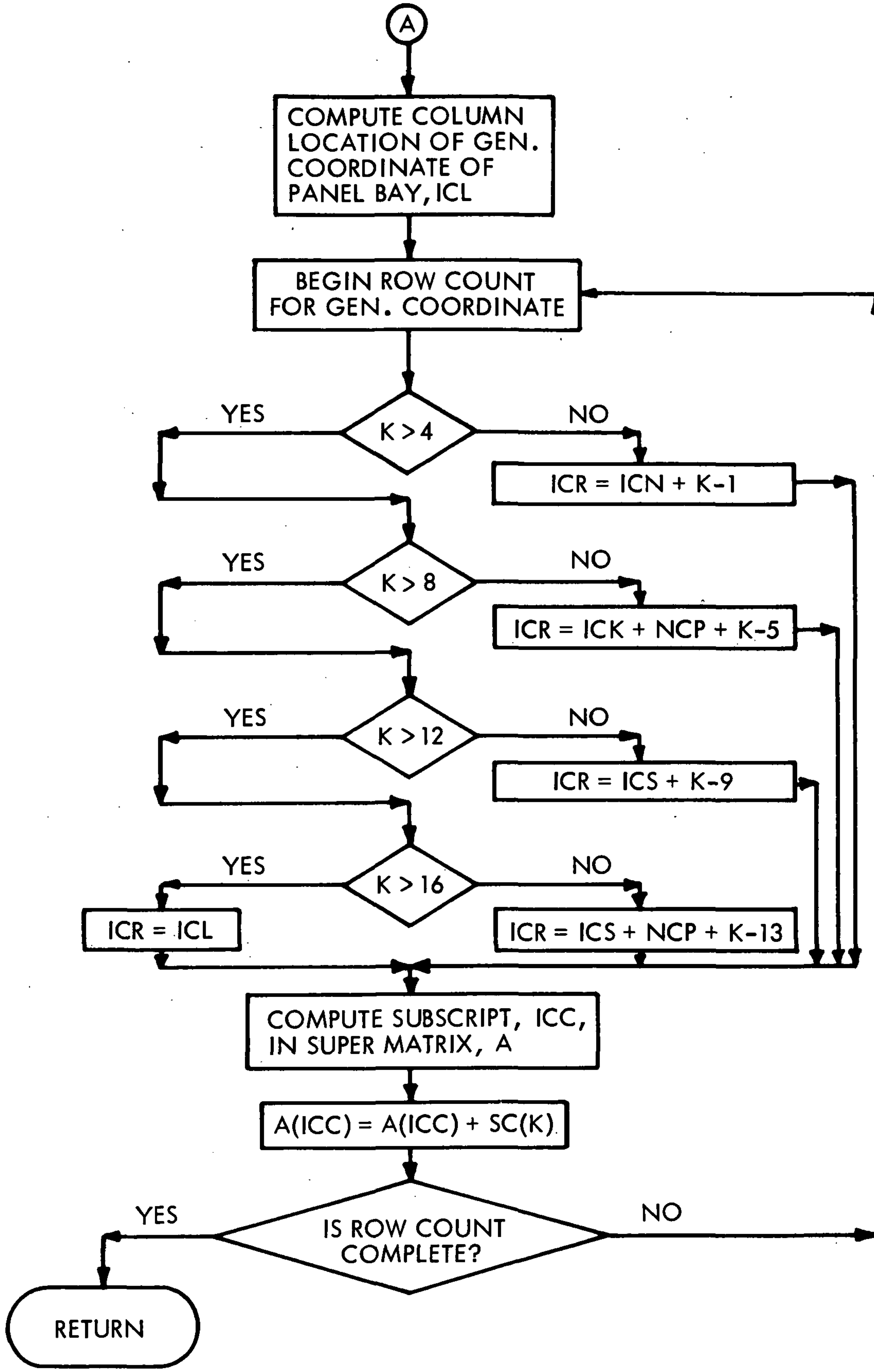
ACCURACY: Not Applicable

SIZE: 000270_8

REFERENCES: None



FLOW CHART: SUBROUTINE ASSYP (A,S1,S2,S3,SC,I,M,J,N,NCP)



FLOW CHART: SUBROUTINE ASSYP (A, S1, S2, S3, SC, I, M, J, N, NCP)

```
      SUBROUTINE ASSYP(A,S1,S2,S3,SC,I,M,J,N,NCP)
      DIMENSION A(2),S1(2),S2(2),S3(2),SC(2)
      NCO=NCP*M*N+(M-1)*(N-1)
      NLM=2*NCP
      NGP=M*(J-1)+I
      NOBAY=(M-1)*(J-1)+I
      ICN=NCP*(NGP-1)+1
      ICS=ICN+NCP*M
      DO 20 K=1,NLM
      DO 20 L=1,NLM
      CALL LOC(K,L,KLS,NLM,1)
      CALL LOC(K,L,KLG,NLM,0)
      INK=ICN+K-1
      INL=ICN+L-1
      CALL LOC(INK,INL,NKL,NCO,1)
      ISK=ICS+K-1
      ISL=ICS+L-1
      CALL LOC(ISK,ISL,IKL,NCO,1)
      CALL LOC(INK,ISL,IKS,NCO,1)
      IF(K-L) 15,10,10
10    A(NKL)=A(NKL)+S1(KLS)
      A(IKL)=A(IKL)+S3(KLS)
15    A(IKS)=A(IKS)+S2(KLG)
20    CONTINUE
      ICL=NCP*M*N+NOBAY
      DO 70 K=1,17
      IF(K-4) 25,25,30
25    ICR=ICN+K-1
      GO TO 65
30    IF(K-8) 35,35,40
35    ICR=ICN+NCP+K-5
      GO TO 65
40    IF(K-12) 45,45,50
45    ICR=ICS+K-9
      GO TO 65
50    IF(K-16) 55,55,60
55    ICR=ICS+NCP+K-13
      GO TO 65
60    ICR=ICL
65    CALL LOC(ICR,ICL,ICC,NCO,1)
      A(ICC)=A(ICC)+SC(K)
70    CONTINUE
      RETURN
      END
```

SUBPROGRAM ASSYP: CARD IMAGE LISTING

SUBROUTINE RIB (I,IØP,D,S1,S2,S3)

PURPOSE: To compute the stiffness and consistent mass matrices for a finite element representation of a thin-walled open-section beam.

SUBPROGRAMS REQUIRED: Zero

VARIABLES:

I - Index denoting rib number for constants in common data block with PLTVIB (see Figure 3)

IØP - IØP = 1, stiffness matrix is computed
IØP = 2, consistent mass matrix is computed

D - Length of beam element

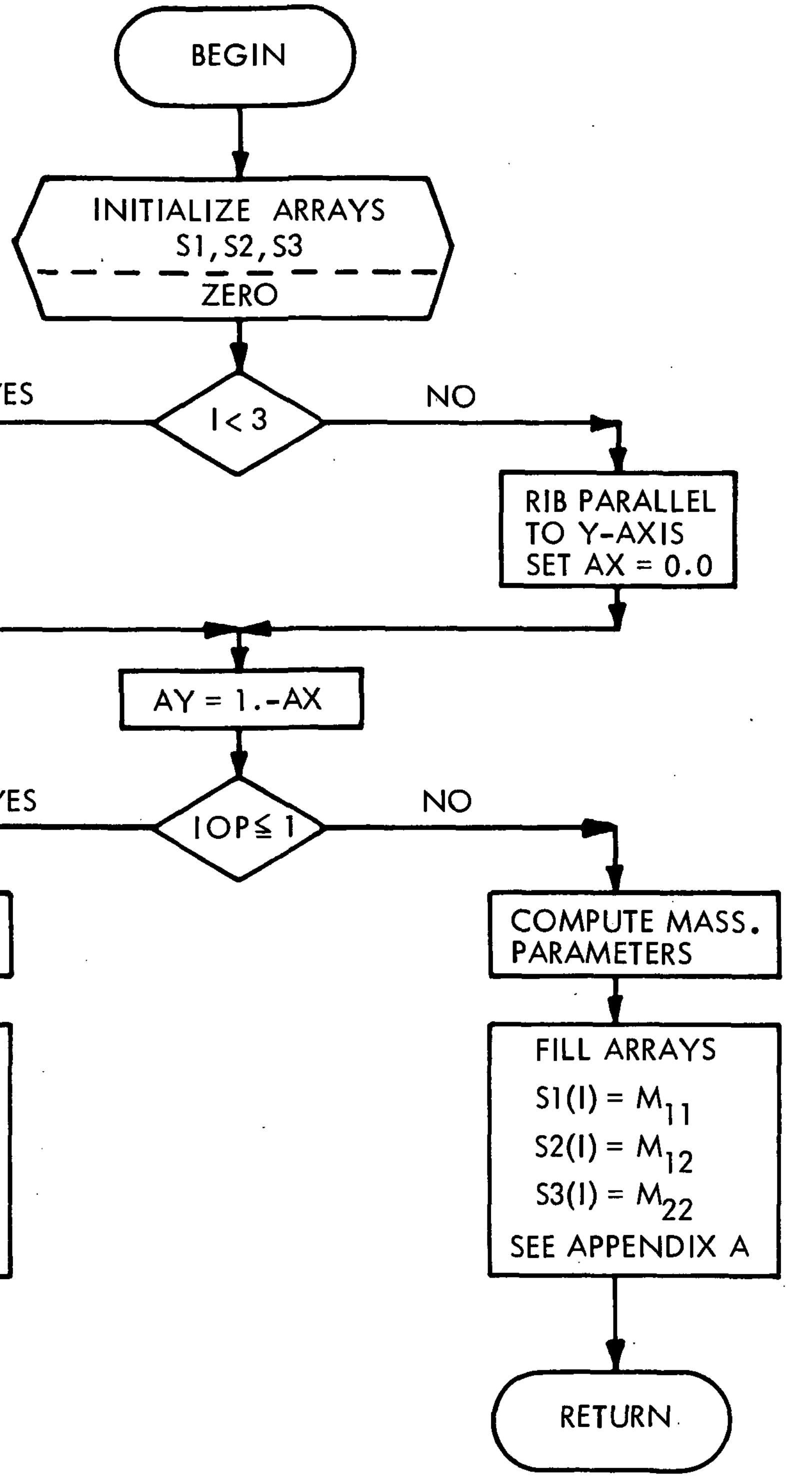
S1,S2,S3 - Partitioned stiffness on mass matrix (see Flow Chart)

RESTRICTIONS: $D \neq 0$

ACCURACY: See Reference 1, p. 8

SIZE: 001175_8

REFERENCES: Reference 1, pp. 5 - 11



FLOW CHART: SUBROUTINE RIB (I,IOP,D,S1,S2,S3)

```
      SUBROUTINE RIB(I,IOP,D,S1,S2,S3)
      DIMENSION ER(4),GR(4),RHO(4),SR2(4),C2(4),SR3(4),C3(4),
     1AR(4),A22(4),A23(4),A33(4),SJ(4),RE2(4),RE3(4),GM(4)
      COMMON ER,GR,RHO,SR2,C2,SR3,C3,
     1AR,A22,A23,A33,SJ,RE2,RE3,GM
      DIMENSION S1(2),S2(2),S3(2)
      CALL ZERO(S1,36)
      CALL ZERO(S2,64)
      CALL ZERO(S3,36)
      IF(I-3) 5,10,10
5     AX=1.0
      GO TO 15
10    AX=0.0
15    AY=1.0-AX
      D2=D*D
      D3=D*D2
      IF(IOP-1) 20,20,25
20    B22=ER(I)*A22(I)/D3
      B23=ER(I)*A23(I)/D3
      B33=ER(I)*A33(I)/D3
      R2= ER(I)*RE2(I)/D3
      R3= ER(I)*RE3(I)/D3
      RX= SR2(I)*B22-SR3(I)*B23-R2
      RY= SR2(I)*B22-SR3(I)*B23+R2
      G1= ER(I)*GM(I)/D3+GR(I)*SJ(I)/(10.*D)
      G2= ER(I)*GM(I)/D2+GR(I)*SJ(I)/60.
      G3= ER(I)*GM(I)/D+GR(I)*SJ(I)*D/30.
      G4= ER(I)*GM(I)/D-GR(I)*SJ(I)*D/60.
      T1X=G1+SR3(I)*SR3(I)*B33-2.*SR2(I)*SR3(I)*B23
     1+SR2(I)*SR2(I)*B22-2.*(SR3(I)*R3-SR2(I)*R2)
      T2X=G2-(SR3(I)*R3-SR2(I)*R2)*D
      T1Y=G1+SR3(I)*SR3(I)*B33-2.*SR2(I)*SR3(I)*B23
     1+SR2(I)*SR2(I)*B22+2.*(SR2(I)*R2-SR3(I)*R3)*D
      T2Y=G2+(SR3(I)*R3-SR2(I)*R2)*D
      S1(1)=  12.*B22
      S1(2)=   6.*(AY*B22*D-2.*AX*RY)
      S1(3)=   4.*(AY*B22*D2+3.*AX*T1X)
      S1(4)=   6.*(2.*AY*RX-AX*B22*D)
      S1(5)=   6.*(AY*RX*D+AX*RY*D)
      S1(6)=   4.*(3.*AY*T1Y+AX*B22*D2)
      S1(7)=   6.*(AY-AX)*R2*D
      S1(8)=   2.*(2.*AY*R2*D2+3.*AX*T2X)
      S1(9)=  -2.*(3.*AY*T2Y-2.*AX*R2*D2)
      S1(10)=  4.*G3
      S2(1)=  -S1(1)
      S2(2)=  -S1(2)
      S2(3)=  -S1(4)
      S2(4)=  -S1(7)
      S2(5)=   6.*(AY*B22*D+2.*AX*RY)
      S2(6)=   2.*(AY*B22*D2-6.*AX*T1X)
      S2(7)=  -6.*(AX*RY*D-AY*RX*D)
      S2(8)=   2.*(AY*R2*D2-3.*AX*T2X)
      S2(9)=  -6.*(2.*AY*RX+AX*B22*D)
      S2(10)= -6.*(AY*RX*D-AX*RY*D)
      S2(11)=  2.*(AX*B22*D2-6.*AY*T1Y)
      S2(12)=  2.*(AX*R2*D2+3.*AY*T2Y)
      S2(13)=  S1(7)
      S2(14)=  2.*(AY*R2*D2+3.*AX*T2X)
```

SUBPROGRAM RIB: CARD IMAGE LISTING 1/2

```
      S2(15)= -2.*(3.*AY*T2Y-AX*R2*D2)
      S2(16)=  2.*G4
      S3(1)=   S1(1)
      S3(2)=  -6.*(AY*B22*D+2.*AX*RY)
      S3(3)=   S1(3)
      S3(4)=   6.*(2.*AY*RX+AX*B22*D)
      S3(5)=  -S1(5)
      S3(6)=   S1(6)
      S3(7)=  -S1(7)
      S3(8)=   2.*(2.*AY*R2*D2-3.*AX*T2X)
      S3(9)=   2.*(3.*AY*T2Y+2.*AX*R2*D2)
      S3(10)=  4.*G3
      RETURN
25    RM= RHO(I)*AR(I)*D/386.
      E2= C2(I)-SR2(I)
      E3= C3(I)-SR3(I)
      R= (E2*E2+E3*E3)/D2
      RP=(A22(I)+A33(I))/(AR(I)*D2)
      P1=13./35.
      P2=11./210.
      P3= 1./105.
      P4= 9./70.
      P5=13./420.
      P6= 1./140.
      S1(1)= P1*RM
      S1(2)= (P1*AX*E2+P2*AY*D)*RM
      S1(3)= (P1*AX*(R+RP)+P3*AY)*RM*D2
      S1(4)=-(P2*AX*D+P1*AY*E2)*RM
      S1(5)= -P2*E2*RM*D
      S1(6)= (P3*AX+P1*AY*(R+RP))*RM*D2
      S1(8)= P2*AX*RM*D3*RP
      S1(9)=-P2*AY*RM*D3*RP
      S1(10)=P3*RM*D*D3*RP
      S2(1)=   P4*RM
      S2(2)=  (P4*AX*E2+P5*AY*D)*RM
      S2(3)= -(P5*AX*D+P4*AY*E2)*RM
      S2(5)=  (P4*AX*E2-P5*AY*D)*RM
      S2(6)=  (P4*AX*(R+RP)-P6*AY)*RM*D2
      S2(7)= -P5*(AX-AY)*E2*RM*D
      S2(8)=   P5*AX*RM*D3*RP
      S2(9)= (P5*AX*D-P4*AY*E2)*RM
      S2(10)=-S2(7)
      S2(11)=-(P6*AX-P4*AY*(R+RP))*RM*D2
      S2(12)= -P5*AY*RM*D3*RP
      S2(14)= -P5*AX*RM*D3*RP
      S2(15)=  P5*AY*RM*D3*RP
      S2(16)= -P6*RM*D*D3*RP
      S3(1)=  S1(1)
      S3(2)=  (P1*AX*E2-P2*AY*D)*RM
      S3(3)=  S1(3)
      S3(4)=  (P2*AX*D-P1*AY*E2)*RM
      S3(5)= -S1(5)
      S3(6)=  S1(6)
      S3(8)= -S1(8)
      S3(9)= -S1(9)
      S3(10)= S1(10)
      RETURN
      END
```

SUBPROGRAM RIB: CARD IMAGE LISTING 2/2

SUBROUTINE ASSYR (A,S1,S2,S3,I,M,J,N,NCP,AX)

PURPOSE: To assemble (add) the rib element stiffness or mass matrices (S1,S2, S3) in the appropriate location in the system free-free stiffness or mass matrix (A).

SUBPROGRAMS REQUIRED: LOC

VARIABLES:

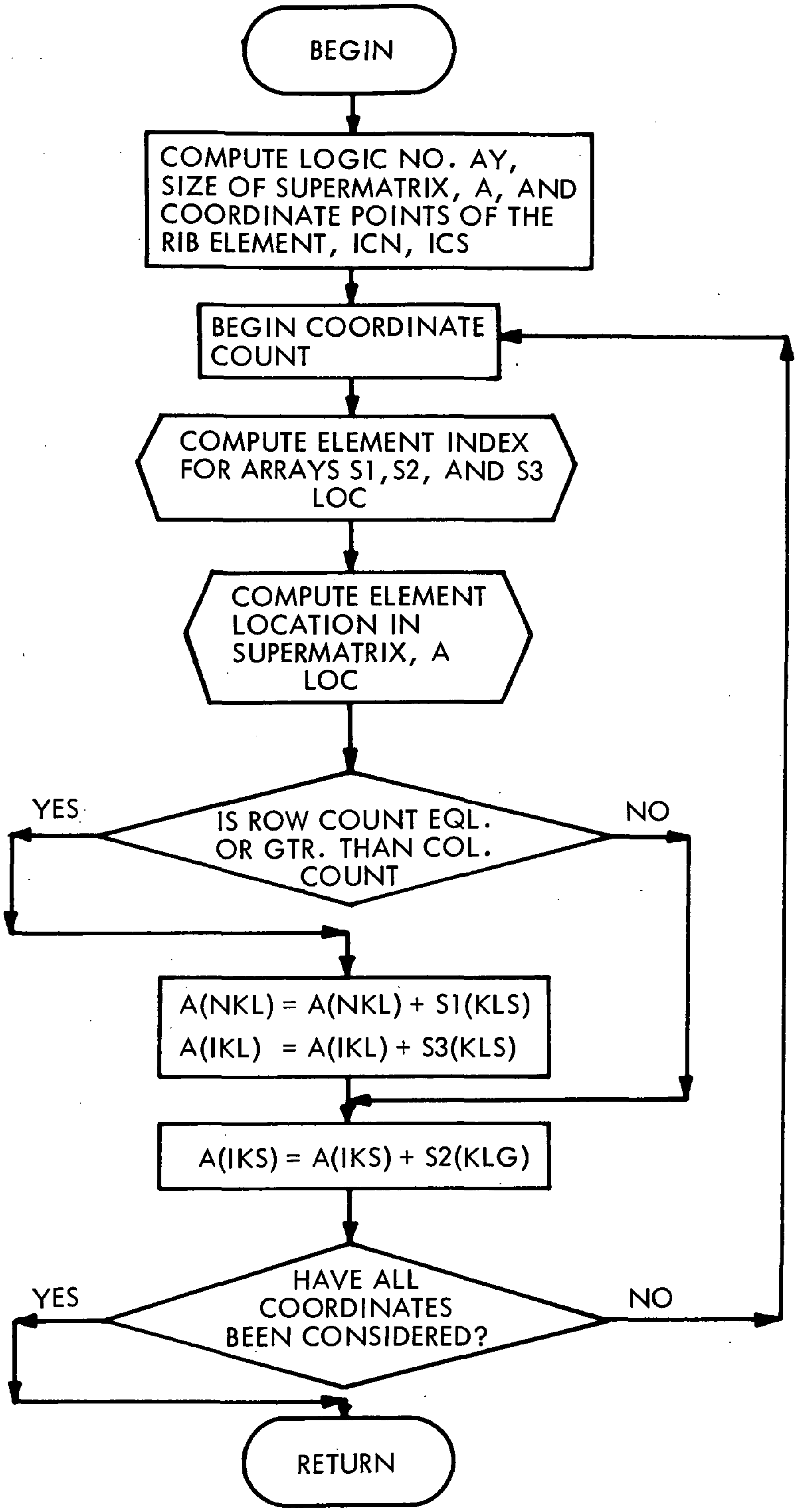
- A - System free-free stiffness on mass matrices
- S1,S2,S3 - Partitioned element stiffness or mass matrix (see Subroutine Rib)
- I - Index for bay number in x-direction
- M - Number of grid points in x-direction
- J - Index for bay number in y-direction
- N - Number of grid points in y-direction
- NCP - Number of coordinates per grid point
- AX - Logic number: AX = 1.0 for ribs parallel to x-axis; AX = 0.0 for ribs parallel to y-axis

RESTRICTIONS: $M \leq 4$, $N \leq 4$

ACCURACY: Not Applicable

SIZE: 000207_8

REFERENCES: None



FLOW CHART: SUBROUTINE ASSYR (A, S1, S2, S3, I, M, J, N, NCP, AX)

```
      SUBROUTINE ASSYR(A,S1,S2,S3,I,M,J,N,NCP,AX)
      DIMENSION A(2),S1(2),S2(2),S3(2)
      AY=1.-AX
      NCO=NCP*M*N+(M-1)*(N-1)
      NGP=M*(J-1)+I
      ICN=NCP*(NGP-1)+1
      ICS=ICN+IFIX(AX)*NCP+IFIX(AY)*NCP*M
      DO 20 K=1,NCP
      DO 20 L=1,NCP
      CALL LOC(K,L,KLS,NCP,1)
      CALL LOC(K,L,KLG,NCP,0)
      INK=ICN+K-1
      INL=ICN+L-1
      CALL LOC(INK,INL,NKL,NCO,1)
      ISK=ICS+K-1
      ISL=ICS+L-1
      CALL LOC(ISK,ISL,IKL,NCO,1)
      CALL LOC(INK,ISL,IKS,NCO,1)
      IF(K-L) 15,10,10
10    A(NKL)=A(NKL)+S1(KLS)
      A(IKL)=A(IKL)+S3(KLS)
15    A(IKS)=A(IKS)+S2(KLG)
20    CONTINUE
      RETURN
      END
```

SUBPROGRAM ASSYR: CARD IMAGE LISTING

SUBROUTINE NONDIM (A,M,N,TK,TL)

PURPOSE: To nondimensionalize the stiffness and mass matrices of the stiffened panel structure.

VARIABLES:

A - Stiffness or mass matrix

M - Number of grid points in the x-direction

N - Number of grid points in the y-direction

TK - Nondimensionalizing parameter for force (stiffness matrix) on mass (mass matrix). In each case the parameter is calculated as the average value of the stiffness or mass of the direct twist terms. See Program PLTVIB statement numbers 270 to 290.

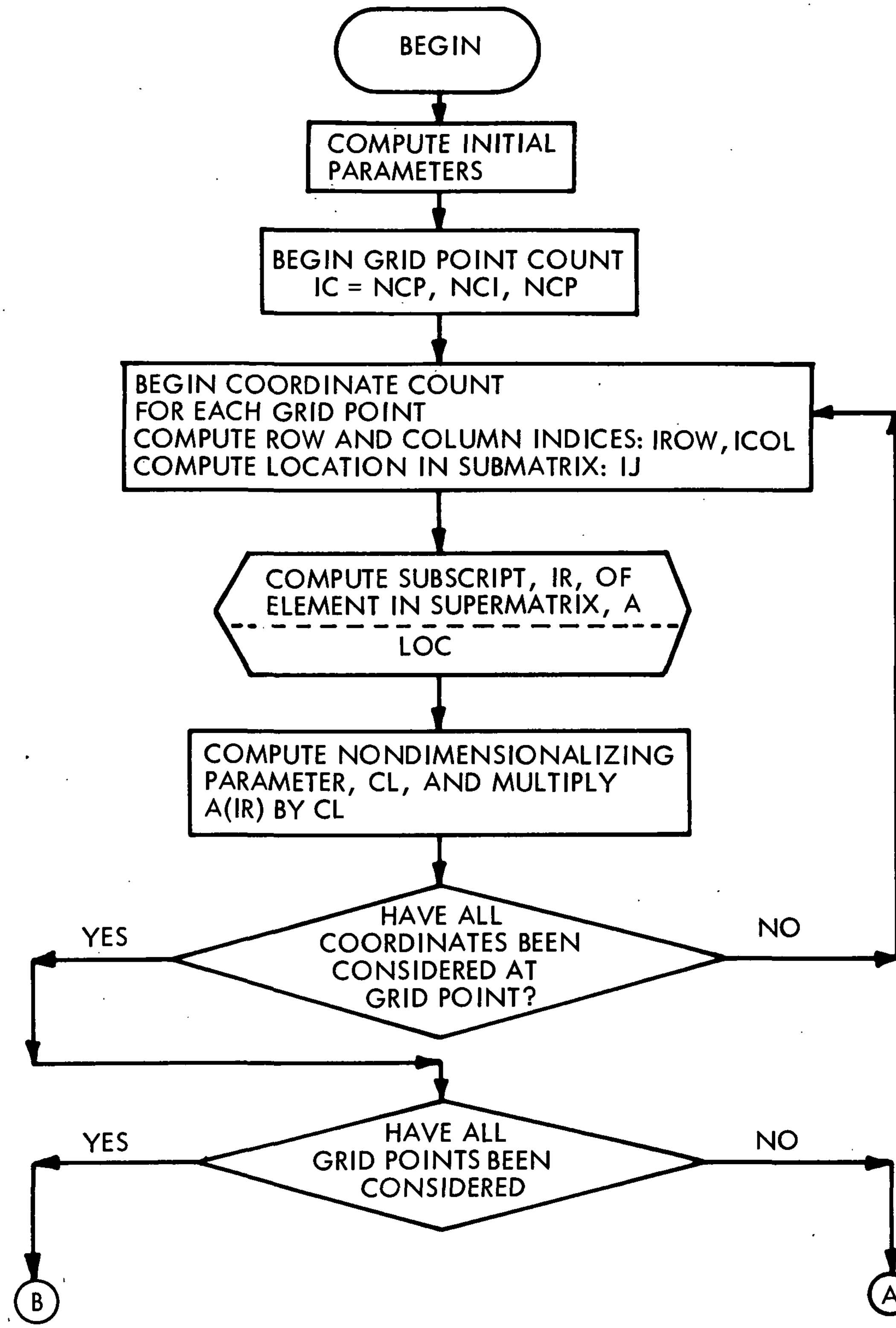
TL - Nondimensionalizing parameter for length. Taken as the diagonal length of bay 5 (see Figure 3) of the structure.

RESTRICTIONS: $TK \neq 0$, $TL \neq 0$

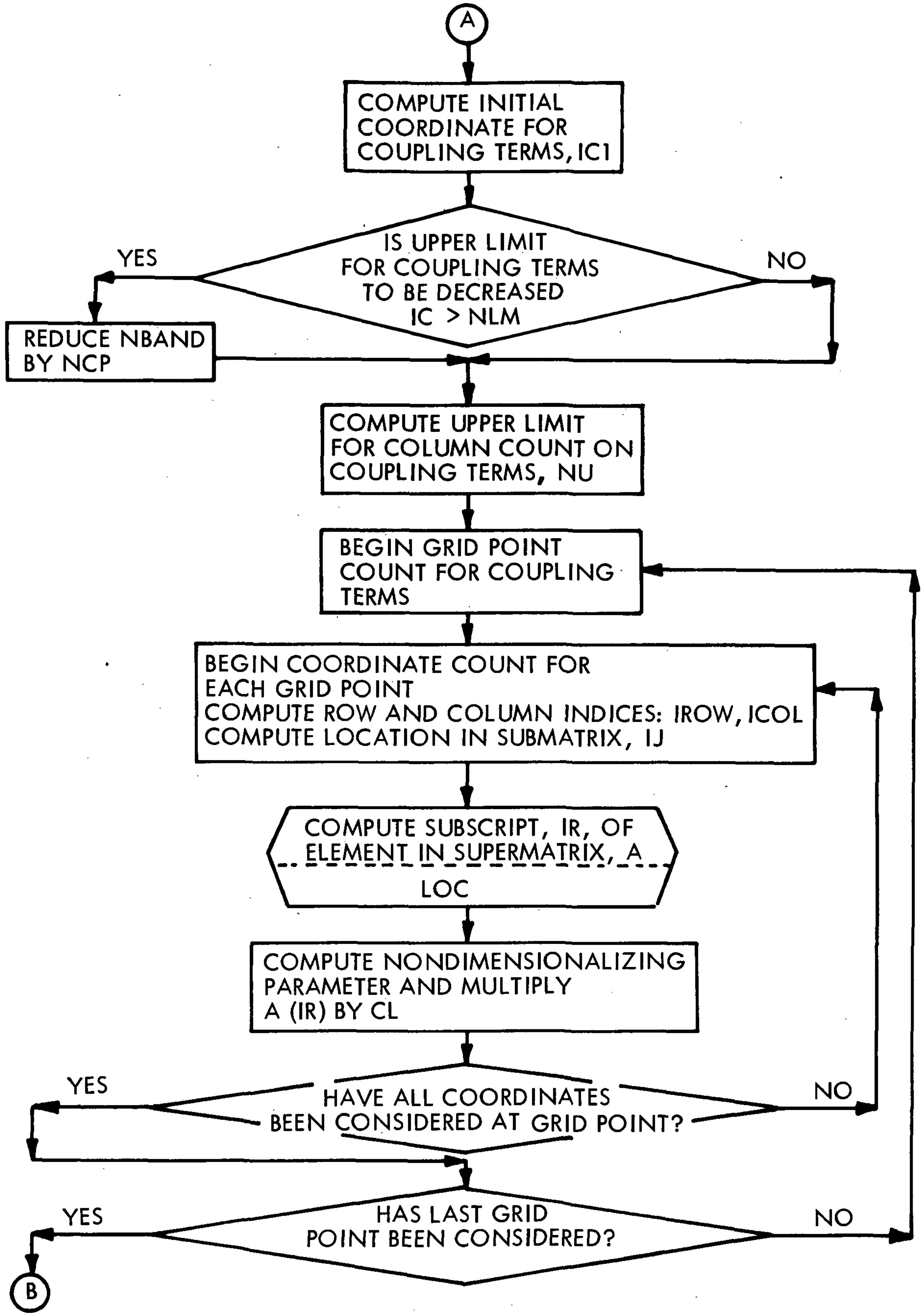
ACCURACY: Not Applicable

SIZE: 000444_8

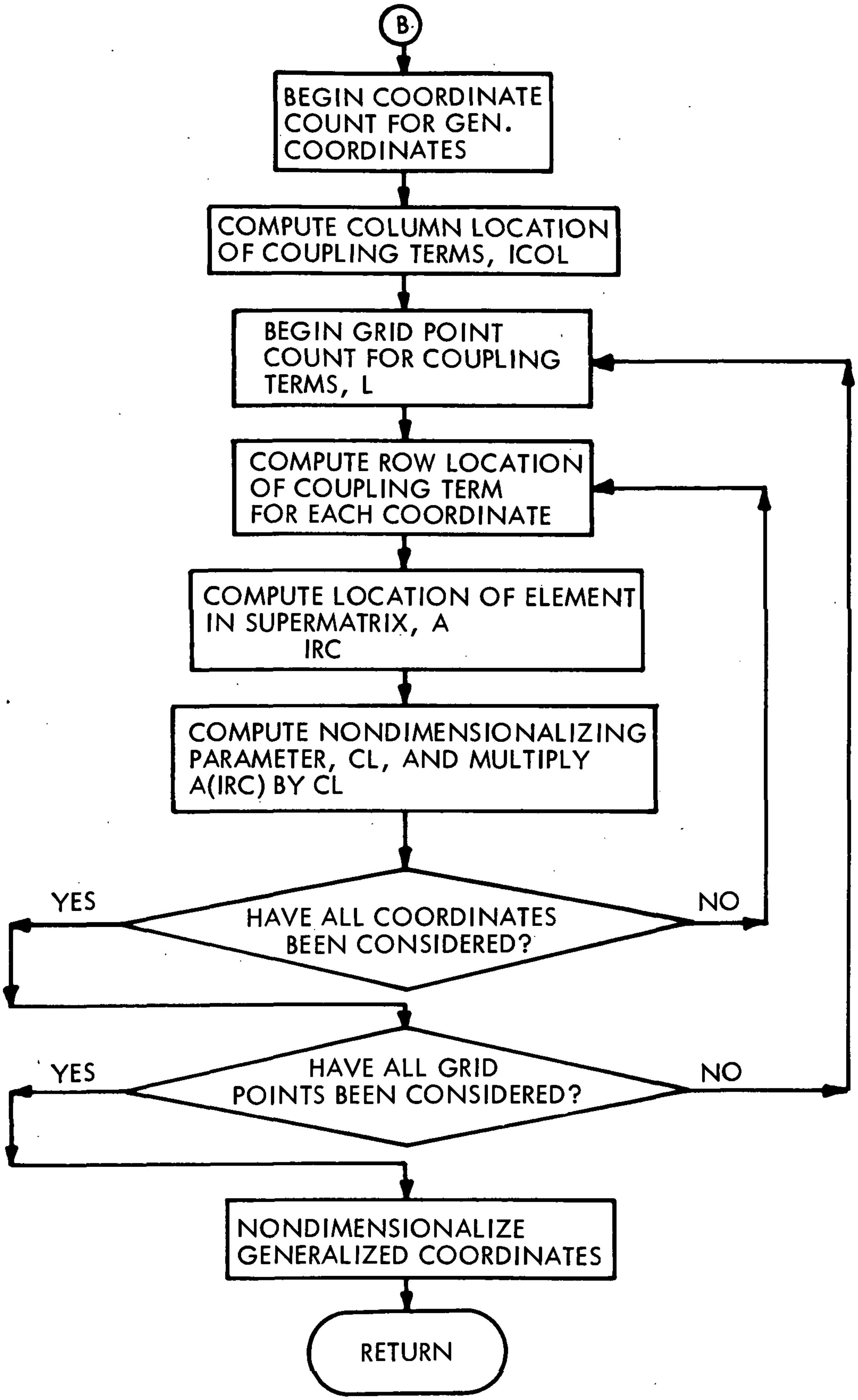
REFERENCES: None



FLOW CHART: SUBROUTINE NONDIM (A,M,N,TK,TL)



FLOW CHART: SUBROUTINE NONDIM (A,M,N,TK,TL)



FLOW CHART: SUBROUTINE NONDIM (A,M,N,TK,TL)

```
      SUBROUTINE NONDIM(A,M,N,TK,TL)
      DIMENSION A(2)
      NCP=4
      NCI=NCP*M*N
      NCO=NCI+(M-1)*(N-1)
      NLM=NCP*(M*N-M-2)+1
      NBAND=NCP*(M+1)
      MBAY=M-1
      NBAY=N-1
      DO 100 IC=NCP,NCI,NCP
      I1=IC-NCP+1
      DO 35 I=1,NCP
      IROW=I1+I-1
      DO 35 J=I,NCP
      ICOL=I1+J-1
      IJ=I+(J*J-J)/2
      CALL LOC(IROW,ICOL,IR,NCO,1)
      GO TO (5,10,15,10,15,15,15,20,20,25),IJ
5     CL=TL*TL/TK
      GO TO 30
10    CL=TL/TK
      GO TO 30
15    CL=1.0/TK
      GO TO 30
20    CL=1.0/(TL*TK)
      GO TO 30
25    CL=1.0/(TL*TL*TK)
30    A(IR)=CL*A(IR)
35    CONTINUE
      IF(IC-NCI) 40,100,100
40    IC1=IC+1
      IF(IC1-NLM) 50,50,45
45    NBAND=NBAND-NCP+1
50    NU=IC+NBAND
      DO 95 JC=IC1,NU,NCP
      IF(JC-NCI) 55,95,95
55    DO 90 J=1,NCP
      ICOL=JC+J-1
      DO 90 I=1,NCP
      IROW=I1+I-1
      CALL LOC(IROW,ICOL,IR,NCO,1)
      IJ=I+NCP*(J-1)
      GO TO (60,65,65,70,65,70,70,75,65,70,70,75,
     170,75,75,80),IJ
60    CL=TL*TL/TK
      GO TO 85
65    CL=TL/TK
      GO TO 85
70    CL=1.0/TK
      GO TO 85
75    CL=1.0/(TL*TK)
      GO TO 85
80    CL=1.0/(TL*TL*TK)
85    A(IR)=CL*A(IR)
90    CONTINUE
95    CONTINUE
100   CONTINUE
      DO 155 J=1,NBAY
```

SUBPROGRAM NONDIM: CARD IMAGE LISTING 1/2

```
      DO 155 I=1,MBAY
      IBAY=I+MBAY*(J-1)
      ICOL=NCI+IBAY
      ICS=(ICOL*ICOL-ICOL)/2
      IC=NCP*IBAY+NCP*(J-1)
      DO 150 L=1,4
      GO TO (105,110,115,120),L
105   ICC=IC
      GO TO 125
110   ICC=IC+NCP
      GO TO 125
115   ICC=IC+NCP*M
      GO TO 125
120   ICC=IC+NCP*(M+1)
125   DO 150 K=1,NCP
      IRR=ICC-NCP+K
      IRC=IRR+ICS
      GO TO (130,135,135,140),K
130   CL=TL*TL/TK
      GO TO 145
135   CL=TL/TK
      GO TO 145
140   CL=1./TK
145   A(IRC)=CL*A(IRC)
150   CONTINUE
155   CONTINUE
      CL=TL*TL/TK
      NS=NCI+1
      DO 160 I=NS,NCO
      II=I*(I+1)/2
      A(II)=CL*A(II)
160   CONTINUE
      RETURN
      END
```

SUBPROGRAM NONDIM: CARD IMAGE LISTING 2/2

SUBROUTINE ZERO (A, N)

PURPOSE: To set the first N elements of a single subscripted array to zero.

SUBPROGRAMS REQUIRED: None

VARIABLES:

A - Array to be initialized

N - Upper limit for elements of A set to zero

RESTRICTIONS: N must be equal to or less than the dimensioned size of A in the calling program.

ACCURACY: Not Applicable

SIZE: 000021_8

REFERENCES: None

SUBROUTINE FILL (A, B, N, MS)

PURPOSE: To fill array A with elements of array B

SUBPROGRAMS REQUIRED: LOC

VARIABLES:

A - Single subscripted array

B - Single subscripted array (symmetric storage mode: LOC)

N - Number of rows or columns in A or B

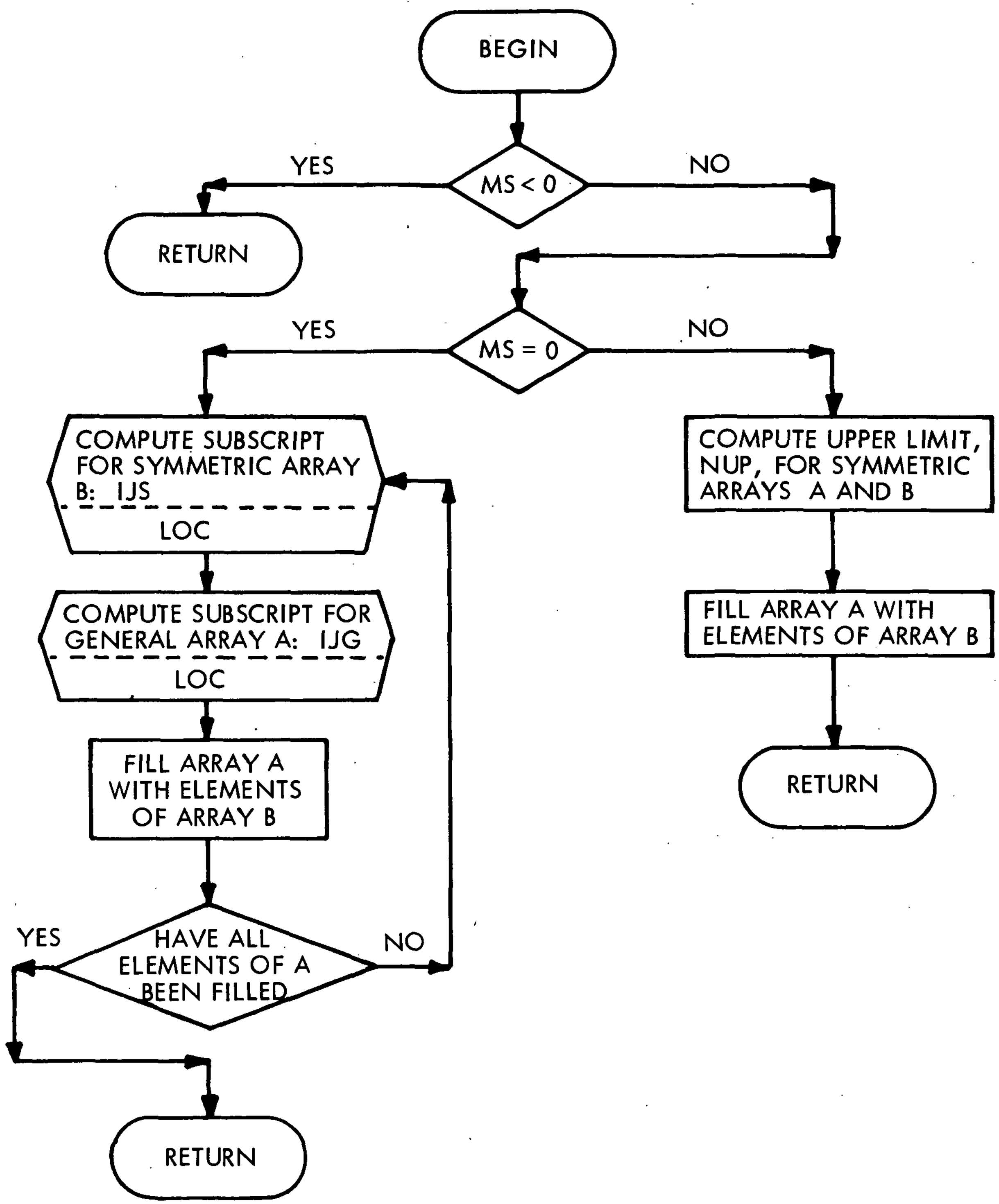
MS - Logic number : MS   0 subroutine is bypassed; MS = 0, A is a general matrix (NXN) and B is a symmetric matrix; MS = 1, A and B are both symmetric matrices

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000076_8

REFERENCES: See Subroutine LOC



FLOW CHART: SUBROUTINE FILL (A,B,N,MS)

```
      SUBROUTINE ZERO(A,N)
      DIMENSION A(2)
      DO 5 I=1,N
      A(I)=0.0
5     CONTINUE
      RETURN
      END
```

SUBPROGRAM ZERO: CARD IMAGE LISTING

```
      SUBROUTINE FILL(A,B,N,MS)
      DIMENSION A(2),B(2)
      IF(MS) 25,5,15
5     DO 10 I=1,N
      DO 10 J=1,N
      CALL LOC(I,J,IJS,N,1)
      CALL LOC(I,J,IJG,N,0)
      A(IJG)=B(IJS)
10    CONTINUE
      RETURN
15    NUP=N*(N+1)/2
      DO 20 I=1,NUP
      A(I)=B(I)
20    CONTINUE
25    RETURN
      END
```

SUBPROGRAM FILL: CARD IMAGE LISTING

SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)

PURPOSE: To remove (set to zero) specified (constrained) coordinates in array A, reorder array A, and calculate the new size of array A.

SUBPROGRAMS REQUIRED: DELETE, LOC

VARIABLES:

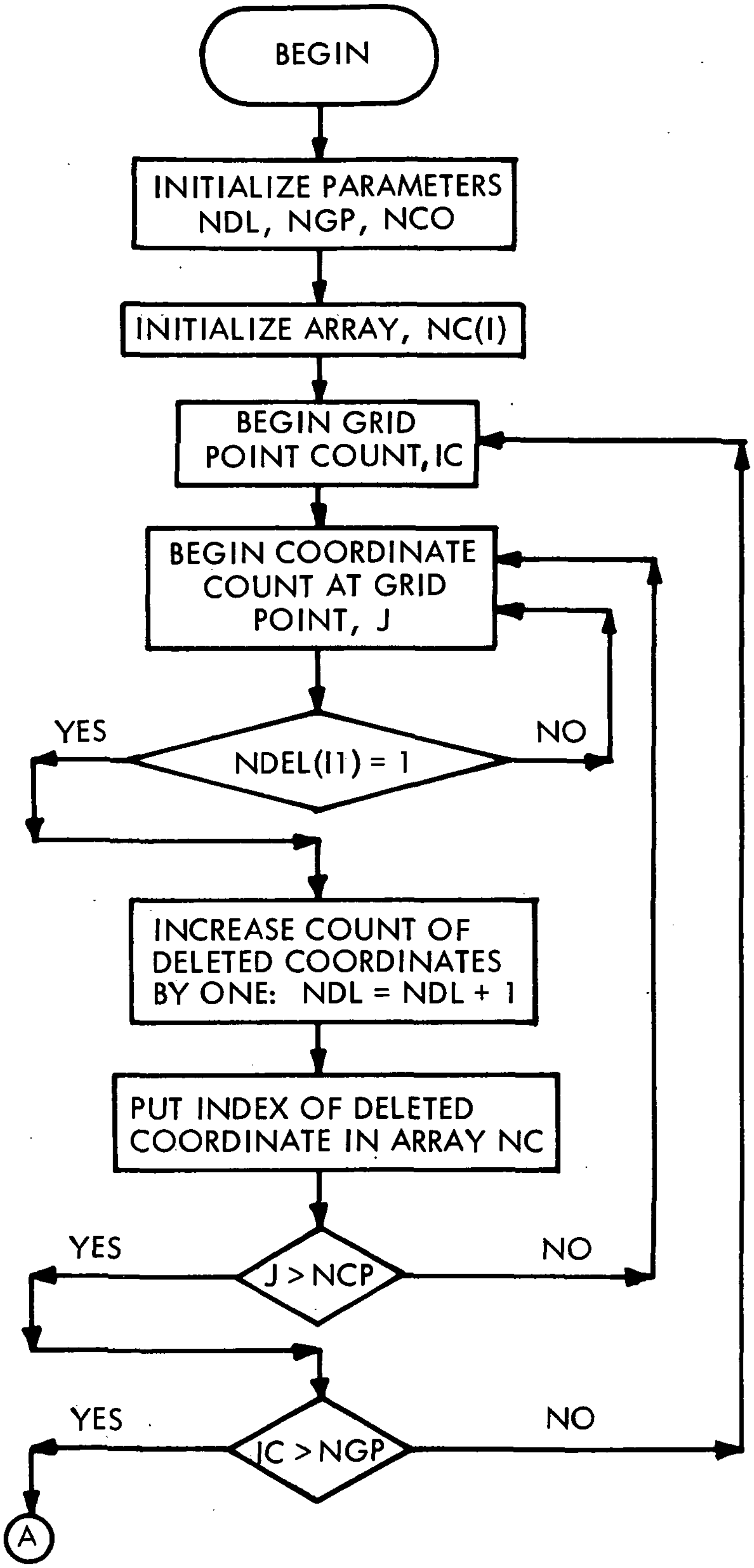
- A(I) - Stiffness or mass matrix of structural idealization
- NDEL(I) - Array of logic numbers: see PLTVIB
- NCP - Number of coordinates at each grid point
- MI - Number of grid points in x-direction
- NJ - Number of grid points in y-direction
- NDL - Number of coordinates removed by this subprogram
- NC(I) - Array of coordinate numbers for which NDEL(I) = 1

RESTRICTIONS: NC(I) must be dimensioned the same as NDEL(I) in program PLTVIB

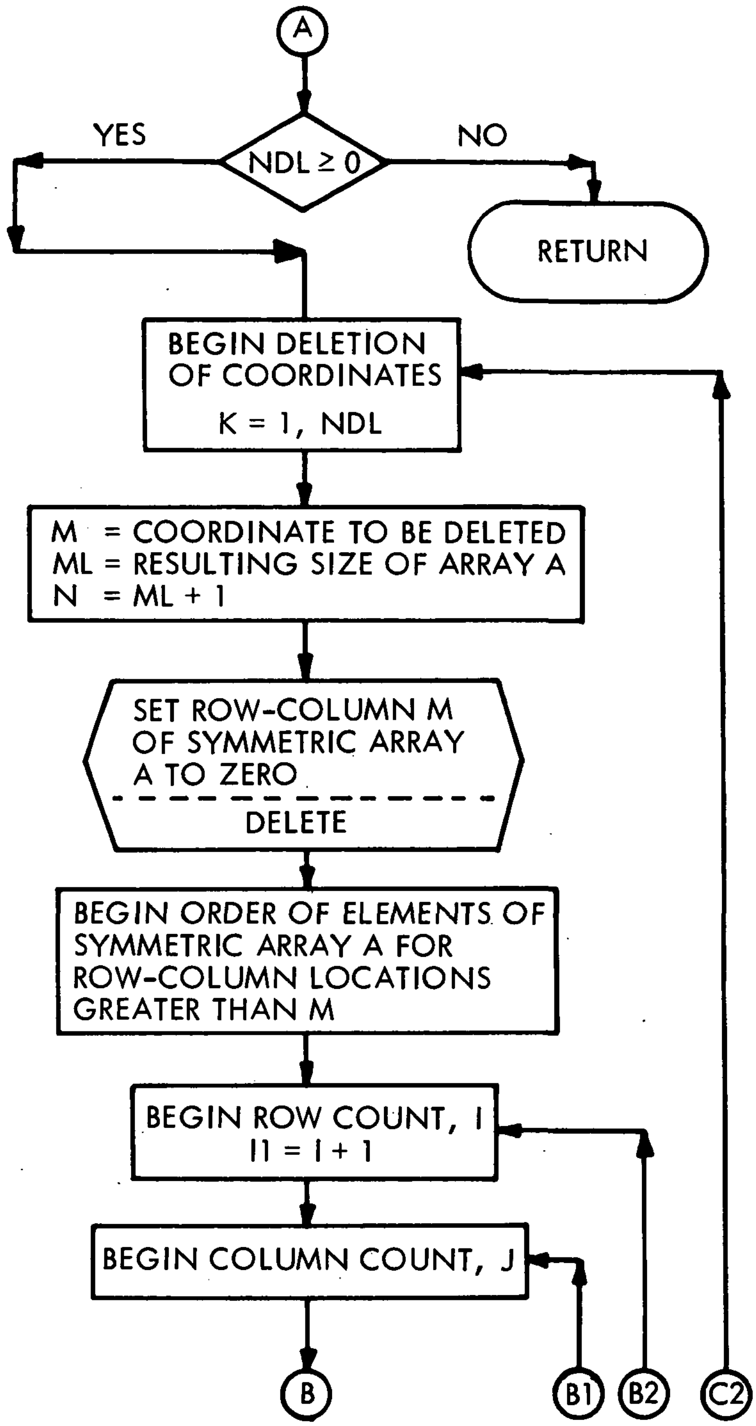
ACCURACY: Not Applicable

SIZE: 000333_8

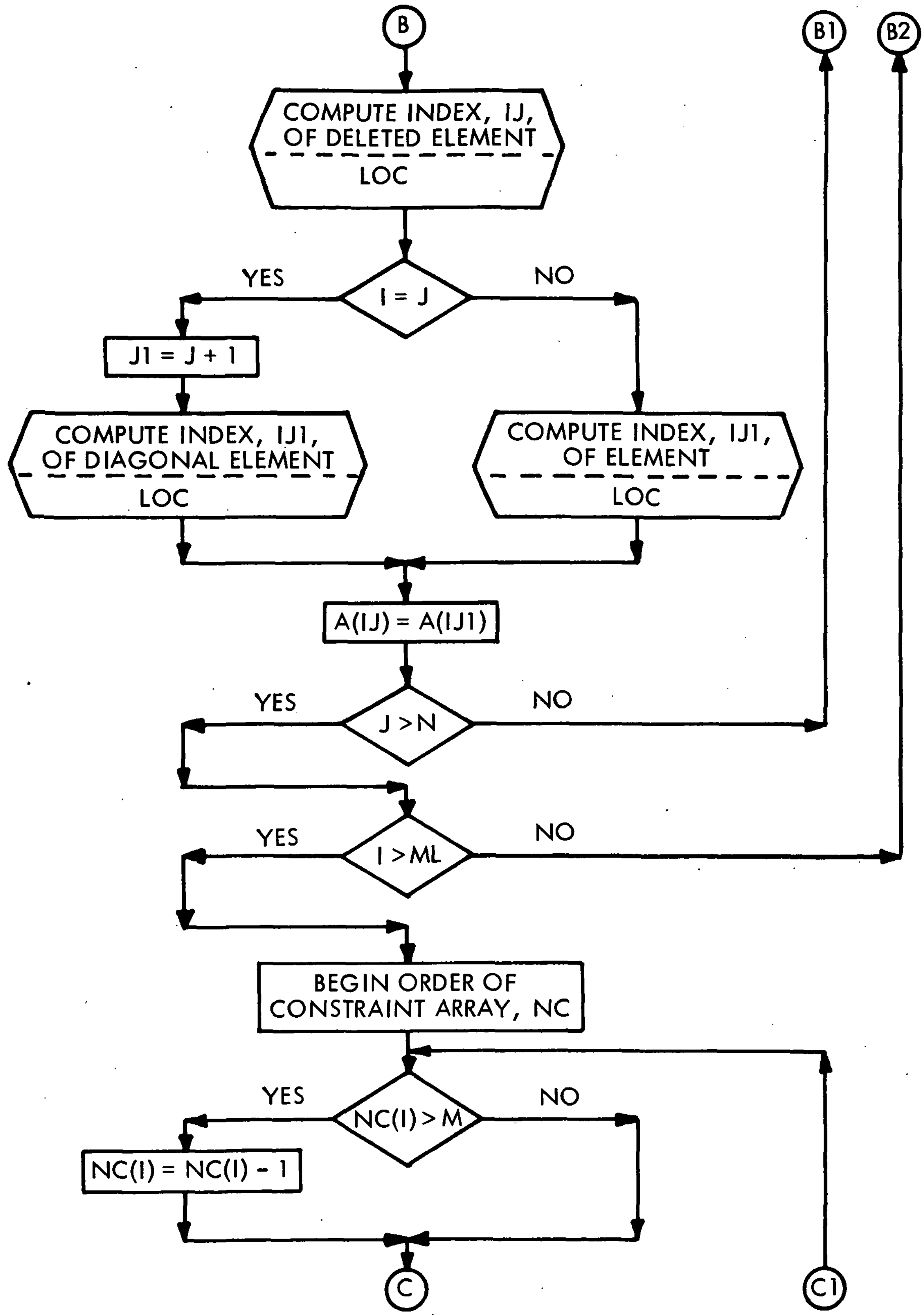
REFERENCES: None



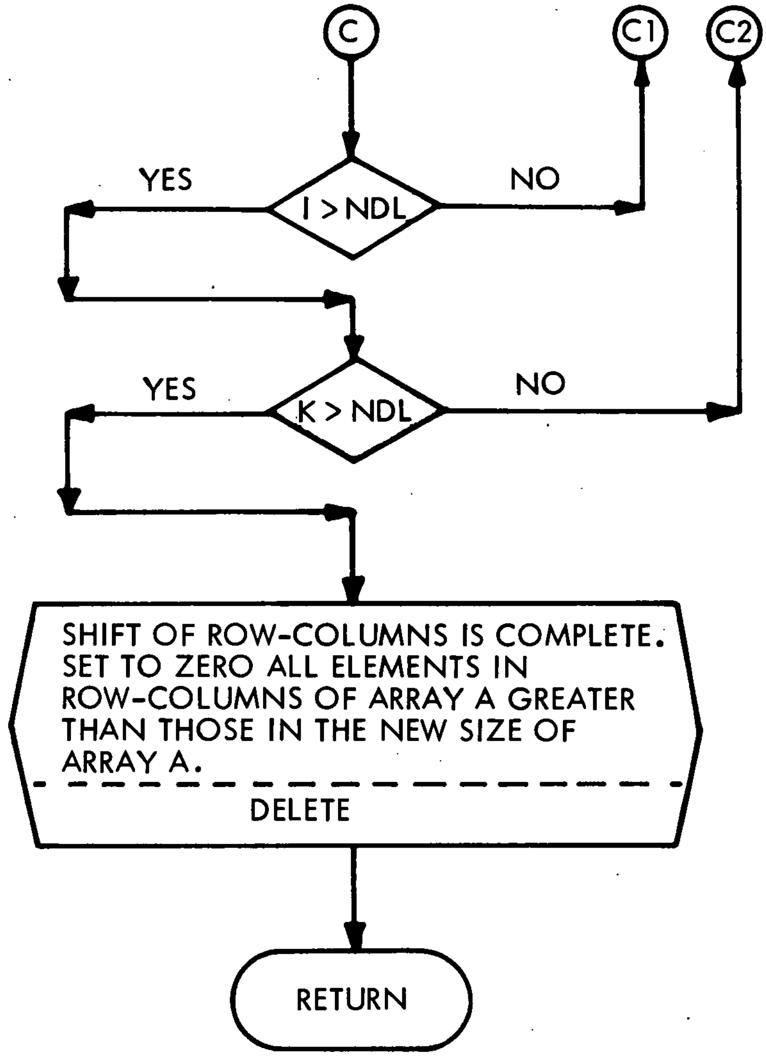
FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)



FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)



FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)



FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)

```
      SUBROUTINE ORDER(A,NDEL,NCP,MI,NI,NDL)
      DIMENSION A(2),NDEL(2),NC(73)
      NDL=0
      NGP=MI*NI
      NCO=NCP*NGP+(MI-1)*(NI-1)
      DO 1 I=1,NCO
      NC(I)=0
1     CONTINUE
      DO 3 IC=1,NGP
      I=NCP*(IC-1)
      DO 3 J=1,NCP
      I1=I+J
      IF(NDEL(I1)) 3,3,2
2     NDL=NDL+1
      NC(NDL)=I1
3     CONTINUE
      IF(NDL) 10,10,31
31    DO 9 K=1,NDL
      M=NC(K)
      ML=NCO-K
      N=ML+1
      CALL DELETE(A,N,M)
      DO 7 I=M,ML
      I1=I+1
      DO 7 J=1,N
      CALL LOC(I,J,IJ,N,1)
      IF(I-J) 5,4,5
4     J1=J+1
      CALL LOC(I1,J1,IJ1,N,1)
      GO TO 6
5     CALL LOC(I1,J,IJ1,N,1)
6     A(IJ)=A(IJ1)
7     CONTINUE
      DO 9 I=1,NDL
      IF(NC(I)-M) 9,9,8
8     NC(I)=NC(I)-1
9     CONTINUE
      M=NCO-NDL+1
      DO 10 K=M,NCO
      CALL DELETE(A,NCO,K)
10    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DELETE(A,N,J)
      DIMENSION A(2)
      DO 1 K=1,N
      CALL LOC(K,J,KJ,N,1)
      A(KJ)=0.0
1     CONTINUE
      RETURN
      END
```

SUBPROGRAMS ORDER AND DELETE: CARD IMAGE LISTINGS

APPENDIX D

COMPUTER PROGRAM USER'S MANUAL

INTRODUCTION

This appendix defines the input data parameters, input data format and output data format for the one-dimensional panel computer program and the two-dimensional panel computer program described in Appendix C. An example problem is included for each computer program listing typical input and output data formats.

ONE-DIMENSIONAL PANEL ARRAY

The one-dimensional panel geometry is illustrated in figure D-1. The structural idealization considers a fundamental mode across the width of the structure (y-direction) so that the finite element model considers only parameter variations along the length of the structure (strip analogy). The finite element model of the one-dimensional panel array then reduces to a simulation of a spring-supported beam. The elastic supports are modeled using the finite element representation of a thin-walled open-section beam as described in reference 1. The lumped parameter model of the elastic supports is given by equations 20a and 20b of reference 1. The definition of the geometric constants given in equations 20a and 20b of reference 1 are defined by figure D-2. The stiffener geometry for a stiffener parallel to the x-axis is presented in figure D-3 for completeness. The definition of the required input data is given below. The choice of structural idealization is best illustrated by an example problem.

ONE-DIMENSIONAL PANEL ARRAY: DEFINITION OF INPUT VARIABLES

The modal analysis of one-dimensional panel arrays is preformed using program BMPROP and the associated subprograms (see page 63). Definition of the required input variables is as follows:

NCASE	Number of data cases to be processed
NDATA	A four digit data case identification number
NBAY	The number of panel bays of the structure (not greater than 5)

NSUP	The number of elastic supports
IOUT	Data output option: IOUT = 0; print parameters NDATA, TK, TL, TM, frequencies and modal amplitudes at each grid point; IOUT > 0; print output for IOUT = 0 and the normalized modal displacement, shear, and bending moment distribution.
IBL	Logic number for applying clamped constraints at the left-hand end of the structure: IBL = 0; left-hand end is free or elastically supported: IBL = 1 the left-hand end of the structure is clamped (translation and slopes set to zero)
IBR	Logic number for applying clamped constraints at the right-hand end of the structure (definition identical to IBL)
NINT	Number of points interior to each element for which normalized displacement shear and bending moment distributions are to be calculated (equal to or less than 5)
BW	Width b of the panel, inches, (see figure D-1)
PR	Poisson's ratio for the cover sheet material
NEL(I)	Number of elements in the I^{th} panel bay
EI(I)	Bending rigidity of I^{th} panel bay (see equation 21, reference 1, p. 11), lb.-in.^{2}
WB(I)	Weight per unit length of I^{th} panel bay (see equation 22, reference 1, p. 11), lb./in.
BL(I)	Length of I^{th} panel bay (dimension a_i, figure D-1)
NCP(I)	Translation coordinate number for locating I^{th} elastic support in structure NCP(I) will be an odd number
SL(I)	Lumped spring constant, K_{zz}, for the I^{th} elastic support (see equation 20a, reference 1, p. 11)
SC(I)	Lumped spring constant, $K_{z\theta}$, for the I^{th} elastic support (see equation 20a, reference 1, p. 11)
SR(I)	Lumped spring constant, $K_{\theta\theta}$, for the I^{th} elastic support (see equation 20a, reference 1, p. 11)
RL(I)	Lumped mass constant, I^*_{zz}, for the I^{th} elastic support (see equation 20b, reference 1, p. 11)

RC(I) Lumped mass constant, $I^*_{z\theta}$, for the I^{th} elastic support (see equation 20b, reference 1, p. 11)

RR(I) Lumped mass constant, $I^*_{\theta\theta}$, for the I^{th} elastic support (see equation 20b, reference 1, p. 11)

Note: To add a lumped mass at a coordinate, input an elastic support with zero stiffness at that coordinate (i.e., SL(I) = SC(I) = SR(I) = 0 at NCP(I))

The input data format is as follows:

CARD 0 (ONE CARD PER DATA SET = NCASE DATA CASES)

COL (FORMAT)	1(I5)
NAME	NCASE

DATA CASE INPUT FORMAT

CARD 1 (ONE CARD PER DATA CASE)

COL (FORMAT)	1(I5)	6(I3)	9(I3)	12(I3)	16(I3)	18(I3)	21(I3)
NAME	NDATA	NBAY	NSUP	IOUT	IBL	IBR	NINT

CARD 2 (ONE CARD PER DATA CASE)

COL (FORMAT	4(E12.5)	16(E12.5)
NAME	BW	PR

CARDS 3 through 3+ NBAY (ONE CARD FOR EACH STRUCTURE BAY)

COL (FORMAT)	1(I3)	4(E12.5)	16(E12.5)	28(E12.5)
NAME	NEL(I)	EI(I)	WB(I)	BL(I)

CARDS 4 + NBAY through 4 + NBAY + 2 NSUP (TWO CARDS FOR EACH ELASTIC SUPPORT)

COL (FORMAT)	1(I3)	5(E12.5)	16(E12.5)	28(E12.5)
NAME	NCP(I)	SL(I)	SC(I)	SR(I)

COL (FORMAT)	5(E12.5)	16(E12.5)	28(E12.5)
NAME	RL(I)	RC(I)	RR(I)

ONE-DIMENSIONAL PANEL ARRAY: EXAMPLE

To illustrate a typical structural idealization consider a one-dimensional panel array consisting of three bays with two interior elastic supports and both ends clamped. Suppose that the span of each bay is 6.0 inches and that the width of the structure is 20.0 inches. The cover sheet is 0.032 in. and the material is 7075-T6 aluminum alloy. The stiffener is taken as a zee section as illustrated in figure 13, reference 1, and the stiffener orientation is taken such that both stiffeners face in the same direction. This data case corresponds to specimen SPI-2-1 for the three-bay configuration described in figure 15 of reference 1. Assuming that the stiffener attach point is directly below the vertical web and that the mass of the skin directly adjacent to the stiffener flange is considered to act with the translational inertia term, I^*_{zz}, for the lumped mass representation the stiffener data is

$$K_{zz} = 630.02 \qquad I^*_{zz} = 0.074299$$

$$K_{z\theta} = 14.271 \qquad I^*_{z\theta} = 0.0$$

$$K_{\theta\theta} = 118.30 \qquad I^*_{\theta\theta} = 0.0074605$$

Since the cover sheet is uniform, the lumped data are

$$EI(I) = 313.34 \qquad WB(I) = 0.03232 \qquad I = 1,2,3.$$

Three* elements are used to model each bay.

The above structural idealization is illustrated in figure D-4. The input data format is illustrated in figure D-5. The output data format is illustrated in figure D-6. In figure D-6 the edited input data is printed, the eigenvalues and eigenvectors are printed, and the interpolated values of the displacement (W), slope (DW/DX), shear (V), and bending moment (M) are printed for the fifteen lower frequency modes (only the fundamental mode is illustrated). The sequence for listing the eigenvector is dimensionless displacement and rotation for each grid point across the structure (see figure D-4). The experimental values for frequency, mode shape, and bending moment distribution (strain) are given in Table II and figure 26 of reference 1.

*Experience has shown that (NBAY-1) elements for each bay insures satisfactory frequency convergence of the lower NBAY modes.

NINE-BAY TWO-DIMENSIONAL PANEL ARRAY

The two-dimensional panel array considered here is the nine-bay configuration illustrated in figure D-7. The structural idealization considers nine plate elements forming the cover sheet and orthogonal stiffeners. The plate elements are described in reference 1 and consider an interior fundamental clamped-clamped plate mode as a generalized coordinate. The stiffener elements are taken as thin-walled open-section beams as described in reference 1. The stiffener geometry is illustrated in figures D-2 and D-3. The element nomenclature is illustrated in figure 3. Definition of the input data is given below.

NINE-BAY TWO-DIMENSIONAL PANEL ARRAY: DEFINITION OF INPUT VARIABLES

The modal analysis of nine-bay two-dimensional panel arrays is performed using program PLTVIB and the associated subprograms (see page 103). Definition of the required input variables (see Subroutine RDNWRT (1)) is as follows:

NDATA	Number of data cases to be processed
NCASE	A four digit data case identification number
A(I)	Length of the I^{th} rib segment parallel to the x-axis (see figure D-7), inches
B(I)	Length of the I^{th} rib segment parallel to the y-axis (see figure D-7), inches
EP	Young's modulus of the cover sheet material, $lbf./in.^2$
HP	Thickness of the cover sheet material, inches
PR	Poisson's ratio of the cover sheet material
RHOP	Weight density of the cover sheet material, $lbf./in.^3$
ER(I)	Young's modulus for the I^{th} rib, $lbf./in.^2$
GR(I)	Shear modulus for the I^{th} rib, $lbf./in.^2$
RHO(I)	Weight density for the I^{th} rib, $lbf./in.^3$
SR2(I)	S_y (I = 1,2) and S_x (I = 3,4), inches*
C2(I)	C_y (I = 1,2) and C_x (I = 3,4), inches*
SR3(I)	S_z, inches*
C3(I)	C_z, inches*

*See figures D-2 and D-3

AR(I)	Cross sectional area of I^{th} rib, in.^{2}
A22(I)	I_{yy} (I = 1,2) and I_{xx} (I = 3,4) of the I^{th} rib, in.^{4} (equation 5a, ref. 1)
A23(I)	I_{yz} (I = 1,2) and I_{xz} (I = 3,4) of the I^{th} rib, in.^{4} (equation 5a, ref. 1)
A33(I)	I_{zz} of the I^{th} rib, in.^{4} (equation 5a, ref. 1)
SJ(I)	St. Venant's torsion constant, in.^{4} (equation 5a, ref. 1)
RE2(I)	R_{ey} (I = 1,2) and R_{ex} (I = 3,4), in.^{5}** (equation 5b, ref. 1)
RE3(I)	R_{ez} for the I^{th} rib, in.^{5}** (equation 5b, ref. 1)
GM(I)	Warping constant for the I^{th} rib, in.^{6}

The input data format is as follows:

CARD 0 (ONE CARD PER DATA SET)

COL (FORMAT)	6(I3)
NAME	NDATA

CARD 1 (ONE CARD PER DATA CASE)

COL (FORMAT)	6(I4)
NAME	NCASE

CARD 2 (ONE CARD PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)
NAME	A(1)	A(2)	A(3)

CARD 3 (ONE CARD PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)
NAME	B(1)	B(2)	B(3)

CARD 4 (ONE CARD PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)	41(E12.5)
NAME	EP	HP	PR	RHOP

CARDS 5, 9, 13, 17 (ONE EACH PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)
NAME	ER(I)	GR(I)	RHO(I)

**See comment on page 6 of reference 1.

CARDS 6, 10, 14, 18 (ONE EACH PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)	41(E12.5)
NAME	SR2(I)	C2(I)	SR3(I)	C3(I)

CARDS 7, 11, 15, 19 (ONE EACH PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)	41(E12.5)
NAME	AR(I)	A22(I)	A23(I)	A33(I)

CARDS 8, 12, 16, 20 (ONE EACH PER DATA CASE)

COL (FORMAT)	5(E12.5)	17(E12.5)	29(E12.5)	41(E12.5)
NAME	SJ(I)	RE2(I)	RE3(I)	GM(I)

NINE-BAY TWO-DIMENSIONAL PANEL ARRAY: EXAMPLE

As an example consider a square nine-bay stiffened panel with identical stiffeners uniformly spaced in x- and y-directions. This example is selected to illustrate the nature of repeated roots and symmetry in the eigenvector (mode shape). Assume that each bay has dimensions (A(I) x B(I)) of 10.0 in. x 10.0 in., that the aluminum cover sheet is 0.032 in. thick, and that the stiffeners are described by the following data:

ER(I) = 10.3×10^6, lbf./in.^{2}

GR(I) = 3.9×10^6, lbf./in.^{2}

RHO(I) = 0.101, lbf./in.^{3}

SR2(I) = 0.0, in.

C2(I) = 0.0, in.

SR3(I) = 0.27191, in.

C3(I) = 0.80525, in.

AR(I) = 0.120, in.^{2}

A22(I) = 0.018389, in.^{4}

A23(I) = 0.0, in.^{4}

A33(I) = 0.022298, in.^{4}

SJ(I) = 4.08×10^{-5}, in.^{4}

RE2(I) = 0.0, in.^{5}

RE3(I) = 0.0, in.^{5}

GM(I) = 2.4445×10^{-3}, in.^{6}

The stiffener cross-section shape and its attachment to the cover sheet is illustrated in figure D-8. Figure D-9 illustrates the input data format. Figure D-10 illustrates the output data format where the edited input data is printed and the eigenvalues and eigenvectors are printed. The sequence for printing the eigenvectors is illustrated in figure D-11. The mode shapes for the four lower frequency modes are given in figure D-12.

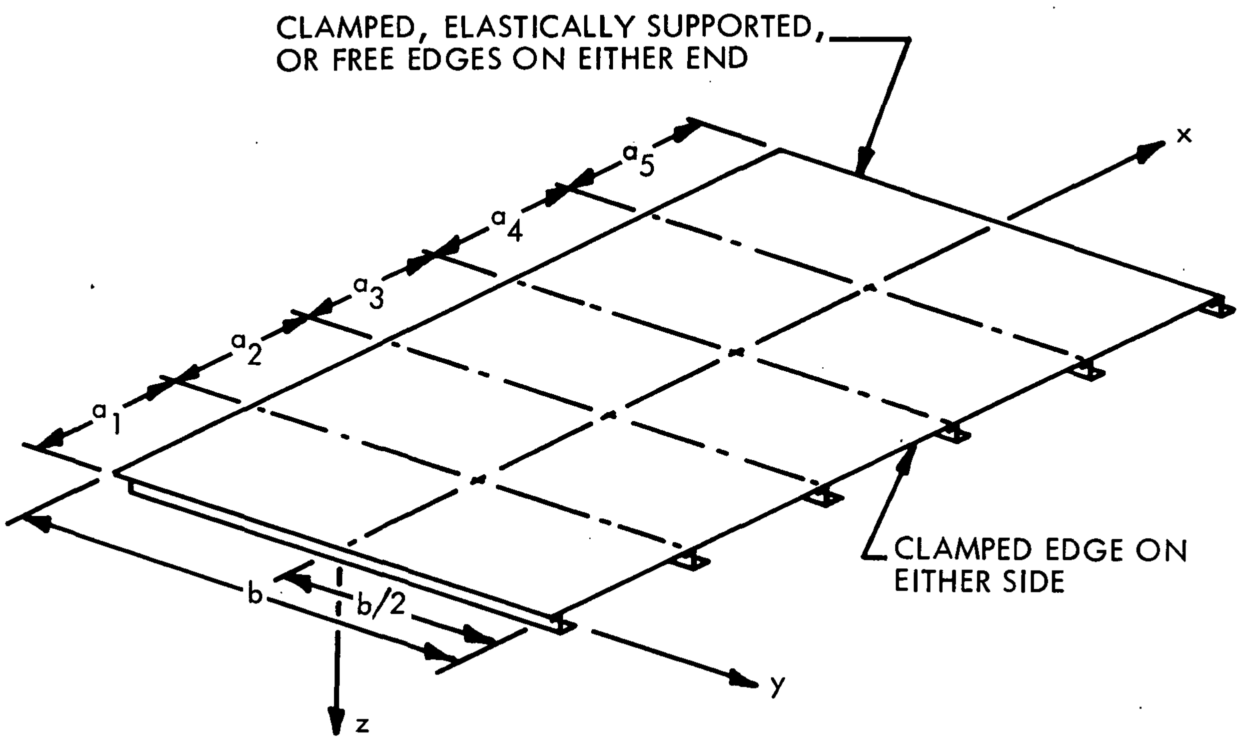


FIGURE D-1. ONE-DIMENSIONAL PANEL ARRAY

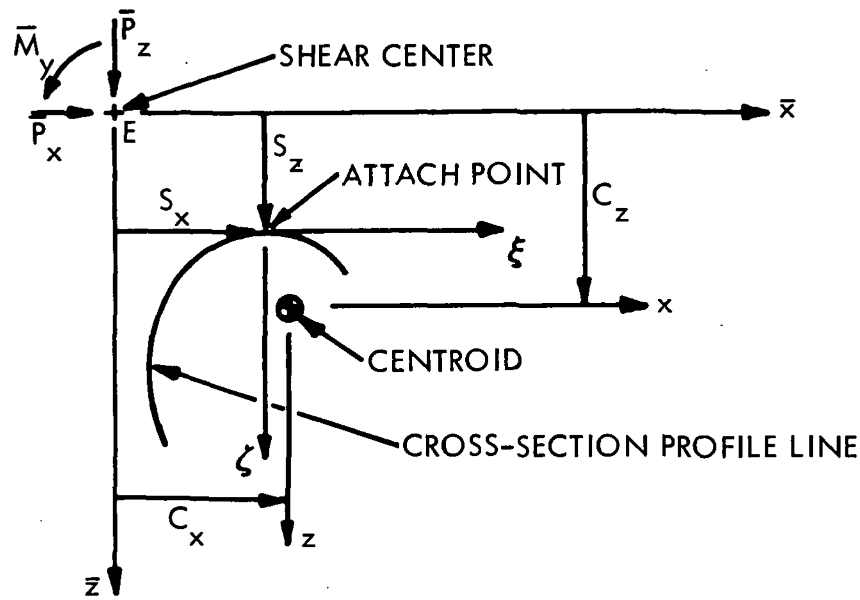


FIGURE D-2. CROSS-SECTION GEOMETRY FOR RIBS PARALLEL TO Y-AXIS

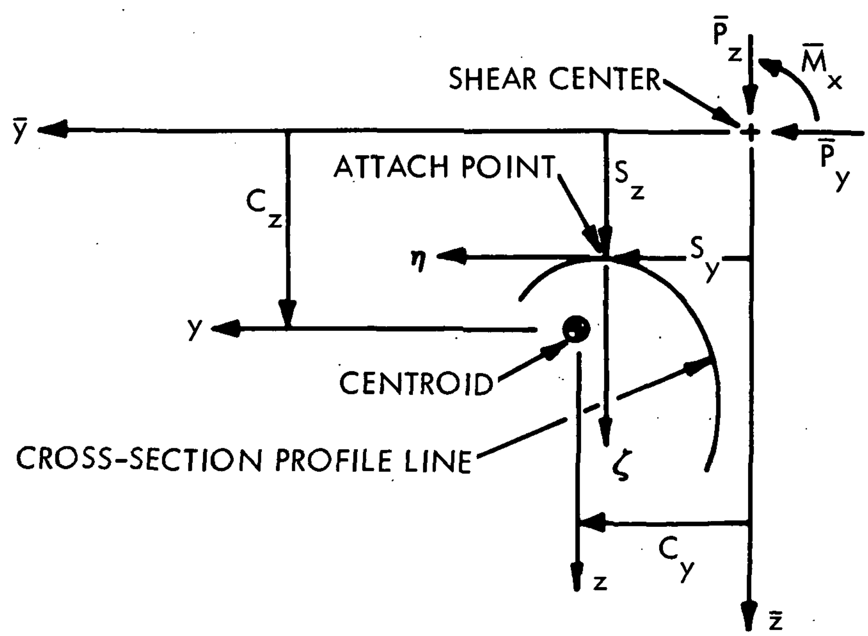
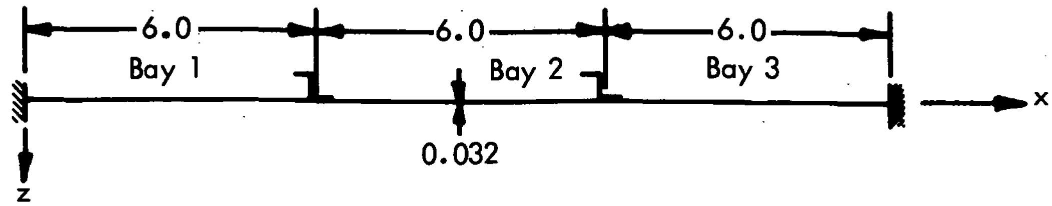
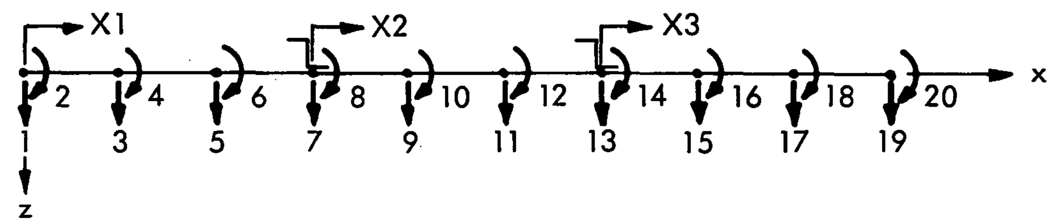


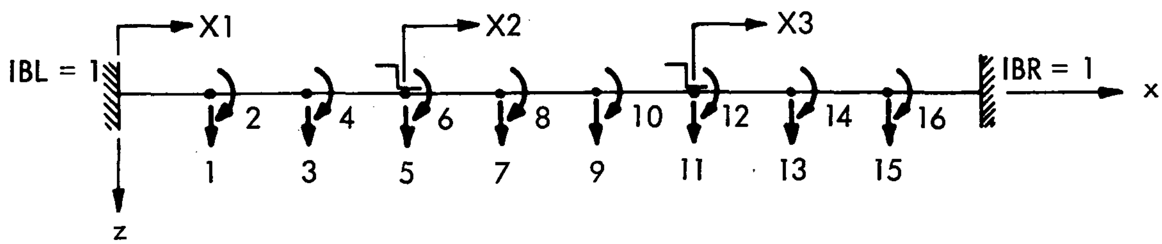
FIGURE D-3. CROSS-SECTION GEOMETRY FOR RIBS PARALLEL TO X-AXIS



a) Section through Centerline of Structure



b) Coordinates for Initial (unconstrained) Structural Idealization



c) Coordinates for Final (constrained) Structural Idealization

FIGURE D-4. STRUCTURAL IDEALIZATION: EXAMPLE PROBLEM THREE BAY ONE-DIMENSIONAL PANEL

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
				1																																		
			1	2			3			2			1			1			1			4																
				2	.	0	0	0	0	0	E	+	0	1		0	.	3	2	0	5	0	E	+	0	1												
		3		3	.	1	3	3	4	0	E	+	0	2		0	.	3	2	3	2	0	E	-	0	1		6	.	0	0	0	0	0	E	+	0	0
		3		3	.	1	3	3	4	0	E	+	0	2		0	.	3	2	3	2	0	E	-	0	1		6	.	0	0	0	0	0	E	+	0	0
		3		3	.	1	3	3	4	0	E	+	0	2		0	.	3	2	3	2	0	E	-	0	1		6	.	0	0	0	0	0	E	+	0	0
		7		6	.	3	0	0	2	0	E	+	0	2		1	.	4	2	7	1	0	E	+	0	2		1	.	1	8	3	0	0	E	+	0	2
				0	.	7	4	2	9	9	E	-	0	1		0	.	0	0	0	0	0	E		0	0		0	.	7	4	6	0	5	E	-	0	2
	1	3		6	.	3	0	0	2	0	E	+	0	2		1	.	4	2	7	1	0	E	+	0	2		1	.	1	8	3	0	0	E	+	0	2
				0	.	7	4	2	9	9	E	-	0	1		0	.	0	0	0	0	0	E		0	0		0	.	7	4	6	0	5	E	-	0	2

FIGURE D-5. EXAMPLE PROBLEM: INPUT DATA FORMAT PROGRAM BMPROP

FREE VIBRATION OF A ONE DIMENSIONAL PANEL ARRAY

DATA CASE 12

NUMBER OF BAYS= 3 NUMBER OF SUPPORTS= 2

PANEL WIDTH= 0.20000E+02 POISSON'S RATIO= 0.32050E+00

BAY NUMBER	NUMBER OF ELEMENTS	BENDING RIGIDITY	WEIGHT PER UNIT AREA	BAY LENGTH
1	3	0.31334E+03	0.32320E-01	0.60000E+01
2	3	0.31334E+03	0.32320E-01	0.60000E+01
3	3	0.31334E+03	0.32320E-01	0.60000E+01

SUPPORT NO. 1 INPUT COORDINATE= 7
KZZ= 0.63002E+03 KZTHETA= 0.14271E+03 KTHETA= 0.11830E+03
IZZ= 0.74299E-01 IZTHETA= 0.00000E+00 ITHETA= 0.74605E-02

SUPPORT NO. 2 INPUT COORDINATE= 13
KZZ= 0.63002E+03 KZTHETA= 0.14271E+03 KTHETA= 0.11830E+03
IZZ= 0.74299E-01 IZTHETA= 0.00000E+00 ITHETA= 0.74605E-02

FIGURE D-6. OUTPUT DATA FORMAT: EDITED OUTPUT DATA, EXAMPLE PROBLEM

```
                    FREE VIBRATION OF A ONE-DIMENSIONAL PANEL ARRAY

                                   DATA CASE  12

FREQUENCY= 0.22146E+04 HZ.

MODE SHAPE

-0.59286E-02-0.81602E-01 0.64859E-02-0.86498E-01 0.12723E-01 0.65049E-01 0.38799E-01 0.69348E+00
-0.39015E-01 0.69162E+00-0.12570E-01 0.62628E-01-0.65202E-02-0.89272E-01 0.60839E-02-0.83510E-01

FREQUENCY= 0.21841E+04 HZ.

MODE SHAPE

-0.17806E-01-0.24433E+00 0.14224E-01-0.27746E+00 0.51926E-02-0.27348E-01 0.32002E-02 0.38369E-01
-0.26304E-03 0.50487E-01 0.10794E-01 0.85765E-01 0.34796E-01 0.69230E+00-0.44287E-01 0.60669E+00

FREQUENCY= 0.21831E+04 HZ.

MODE SHAPE

 0.44093E-01 0.60482E+00-0.34691E-01 0.68891E+00-0.96963E-02 0.89343E-01 0.31750E-02 0.10081E+00
-0.44390E-02 0.95477E-01 0.29662E-02 0.41345E-01 0.13246E-01 0.26822E+00-0.17115E-01 0.23438E+00

FREQUENCY= 0.16370E+04 HZ.

MODE SHAPE

-0.16652E-02 0.24144E+00-0.33123E-01-0.14216E+00-0.12200E-01-0.32390E+00 0.48730E- 1-0.55555E+00
 0.47718E-01 0.56086E+00-0.10684E-01 0.32229E+00-0.33770E-01 0.14464E+00-0.16789E-02-0.24787E+00

FREQUENCY= 0.15018E+04 HZ.

MODE SHAPE

-0.14264E-01 0.49567E+00-0.52034E-01-0.38591E+00 0.12697E-01-0.26694E+00 0.25523E-01 0.36288E-01
-0.23380E-01 0.67884E-01-0.16057E-01-0.27151E+00 0.55155E-01-0.40966E+00 0.15161E-01 0.52807E+00
```

FIGURE D-6. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

```
FREQUENCY= 0.14314E+04 HZ.

MODE SHAPE

 0.20075E-01-0.47805E+00 0.39897E-01 0.41477E+00-0.26459E-01 0.56646E-01 0.22139E-01-0.35479E+00
 0.22984E-01 0.35358E+00-0.25555E-01-0.45883E-01 0.36503E-01-0.38016E+00 0.18416E-01 0.43894E+00

FREQUENCY= 0.10779E+04 HZ.

MODE SHAPE

-0.42889E-01 0.29934E+00 0.29080E-01-0.34273E+00 0.19237E-01 0.51959E+00-0.91371E-01-0.85631E-01
 0.92372E-01-0.57464E-01-0.15062E-01 0.51746E+00-0.29636E-01-0.35522E+00 0.44298E-01 0.30882E+00

FREQUENCY= 0.91226E+03 HZ.

MODE SHAPE

-0.52173E-01 0.22241E+00 0.55437E-01-0.24407E+00-0.93691E-02 0.47409E+00-0.68465E-02-0.39075E+00
-0.21049E-02 0.38760E+00-0.17145E-01-0.47678E+00 0.58187E-01 0.26047E+00-0.55314E- 1-0.23547E+00

FREQUENCY= 0.61498E+03 HZ.

MODE SHAPE

-0.29406E+00 0.39500E+00 0.32425E+00-0.41994E-01-0.17535E+00 0.15785E+00 0.33269E+ 0-0.18805E+00
-0.33638E+00-0.16173E+00 0.16970E+00 0.97014E-01-0.28483E+00-0.40556E-01 0.25956E+00 0.34819E+00

FREQUENCY= 0.51252E+03 HZ.

MODE SHAPE

-0.24741E+00 0.15803E+00 0.22079E+00 0.23024E+00-0.90784E-01-0.38635E+00 0.36510E-01 0.40397E+00
 0.81548E-01-0.36428E+00-0.87254E-01 0.38097E+00 0.22660E+00-0.23710E+00-0.25326E+ 0-0.16195E+00
```

FIGURE D-6. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

```
FREQUENCY= 0.40419E+03 HZ.

MODE SHAPE

-0.19669E+00-0.47799E-03 0.99424E-01 0.32641E+00 0.22240E-01-0.44718E+00-0.20419E+00 0.24689E+00
 0.21339E+00 0.19202E+00-0.61853E-01-0.46601E+00-0.12521E+00 0.40674E+00 0.23926E+ 0 0.61541E-03

FREQUENCY= 0.28569E+03 HZ.

MODE SHAPE

-0.27949E+00-0.16821E+00-0.36683E-01 0.52010E+00 0.23223E+00-0.19090E+00-0.15459E+00-0.34219E+00
-0.11761E+00 0.38588E+00 0.20996E+00 0.28396E-01-0.16393E-01-0.36728E+00-0.18785E+00 0.11089E+00

FREQUENCY= 0.22294E+03 HZ.

MODE SHAPE

-0.19303E+00-0.16827E+00-0.10257E+00 0.33362E+00 0.24598E+00 0.23351E+00 0.30065E+ 0-0.27188E+00
-0.16491E+00-0.45049E+00-0.26182E+00 0.27734E+00 0.84665E-01 0.31378E+00 0.17286E+00-0.14884E+00

FREQUENCY= 0.15081E+03 HZ.

MODE SHAPE

 0.70434E-02 0.87246E-02 0.10034E-01-0.38561E-02 0.33860E-02-0.46581E-02 0.97569E-02 0.19778E-01
 0.52189E-01 0.75095E-01 0.20502E+00 0.27794E+00 0.60333E+00 0.23110E+00 0.42329E+00-0.52442E+00

FREQUENCY= 0.13356E+03 HZ.

MODE SHAPE

 0.37344E+00 0.48855E+00 0.59755E+00-0.11907E+00 0.26399E+00-0.34988E+00 0.14336E+00 0.18782E-02
 0.13263E+00-0.55597E-01 0.36349E-01-0.10653E+00-0.36281E-01-0.33011E-01-0.29893E-01 0.36190E-01

FREQUENCY= 0.10932E+03 HZ.

MODE SHAPE

-0.11838E+00-0.15800E+00-0.18767E+00 0.59874E-01 0.21177E-01 0.34200E+00 0.43930E+ 0 0.33925E+00
 0.50686E+00-0.22071E+00 0.13715E+00-0.37636E+00-0.92173E-01-0.89548E-01-0.74344E-01 0.92762E-01
```

FIGURE D-6. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

FREQUENCY = 0.10932E+03 HZ.

BAY 1

X	W	DW/DX	V	M
0.000	0.00000E+00	0.00000E+00	0.44278E+00	-0.66679E+00
0.500	-0.20415E-01	-0.16172E+00	0.44106E+00	-0.46165E+00
1.000	-0.72597E-01	-0.20698E+00	0.43014E+00	-0.25914E+00
1.500	-0.14296E+00	-0.25248E+00	0.40388E+00	-0.65074E-01
2.000	-0.21790E+00	-0.41492E+00	0.35947E+00	0.11265E+00
2.000	-0.21790E+00	-0.41492E+00	0.35947E+00	0.11265E+00
2.500	-0.28390E+00	-0.35376E+00	0.29749E+00	0.26561E+00
3.000	-0.33181E+00	-0.26750E+00	0.22136E+00	0.38638E+00
3.500	-0.35465E+00	-0.11190E+00	0.13639E+00	0.46955E+00
4.000	-0.34545E+00	0.15724E+00	0.49602E-01	0.51259E+00
4.000	-0.34545E+00	0.15724E+00	0.49602E-01	0.51259E+00
4.500	-0.29940E+00	0.23952E+00	-0.30415E-01	0.51660E+00
5.000	-0.21815E+00	0.22203E+00	-0.94728E-01	0.48681E+00
5.500	-0.10445E+00	0.35737E+00	-0.13502E+00	0.43246E+00
6.000	0.38983E-01	0.89815E+00	-0.14365E+00	0.36648E+00

BAY 2

X	W	DW/DX	V	M
0.000	0.38983E-01	0.89815E+00	-0.96445E+00	0.82748E+00
0.500	0.21850E+00	0.10000E+01	-0.93361E+00	0.38565E+00
1.000	0.42445E+00	0.86570E+00	-0.85484E+00	-0.31022E-01
1.500	0.63008E+00	0.74582E+00	-0.72494E+00	-0.39930E+00
2.000	0.80865E+00	0.89093E+00	-0.54725E+00	-0.69600E+00
2.000	0.80865E+00	0.89093E+00	-0.54725E+00	-0.69600E+00
2.500	0.93495E+00	0.62932E+00	-0.33169E+00	-0.90101E+00
3.000	0.99969E+00	0.40570E+00	-0.92580E-01	-0.10000E+01
3.500	0.10000E+01	0.57060E-01	0.15458E+00	-0.98563E+00
4.000	0.93303E+00	-0.57963E+00	0.39361E+00	-0.85788E+00
4.000	0.93303E+00	-0.57963E+00	0.39361E+00	-0.85788E+00
4.500	0.80203E+00	-0.75310E+00	0.60801E+00	-0.62437E+00
5.000	0.62856E+00	-0.69373E+00	0.78449E+00	-0.29982E+00
5.500	0.43719E+00	-0.67950E+00	0.91561E+00	0.96218E-01
6.000	0.25247E+00	-0.98839E+00	0.10000E+01	0.54217E+00

BAY 3

X	W	DW/DX	V	M
0.000	0.25247E+00	-0.98839E+00	-0.79187E-01	0.52150E+00
0.500	0.96812E-01	-0.75629E+00	-0.36966E-01	0.49605E+00
1.000	-0.24596E-01	-0.50929E+00	-0.28777E-01	0.48196E+00
1.500	-0.11301E+00	-0.31354E+00	-0.46355E-01	0.46537E+00
2.000	-0.16967E+00	-0.23517E+00	-0.81741E-01	0.43621E+00
2.000	-0.16967E+00	-0.23517E+00	-0.81741E-01	0.43621E+00
2.500	-0.19573E+00	-0.10180E+00	-0.12726E+00	0.38799E+00
3.000	-0.19521E+00	-0.23231E-01	-0.17580E+00	0.31771E+00
3.500	-0.17372E+00	0.69068E-01	-0.22153E+00	0.22537E+00
4.000	-0.13685E+00	0.24361E+00	-0.25996E+00	0.11338E+00
4.000	-0.13685E+00	0.24361E+00	-0.25996E+00	0.11338E+00
4.500	-0.91455E-01	0.26532E+00	-0.28810E+00	-0.14141E-01
5.000	-0.47081E-01	0.23196E+00	-0.30501E+00	-0.15210E+00
5.500	-0.13379E-01	0.14352E+00	-0.31213E+00	-0.29552E+00
6.000	0.00000E+00	0.00000E+00	-0.31326E+00	-0.44066E+00

FIGURE D-6. OUTPUT DATA FORMAT: NORMALIZED MODE SHAPE AND STRESS RESULTANTS

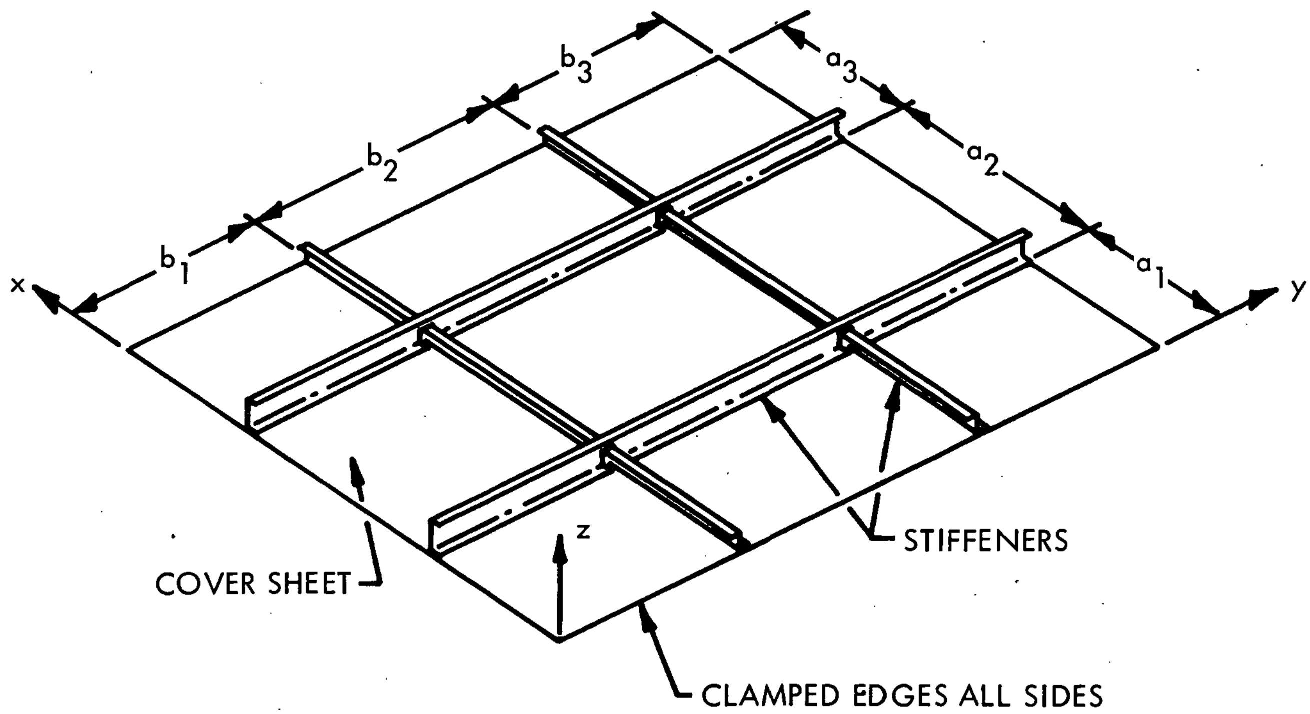
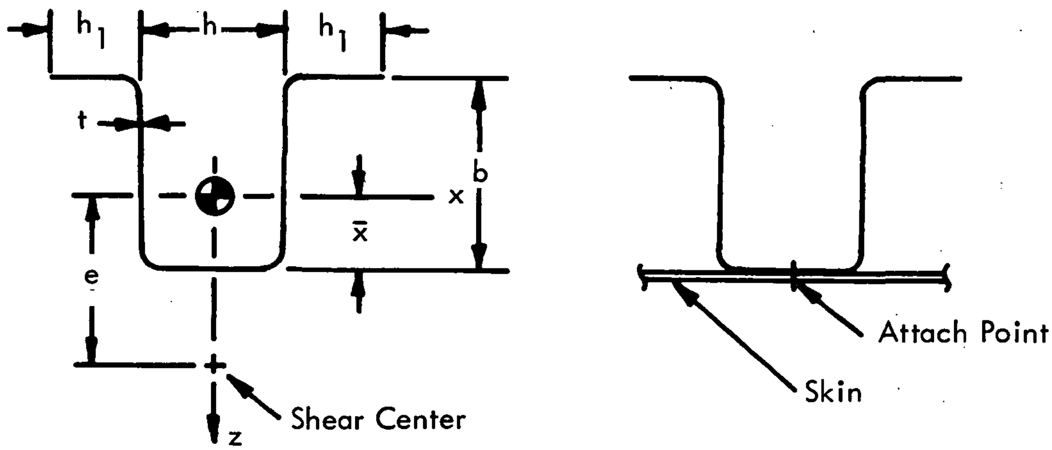


FIGURE D-7. NINE BAY TWO-DIMENSIONAL STRUCTURE



t = 0.032, in.

b = 1.000, in.

h = 0.75, in.

h_1 = 0.50, in.

x = 0.533, in.

e = 0.2719, in.

A = 0.120, in.^{2}

I_{xx} = 0.022299, in.^{4}

I_{xz} = 0.0, in.^{4}

I_{zz} = 0.018389, in.^{4}

J = 0.0000408, in.^{4}

R_{ex} = 0.0, in.^{5}

R_{ez} = 0.0, in.^{5}

Γ_e = 0.0024445, in.^{6*}

*Pole taken at shear center

FIGURE D-8. STIFFENER CROSS-SECTION SHAPE: EXAMPLE PROBLEM NINE-BAY TWO-DIMENSIONAL PANEL

1000				
1.00000E 01	1.00000E 01	1.00000E 01		
1.00000E 01	1.00000E 01	1.00000E 01		
1.03000E 07	0.03200E 00	0.32050E 00	0.10100E 00	
1.03000E 07	3.90000E 06	0.10100E 00		Rib 1
0.00000E 00	0.00000E 00	0.27191E 00	0.80525E 00	Rib 1
0.12000E 00	1.83890E-02	0.00000E 00	2.22985E-02	Rib 1
0.40800E-04	0.00000E 00	0.00000E 00	2.44450E-03	Rib 1
1.03000E 07	3.90000E 06	0.10100E 00		Rib 2
0.00000E 00	0.00000E 00	0.27191E 00	0.80525E 00	Rib 2
0.12000E 00	1.83890E-02	0.00000E 00	2.22985E-02	Rib 2
0.40800E-04	0.00000E 00	0.00000E 00	2.44450E-03	Rib 2
1.03000E 07	3.90000E 06	0.10100E 00		Rib 3
0.00000E 00	0.00000E 00	0.27191E 00	0.80525E 00	Rib 3
0.12000E 00	1.83890E-02	0.00000E 00	2.22985E-02	Rib 3
0.40800E-04	0.00000E 00	0.00000E 00	2.44450E-03	Rib 3
1.03000E 07	3.90000E 06	0.10100E 00		Rib 4
0.00000E 00	0.00000E 00	0.27191E 00	0.80525E 00	Rib 4
0.12000E 00	1.83890E-02	0.00000E 00	2.22985E-02	Rib 4
0.40800E-04	0.00000E 00	0.00000E 00	2.44450E-03	Rib 4

NOTE: NDATA = 1 FOR THIS EXAMPLE

FIGURE D-9. INPUT DATA FORMAT: EXAMPLE PROBLEM

DATA CASE 1000

FREE VIBRATION OF A
NINE BAY ORTHOGONALLY STIFFENED PANEL

STRUCTURAL GEOMETRY

A1= 0.10000E+02 A2= 0.10000E+02 A3= 0.10000E+02

B1= 0.10000E+02 B2= 0.10000E+02 B3= 0.10000E+02

COVER SHEET DATA

YOUNG'S MODULUS= 0.10300E+08 POISSON'S RATIO= 0.32050E+00
THICKNESS = 0.32000E-01 WEIGHT/VOLUME = 0.10100E+00
BENDING RIGIDITY= 0.31346E+02

STIFFENER DATA

STIFFENERS PARALLEL TO X-AXIS

STIFFENER NO. 1	E = 0.10300E+08	G = 0.39000E+07	RHO = 0.10100E+00
SY= 0.00000E+00	CY = 0.00000E+00	SZ = 0.27191E+00	CZ = 0.80525E+00
A = 0.12000E+00	IYY= 0.18389E-01	IYZ= 0.00000E+00	IZZ = 0.22298E-01
J = 0.40800E-04	REY= 0.00000E+00	REZ= 0.00000E+00	GAMMA= 0.24445E-02

STIFFENERS PARALLEL TO X-AXIS

STIFFENER NO. 2	E = 0.10300E+08	G = 0.39000E+07	RHO = 0.10100E+00
SY= 0.00000E+00	CY = 0.00000E+00	SZ = 0.27191E+00	CZ = 0.80525E+00
A = 0.12000E+00	IYY= 0.18389E-01	IYZ= 0.00000E+00	IZZ = 0.22298E-01
J = 0.40800E-04	REY= 0.00000E+00	REZ= 0.00000E+00	GAMMA= 0.24445E-02

STIFFENERS PARALLEL TO Y-AXIS

STIFFENER NO. 3	E = 0.10300E+08	G = 0.39000E+07	RHO = 0.10100E+00
SX= 0.00000E+00	CX = 0.00000E+00	SZ = 0.27191E+00	CZ = 0.80525E+00
A = 0.12000E+00	IXX= 0.18389E-01	IXZ= 0.00000E+00	IZZ = 0.22298E-01
J = 0.40800E-04	REX= 0.00000E+00	REZ= 0.00000E+00	GAMMA= 0.24445E-02

STIFFENERS PARALLEL TO Y-AXIS

STIFFENER NO. 4	E = 0.10300E+08	G = 0.39000E+07	RHO = 0.10100E+00
SX= 0.00000E+00	CX = 0.00000E+00	SZ = 0.27191E+00	CZ = 0.80525E+00
A = 0.12000E+00	IXX= 0.18389E-01	IXZ= 0.00000E+00	IZZ = 0.22298E-01
J = 0.40800E-04	REX= 0.00000E+00	REZ= 0.00000E+00	GAMMA= 0.24445E-02

FIGURE D-10. OUTPUT DATA FORMAT: EDITED INPUT DATA, EXAMPLE PROBLEM

DATA CASE 1000

NONDIMENSIONALIZING CONSTANTS

TK= 0.11482E+06 TL= 0.14142E+02 TM= 0.14284E-02

EIGENVALUE= 0.32763E+01 FREQUENCY= 0.25828E+04,HZ.

EIGENVECTOR

-0.60316E-02	-0.10599E+00	0.10599E+00	-0.47696E+00	0.60316E-02
0.10599E+00	0.10599E+00	-0.47696E+00	0.60316E-02	-0.10599E+00
-0.10599E+00	-0.47696E+00	-0.60316E-02	0.10599E+00	-0.10599E+00
-0.47696E+00	-0.24869E-02	0.62428E-08	0.24869E-02	0.12935E-08
0.37093E-09	0.96136E-09	0.24869E-02	-0.38044E-08	-0.24869E-02

EIGENVALUE= 0.24023E+01 FREQUENCY= 0.22116E+04,HZ.

EIGENVECTOR

0.40668E-02	0.29630E+00	0.12674E+00	-0.23973E+00	0.85587E-02
0.27893E+00	0.77907E-01	0.50451E+00	-0.85587E-02	0.27892E+00
0.77911E-01	-0.50452E+00	-0.40668E-02	0.29630E+00	0.12675E+00
0.23973E+00	0.35553E-02	0.98020E-02	0.74823E-02	-0.34873E-02
-0.41871E-07	0.34873E-02	-0.74823E-02	-0.98019E-02	-0.35553E-02

EIGENVALUE= 0.24023E+01 FREQUENCY= 0.22116E+04,HZ.

EIGENVECTOR

-0.85587E-02	-0.77911E-01	0.27892E+00	0.50452E+00	0.40668E-02
-0.12674E+00	0.29630E+00	0.23972E+00	-0.40668E-02	-0.12674E+00
0.29630E+00	-0.23974E+00	0.85587E-02	-0.77908E-01	0.27893E+00
-0.50451E+00	-0.74823E-02	-0.34873E-02	0.35553E-02	-0.98019E-02
-0.53850E-07	0.98020E-02	-0.35553E-02	0.34874E-02	0.74823E-02

EIGENVALUE= 0.23187E+01 FREQUENCY= 0.21728E+04,HZ.

EIGENVECTOR

0.53408E-07	-0.35356E+00	-0.35356E+00	-0.48897E-05	-0.18011E-06
0.35355E+00	-0.35356E+00	-0.28779E-05	0.15584E-06	-0.35356E+00
0.35355E+00	-0.26838E-04	-0.27049E-07	0.35355E+00	0.35355E+00
-0.59723E-05	0.43941E-07	-0.12487E-06	-0.13818E-06	0.24371E-06
-0.41365E-07	-0.19978E-06	0.55218E-07	0.16433E-06	-0.10497E-07

EIGENVALUE= 0.89302E+00 FREQUENCY= 0.13484E+04,HZ.

EIGENVECTOR

-0.17764E-01	0.35152E+00	-0.35152E+00	0.38818E-01	-0.17764E-01
0.35152E+00	0.35152E+00	-0.38818E-01	-0.17764E-01	-0.35152E+00
-0.35152E+00	-0.38819E-01	-0.17764E-01	-0.35152E+00	0.35152E+00
0.38818E-01	0.19067E-01	0.68695E-02	0.19067E-01	0.68695E-02
-0.50232E-01	0.68695E-02	0.19067E-01	0.68695E-02	0.19067E-01

EIGENVALUE= 0.81502E+00 FREQUENCY= 0.12882E+04,HZ.

EIGENVECTOR

0.21390E-01	-0.21274E+00	0.47758E+00	0.11585E+00	0.10171E-01
0.11434E+00	-0.44260E+00	-0.55088E-01	-0.10171E-01	0.11434E+00
-0.44260E+00	0.55081E-01	-0.21390E-01	-0.21274E+00	0.47758E+00
-0.11584E+00	-0.19860E-01	0.12966E-01	-0.94438E-02	0.46087E-02
-0.10139E-07	-0.46087E-02	0.94437E-02	-0.12966E-01	0.19859E-01

FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

EIGENVALUE= 0.81502E+00 FREQUENCY= 0.12882E+04,HZ.

EIGENVECTOR

-0.10171E-01	0.44260E+00	0.11433E+00	-0.55078E-01	0.21390E-01
-0.47758E+00	-0.21274E+00	-0.11586E+00	-0.21390E-01	-0.47758E+00
-0.21274E+00	0.11586E+00	0.10171E-01	0.44260E+00	0.11434E+00
0.55060E-01	0.94437E-02	0.46087E-02	-0.19859E-01	-0.12966E-01
0.35098E-07	0.12966E-01	0.19860E-01	-0.46088E-02	-0.94437E-02

EIGENVALUE= 0.75190E+00 FREQUENCY= 0.12373E+04,HZ.

EIGENVECTOR

0.11632E-07	0.35283E+00	0.35283E+00	0.14321E-06	0.42211E-08
0.35283E+00	-0.35283E+00	-0.44439E-06	0.25086E-08	-0.35283E+00
0.35283E+00	0.11360E-06	-0.68469E-08	-0.35283E+00	-0.35283E+00
0.66447E-07	-0.81120E-08	0.31864E-01	-0.74018E-08	-0.31864E-01
0.45107E-08	-0.31864E-01	0.39202E-08	0.31864E-01	0.21881E-08

EIGENVALUE= 0.71075E+00 FREQUENCY= 0.12030E+04,HZ.

EIGENVECTOR

-0.14213E-04	-0.16918E-02	0.16918E-02	0.49999E+00	0.14214E-04
0.16918E-02	0.16918E-02	0.49999E+00	0.14214E-04	-0.16919E-02
-0.16918E-02	0.49999E+00	-0.14214E-04	0.16919E-02	-0.16918E-02
0.49999E+00	-0.12440E-02	-0.46570E-08	0.12440E-02	-0.23489E-08
-0.22390E-08	0.12274E-08	0.12440E-02	0.33422E-08	-0.12440E-02

EIGENVALUE= 0.37975E+00 FREQUENCY= 0.87932E+03,HZ.

EIGENVECTOR

0.87165E-04	-0.11064E-04	0.82126E-03	-0.64778E+00	-0.38151E-04
-0.74343E-03	0.11077E-02	-0.28351E+00	0.38149E-04	-0.74342E-03
0.11077E-02	0.28352E+00	-0.87168E-04	-0.11038E-04	0.82126E-03
0.64776E+00	0.15233E-02	-0.91032E-03	-0.66667E-03	-0.23273E-02
0.89807E-07	0.23273E-02	0.66670E-03	0.91024E-03	-0.15232E-02

EIGENVALUE= 0.37975E+00 FREQUENCY= 0.87932E+03,HZ.

EIGENVECTOR

-0.38152E-04	0.11077E-02	0.74341E-03	0.28350E+00	-0.87171E-04
0.82128E-03	0.11050E-04	-0.64776E+00	0.87167E-04	0.82128E-03
0.11093E-04	0.64778E+00	0.38148E-04	0.11077E-02	0.74341E-03
-0.28353E+00	-0.66665E-03	0.23272E-02	-0.15232E-02	-0.91034E-03
0.13128E-06	0.91021E-03	0.15233E-02	-0.23274E-02	0.66672E-03

EIGENVALUE= 0.28821E+00 FREQUENCY= 0.76604E+03,HZ.

EIGENVECTOR

0.71024E-04	0.41956E-03	-0.41951E-03	0.49998E+00	0.71021E-04
0.41952E-03	0.41954E-03	-0.50000E+00	0.71026E-04	-0.41953E-03
-0.41953E-03	-0.49997E+00	0.71024E-04	-0.41950E-03	0.41954E-03
0.49999E+00	-0.12207E-02	0.24255E-02	-0.12207E-02	0.24254E-02
-0.50403E-02	0.24255E-02	-0.12207E-02	0.24254E-02	-0.12207E-02

EIGENVALUE= 0.20602E+00 FREQUENCY= 0.64767E+03,HZ.

EIGENVECTOR

-0.23805E+00	0.28184E+00	-0.28183E+00	0.17558E+00	0.23805E+00
-0.28184E+00	-0.28183E+00	0.17558E+00	0.23805E+00	0.28183E+00
0.28183E+00	0.17558E+00	-0.23805E+00	-0.28183E+00	0.28184E+00
0.17558E+00	0.60366E-01	0.26440E-07	-0.60366E-01	-0.10817E-07
-0.13894E-07	0.33108E-07	-0.60366E-01	-0.69448E-08	0.60366E-01

FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

EIGENVALUE= 0.97947E-01 FREQUENCY= 0.44657E+03,HZ.

EIGENVECTOR

0.12541E-01	0.42314E+00	0.41250E+00	0.42688E-02	-0.29902E+00
-0.14430E+00	-0.10926E+00	0.10186E+00	0.29902E+00	-0.14430E+00
-0.10926E+00	-0.10186E+00	-0.12541E-01	0.42314E+00	0.41250E+00
-0.42720E-02	-0.24159E-02	0.82194E-01	0.57600E-01	-0.89391E-01
-0.34003E-07	0.89391E-01	-0.57600E-01	-0.82194E-01	0.24158E-02

EIGENVALUE= 0.97947E-01 FREQUENCY= 0.44657E+03,HZ.

EIGENVECTOR

-0.29902E+00	-0.10926E+00	0.14430E+00	-0.10186E+00	-0.12541E-01
0.41250E+00	-0.42314E+00	0.42724E-02	0.12541E-01	0.41250E+00
-0.42314E+00	-0.42709E-02	0.29902E+00	-0.10926E+00	0.14430E+00
0.10186E+00	0.57600E-01	0.89391E-01	0.24158E-02	0.82194E-01
-0.30050E-07	-0.82194E-01	-0.24158E-02	-0.89391E-01	-0.57600E-01

EIGENVALUE= 0.29039E-01 FREQUENCY= 0.24316E+03,HZ.

EIGENVECTOR

0.19097E+00	0.28427E+00	-0.28427E+00	0.10907E+00	0.19097E+00
0.28427E+00	0.28427E+00	-0.10907E+00	0.19097E+00	-0.28427E+00
-0.28427E+00	-0.10907E+00	0.19097E+00	-0.28427E+00	0.28427E+00
0.10907E+00	-0.35377E-01	-0.11373E+00	-0.35377E-01	-0.11373E+00
-0.32140E+00	-0.11373E+00	-0.35378E-01	-0.11373E+00	-0.35377E-01

EIGENVALUE= 0.60586E-02 FREQUENCY= 0.11107E+03,HZ.

EIGENVECTOR

-0.63666E-03	0.46583E-02	-0.46580E-02	-0.21134E-01	-0.63666E-03
0.46582E-02	0.46580E-02	0.21127E-01	-0.63664E-03	-0.46583E-02
-0.46580E-02	0.21138E-01	-0.63665E-03	-0.46582E-02	0.46581E-02
-0.21133E-01	-0.47369E+00	-0.81052E-01	-0.47369E+00	-0.81030E-01
0.27245E+00	-0.81037E-01	-0.47370E+00	-0.81047E-01	-0.47369E+00

EIGENVALUE= 0.60484E-02 FREQUENCY= 0.11097E+03,HZ.

EIGENVECTOR

0.16332E-07	0.74793E-02	0.74795E-02	-0.81798E-06	0.37344E-07
0.74795E-02	-0.74795E-02	0.65948E-05	0.88572E-08	-0.74794E-02
0.74795E-02	-0.28675E-05	0.39173E-07	-0.74795E-02	-0.74796E-02
-0.20951E-05	0.92277E-05	-0.49988E+00	0.27817E-05	0.49989E+00
-0.48667E-05	0.49989E+00	0.10172E-04	-0.49989E+00	0.68510E-05

EIGENVALUE= 0.60384E-02 FREQUENCY= 0.11088E+03,HZ.

EIGENVECTOR

-0.87996E-03	0.56074E-02	0.45847E-02	-0.40223E-01	-0.39097E-02
0.34193E-02	0.11253E-02	0.17870E+00	0.39097E-02	0.34193E-02
0.11252E-02	-0.17867E+00	0.87999E-03	0.56075E-02	0.45847E-02
0.40199E-01	-0.14271E+00	-0.17723E+00	-0.63406E+00	0.11211E+00
-0.53555E-05	-0.11211E+00	0.63405E+00	0.17724E+00	0.14270E+00

EIGENVALUE= 0.60384E-02 FREQUENCY= 0.11088E+03,HZ.

EIGENVECTOR

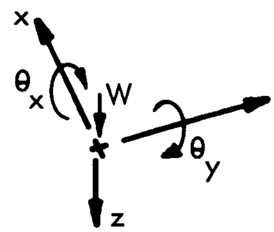
-0.39097E-02	0.11253E-02	-0.34192E-02	-0.17867E+00	0.87993E-03
0.45847E-02	-0.56076E-02	-0.40227E-01	-0.87994E-03	0.45847E-02
-0.56076E-02	0.40210E-01	0.39097E-02	0.11253E-02	-0.34192E-02
0.17869E+00	-0.63405E+00	-0.11212E+00	0.14271E+00	-0.17724E+00
0.46017E-05	0.17723E+00	-0.14270E+00	0.11211E+00	0.63406E+00

FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

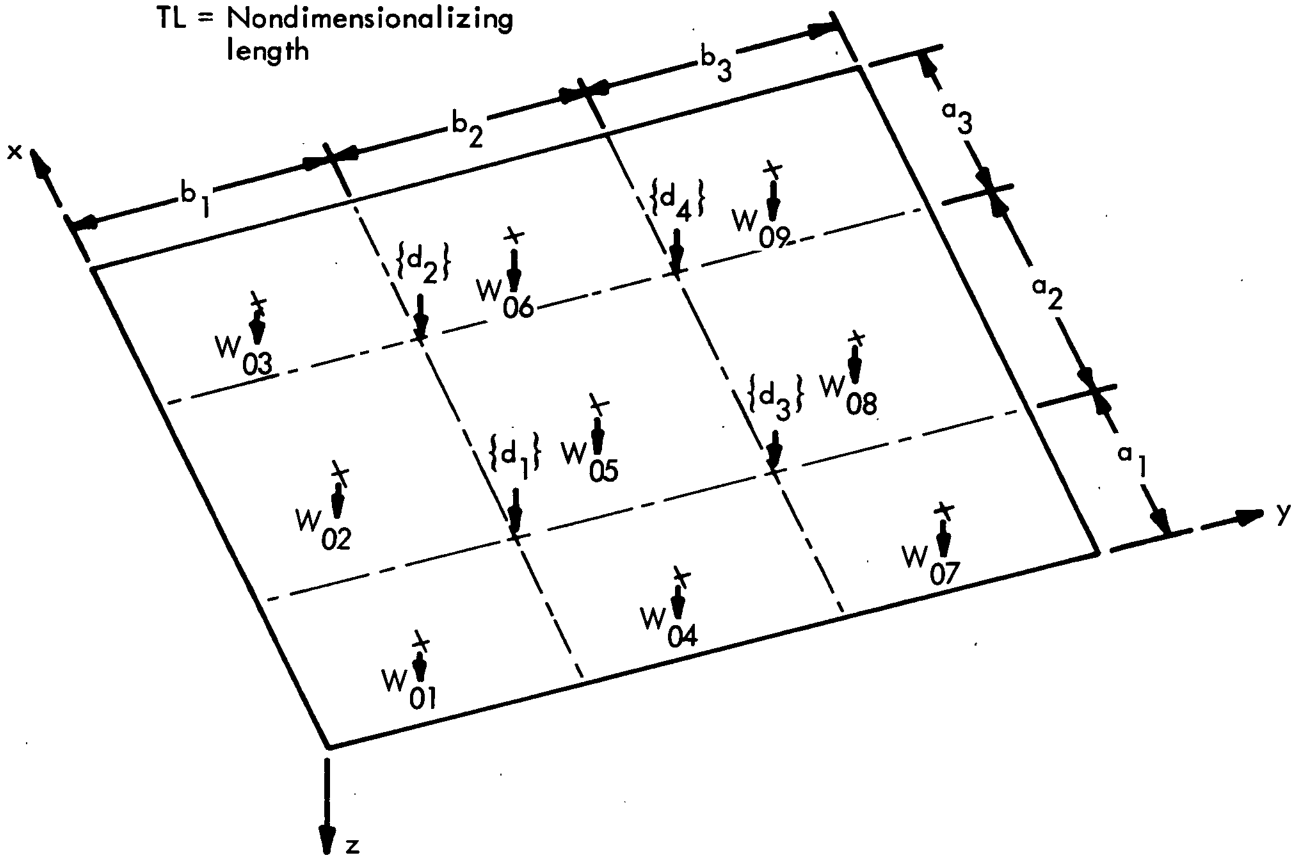
```
EIGENVALUE= 0.60356E-02                                  FREQUENCY= 0.11086E+03,HZ.
                                    EIGENVECTOR
  0.13580E-02  -0.33017E-02   0.33017E-02   0.20068E+00  -0.13580E-02
  0.33017E-02   0.33017E-02   0.20068E+00  -0.13580E-02  -0.33017E-02
 -0.33018E-02   0.20068E+00   0.13580E-02   0.33017E-02  -0.33016E-02
  0.20068E+00   0.45793E+00  -0.20494E-05  -0.45793E+00  -0.10528E-05
  0.13705E-05  -0.37832E-06  -0.45794E+00   0.34345E-05   0.45793E+00

EIGENVALUE= 0.59587E-02                                  FREQUENCY= 0.11015E+03,HZ.
                                    EIGENVECTOR
  0.60602E-04   0.85982E-02   0.84885E-02  -0.85462E-02  -0.33269E-02
 -0.31681E-02  -0.28569E-02  -0.47012E+00   0.33269E-02  -0.31682E-02
 -0.28569E-02   0.47008E+00  -0.60605E-04   0.85981E-02   0.84885E-02
  0.85763E-02  -0.29595E-02  -0.34862E+00   0.16281E+00   0.36154E+00
  0.66564E-05  -0.36155E+00  -0.16280E+00   0.34860E+00   0.29670E-02

EIGENVALUE= 0.59587E-02                                  FREQUENCY= 0.11015E+03,HZ.
                                    EIGENVECTOR
 -0.33269E-02  -0.28570E-02   0.31681E-02   0.47010E+00  -0.60569E-04
  0.84884E-02  -0.85982E-02  -0.85575E-02   0.60579E-04   0.84884E-02
 -0.85981E-02   0.85674E-02   0.33269E-02  -0.28569E-02   0.31681E-02
 -0.47011E+00   0.16281E+00  -0.36154E+00   0.29679E-02  -0.34861E+00
 -0.27819E-05   0.34861E+00  -0.29679E-02   0.36154E+00  -0.16281E+00

EIGENVALUE= 0.57948E-02                                  FREQUENCY= 0.10862E+03,HZ.
                                    EIGENVECTOR
  0.43013E-02   0.54057E-02  -0.54055E-02  -0.43021E+00   0.43013E-02
  0.54055E-02   0.54056E-02   0.43020E+00   0.43013E-02  -0.54057E-02
 -0.54056E-02   0.43022E+00   0.43013E-02  -0.54055E-02   0.54057E-02
 -0.43021E+00  -0.56561E-01   0.24290E+00  -0.56552E-01   0.24290E+00
 -0.10284E+00   0.24289E+00  -0.56565E-01   0.24290E+00  -0.56556E-01

EIGENVALUE= 0.55392E-02                                  FREQUENCY= 0.10620E+03,HZ.
                                    EIGENVECTOR
  0.15788E-01   0.26641E-01  -0.26641E-01   0.38127E+00   0.15788E-01
  0.26641E-01   0.26641E-01  -0.38126E+00   0.15788E-01  -0.26641E-01
 -0.26641E-01  -0.38127E+00   0.15788E-01  -0.26641E-01   0.26641E-01
  0.38126E+00   0.73416E-01   0.76488E-01   0.73411E-01   0.76484E-01
  0.60574E+00   0.76489E-01   0.73419E-01   0.76485E-01   0.73413E-01
```

FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

$$\{d_i\} = \begin{Bmatrix} W_i/TL \\ \theta_x \\ \theta_y \\ \theta_{xy*}TL \end{Bmatrix}$$



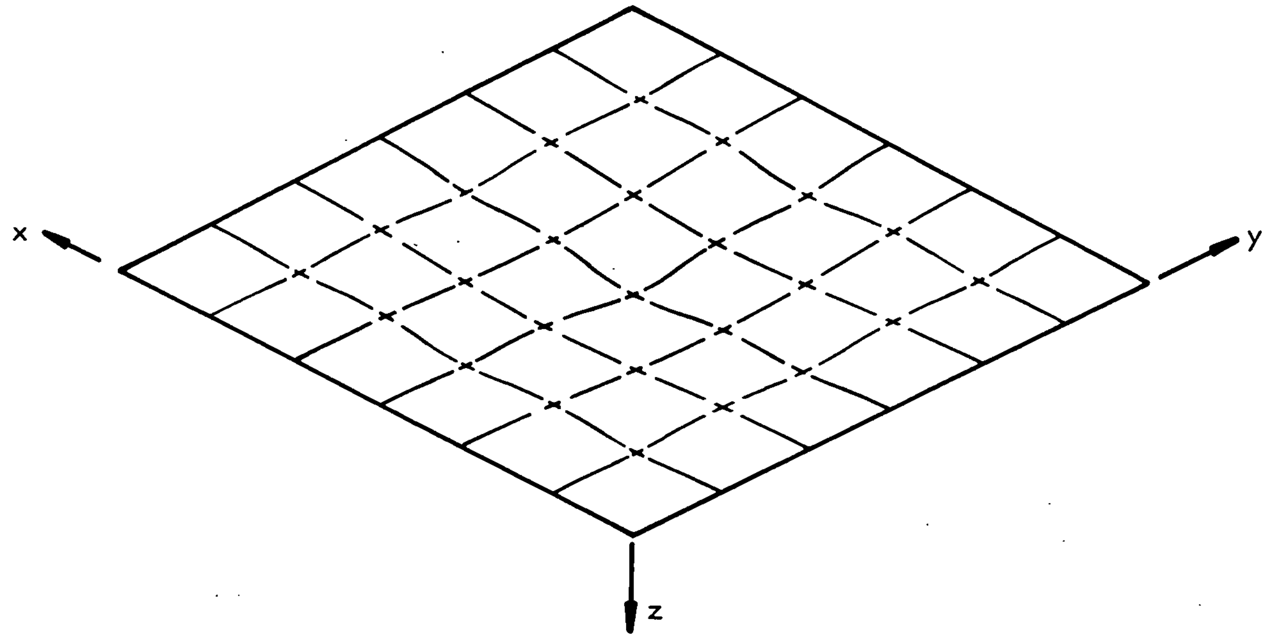
TL = Nondimensionalizing length



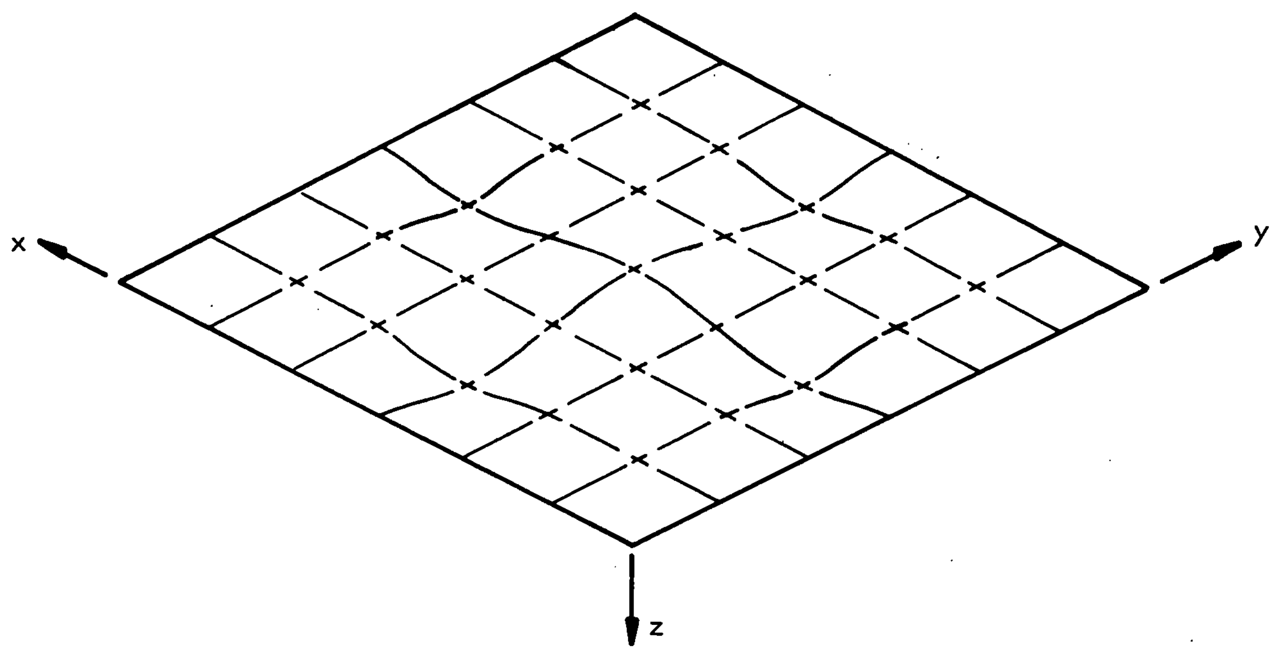
Eigenvectors listed in the sequence:

$$\left\{\{d_1\}\ ,\ \{d_2\}\ ,\ \{d_3\}\ ,\ \{d_4\}\ ,\ \{W_{01}/TL,\ W_{02}/TL,\ \ldots,\ W_{09}/TL\}\right\}$$

FIGURE D-11. EIGENVECTOR NOTATION: NINE-BAY TWO-DIMENSIONAL PANEL ARRAY

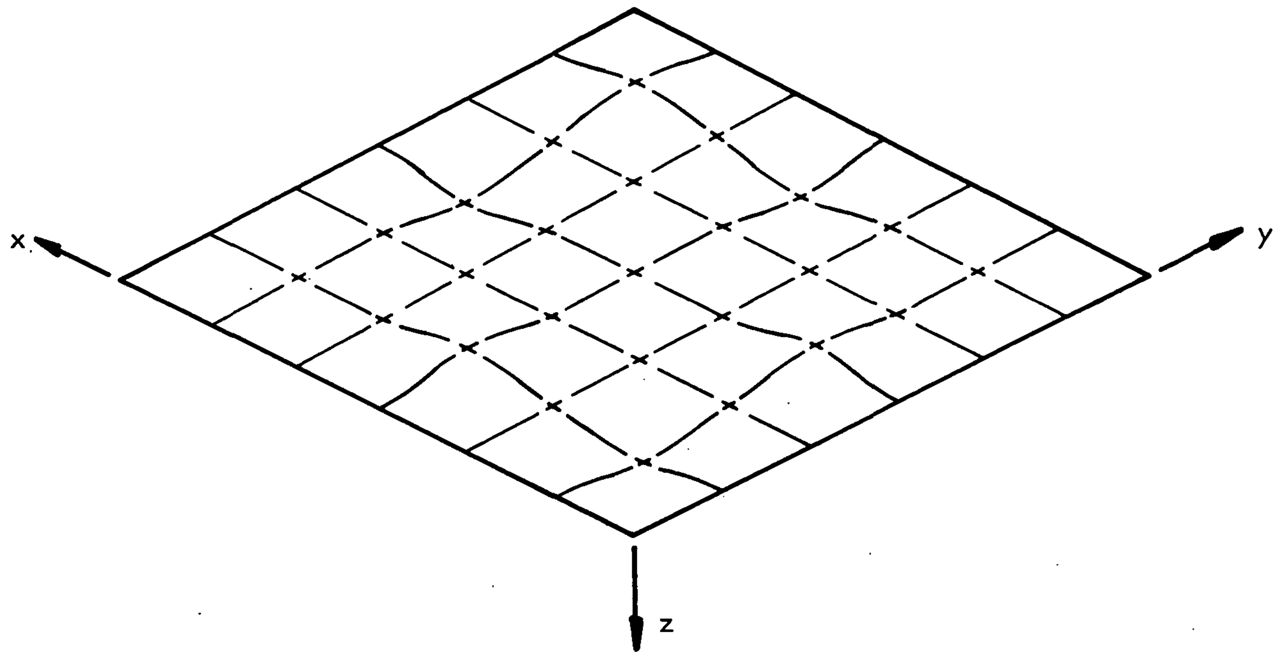


Mode: f = 106.2 Hz.

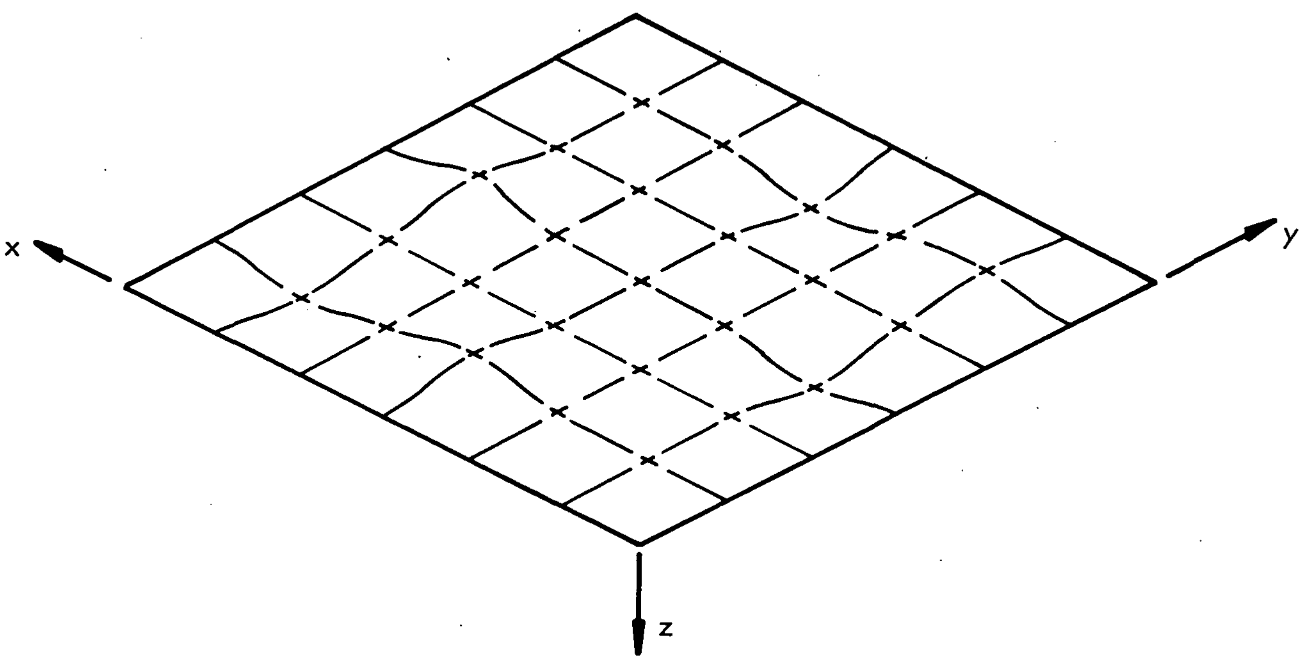


Mode: f = 108.62 Hz.

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM



Mode: f = 110.15 Hz. (repeated root)



Mode: f = 110.15 Hz. (repeated root)

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM

APPENDIX E

CHLADNI PATTERNS FOR STIFFENED PANEL ARRAYS

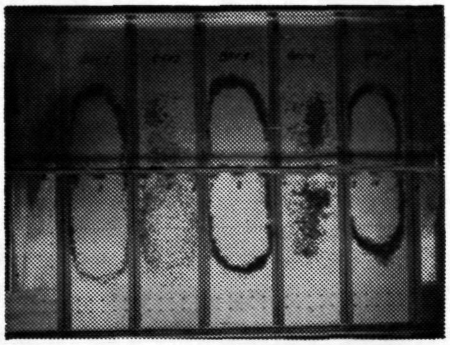
As described in the main text, photographs were taken of each mode excited. For the one-dimensional arrays, only the structure modes with fundamentals across the bay width are given except as indicated. Under each photograph appears the following notation:

$$f = N/M : R : Q$$

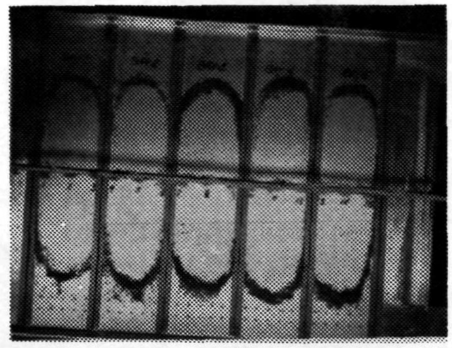
where N is the experimental frequency for the mode.
M is the computed value (if applicable)
R is the speaker condition (see figure 15, reference 1)
Q is the number of unsupported bays (Q = 5 or Q = 3).

Not all of the modes illustrated were predominant.

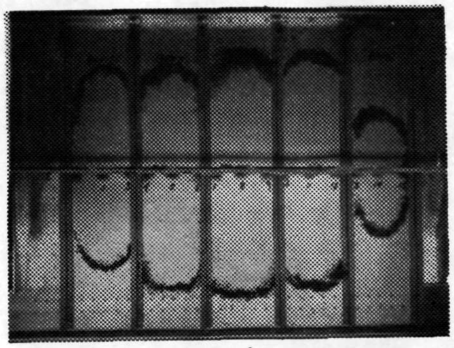
The modal patterns for the nine-bay specimens are also given. All of the predominant modes excited consisted of coupled fundamental modes for the individual bays. Higher modes are also illustrated. The notation indicating the experimental frequency, the computed frequency, and the speaker phase condition is similar to that described above.



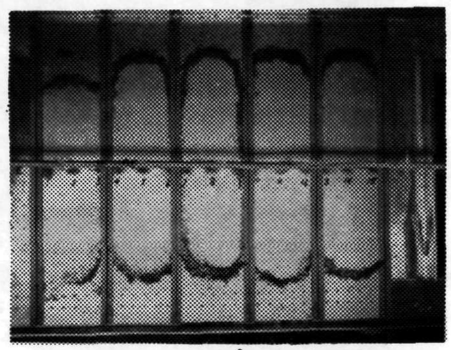
f = 82/92:A:5



f = 106/-:A:5

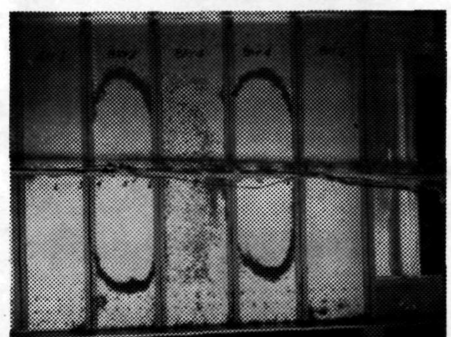


f = 119/121:A:5

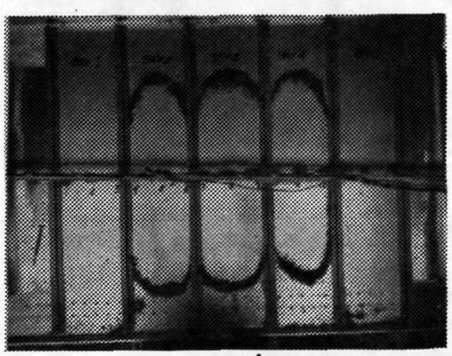


f = 126/117:A:5

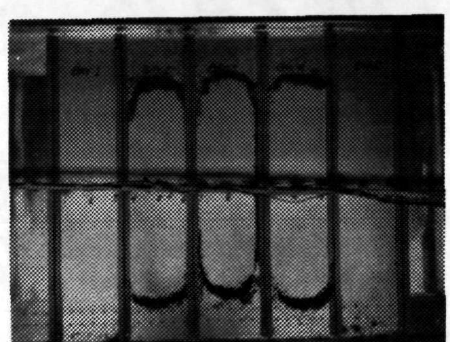
f = 234/-:A:5



f = 108/101:A:3

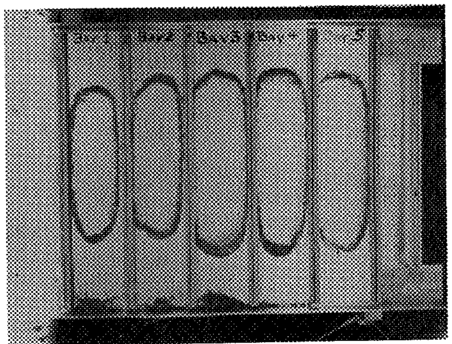


f = 115/-:A:3

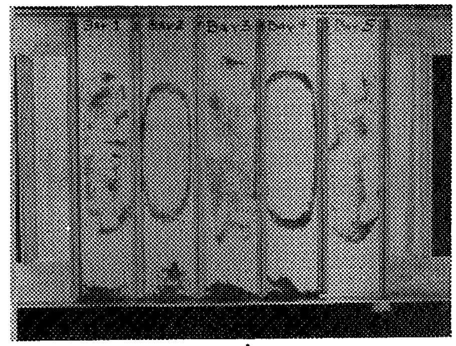


f = 127/151:B:3

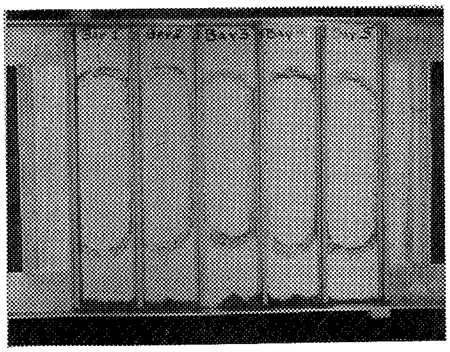
CHLADNI PATTERNS SPECIMEN SPI-1



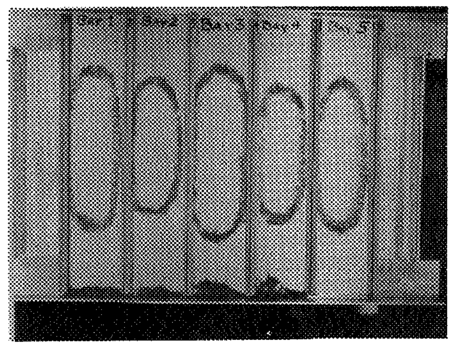
f = 88/95:A:5



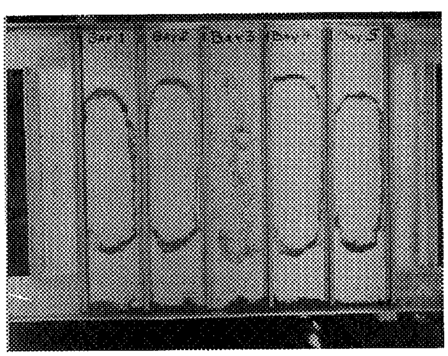
f = 92/–:A:5



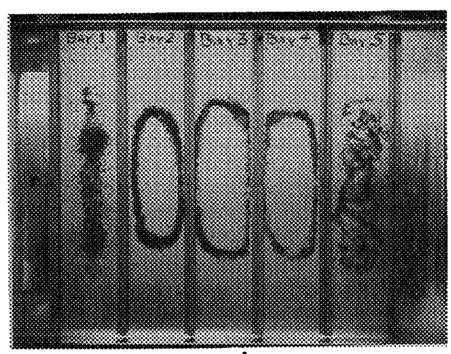
f = 103/99:A:5



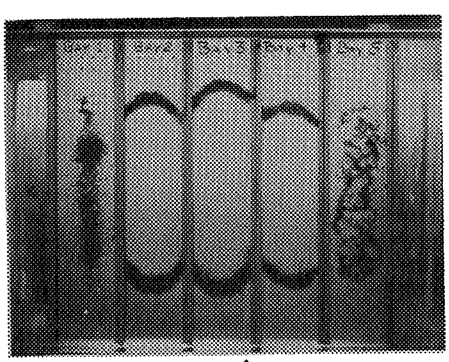
f = 113/–:A:5



f = 120/118:B:5



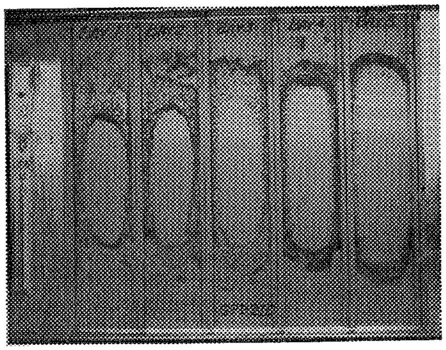
f = 91/109:A:3



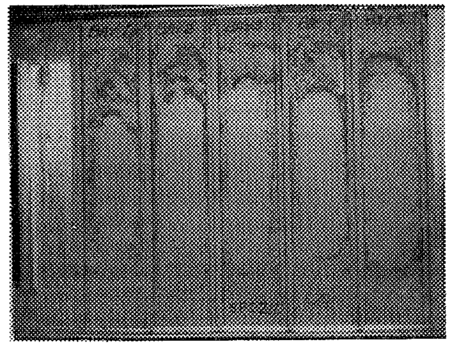
f = 109/151:A:3

f = 127/133:B:3

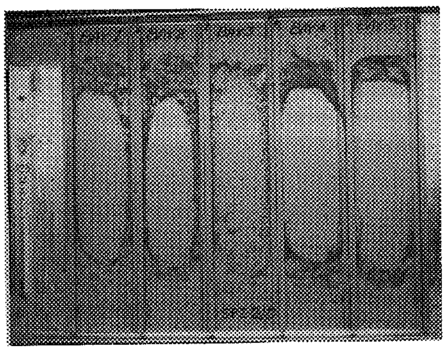
CHLADNI PATTERNS SPECIMEN SPI-2-1



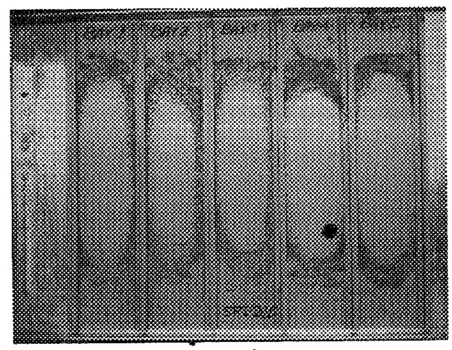
f = 80/–:A:5



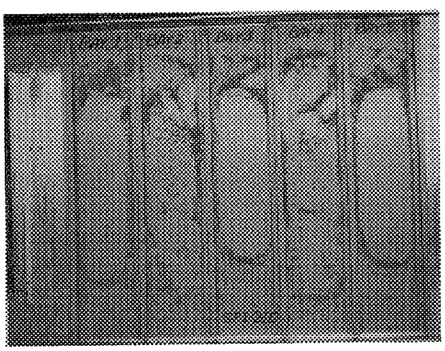
f = 88/91:A:5



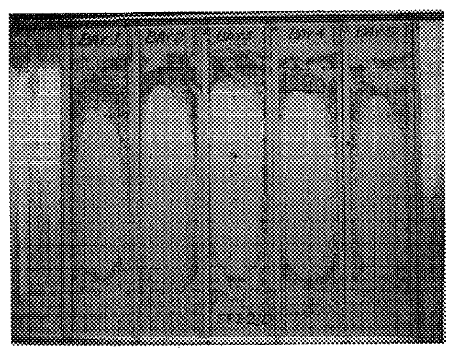
f = 100/113:A:5



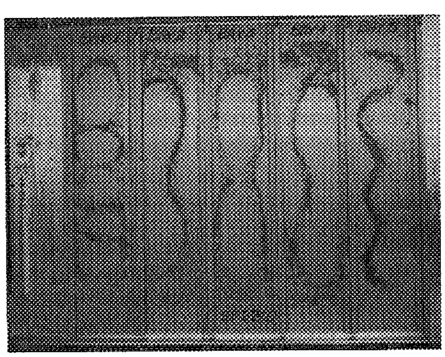
f = 111/121:A:5



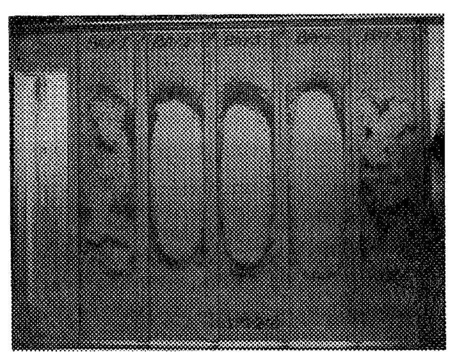
f = 112/–:C:5



f = 128/181:B:5

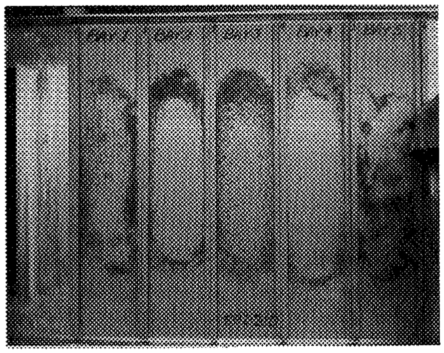


f = 229/–:A:5



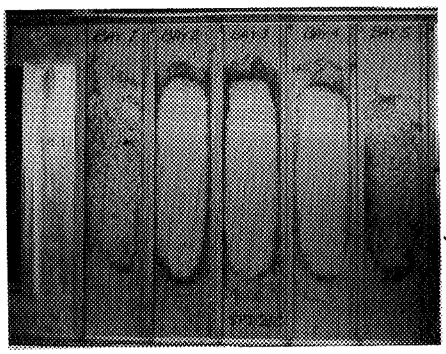
f = 94/102:A:3

CHLADNI PATTERNS SPECIMEN SPI–2–1D



f = 98/–: A:3

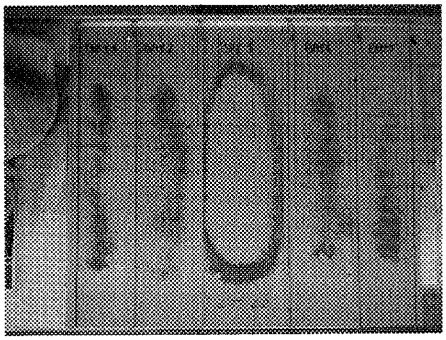
f = 108/128: B:3



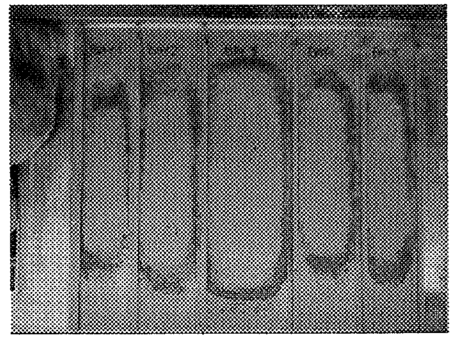
f = 134/147:B:3

f = 249/–:B:3

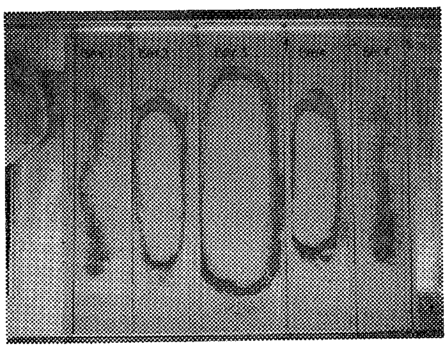
CHLADNI PATTERNS SPECIMEN SPI-2-1D



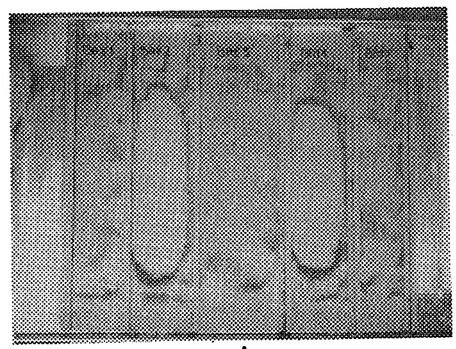
f = 57/70: A:5



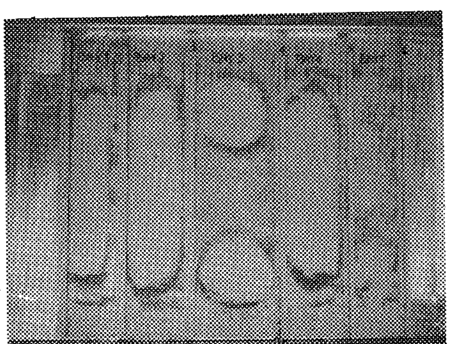
f = 61/–: A:5



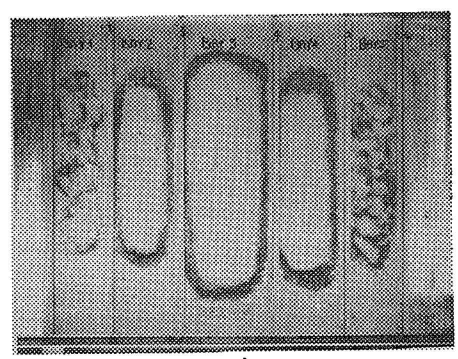
f = 68–: A:5



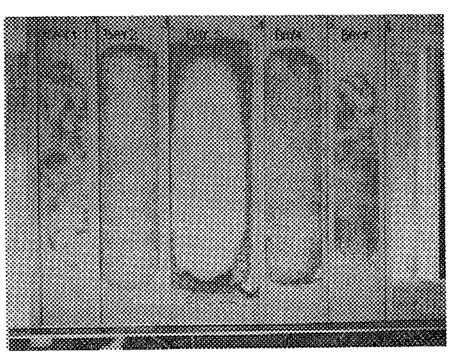
f = 94/110: B:5



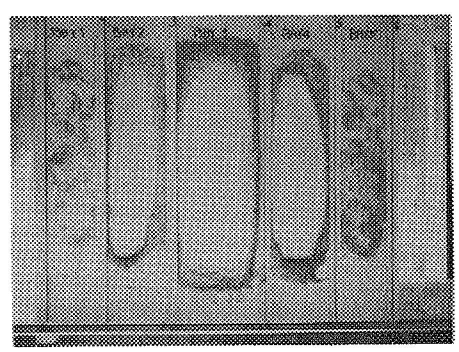
f = 98/–: B:5



f = 51/71: A:3

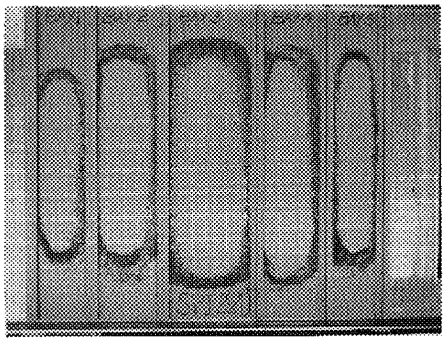


f = 61/–: A:3

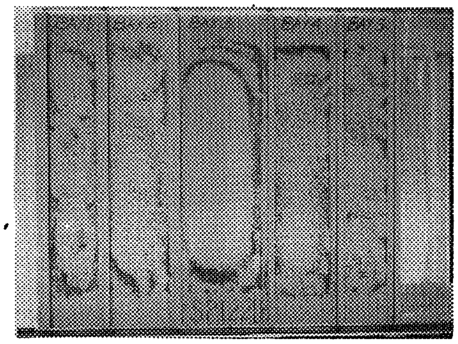


f = 67/–: A:3

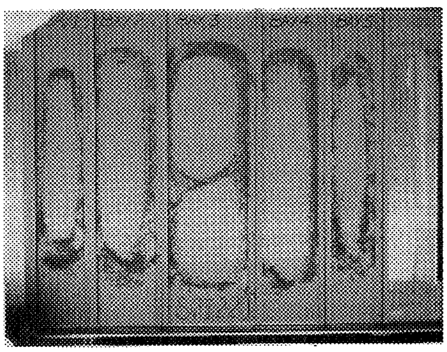
CHLADNI PATTERNS SPECIMEN SPI-2-2



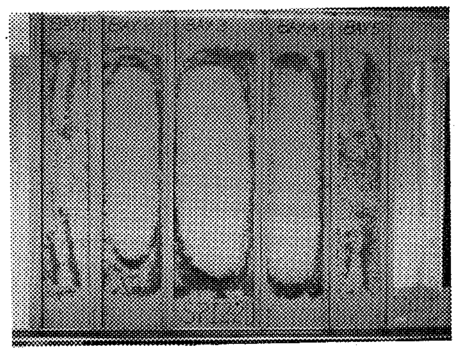
f = 55/–:A:5



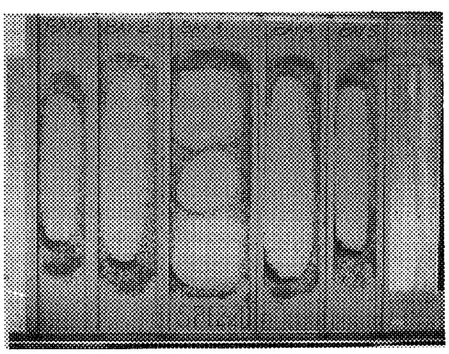
f = 68/68:D:5



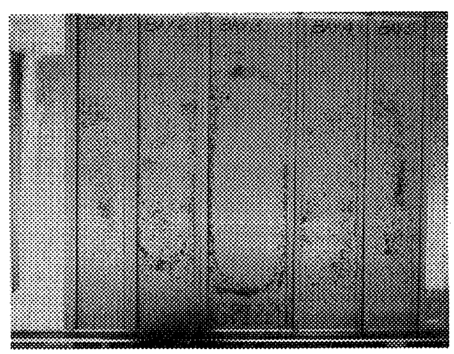
f = 91/–:A:5



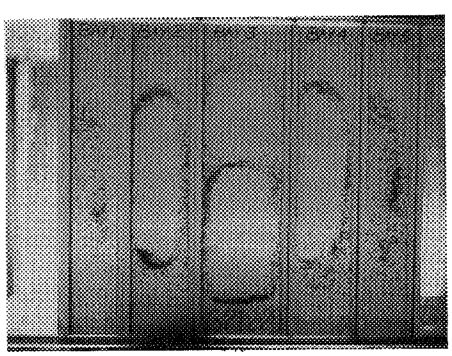
f = 96/102:B:5



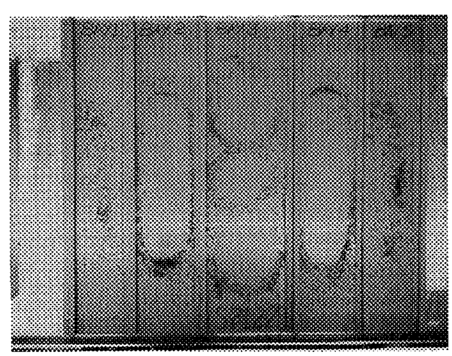
f = 119/–:A:5



f = 64/70:A:3

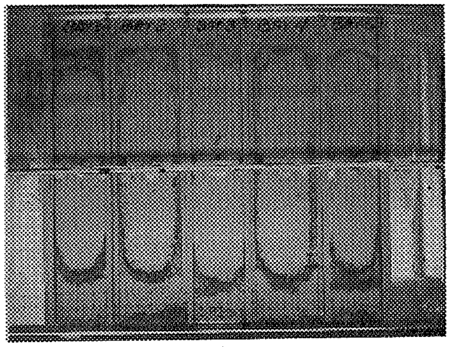


f = 102/–:A:3

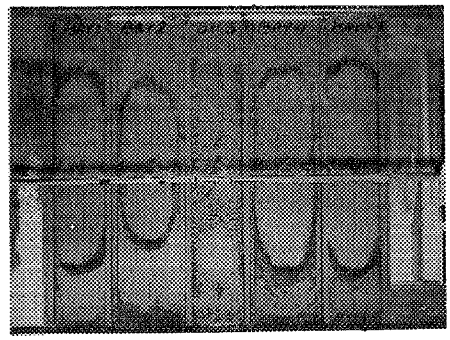


f = 112/–:A:3

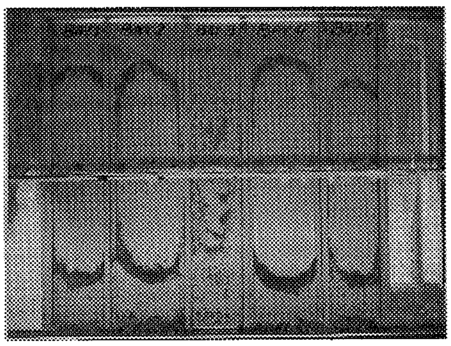
CHLADNI PATTERNS SPECIMEN SPI-2-2D



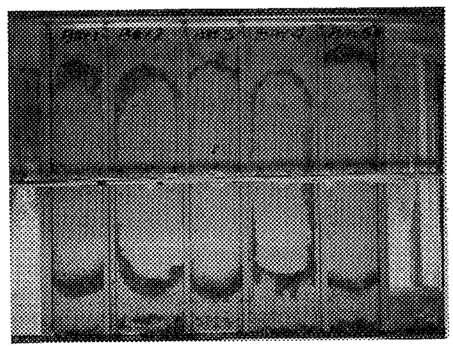
f = 80/94:A:5



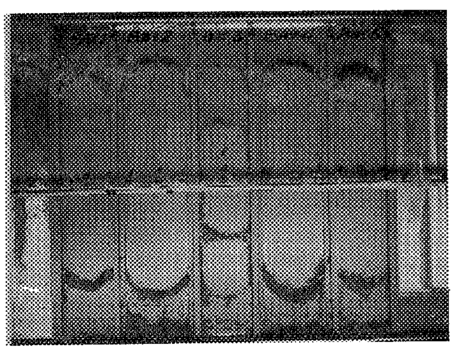
f = 88/98:B:5



f = 93/–:A:5

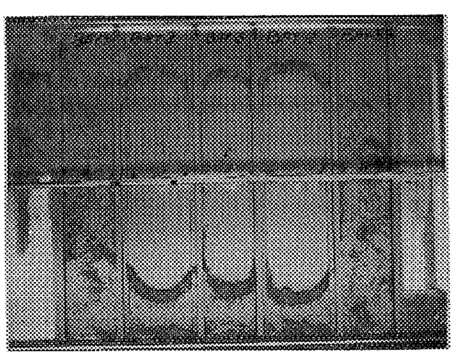


f = 107/120:A:5

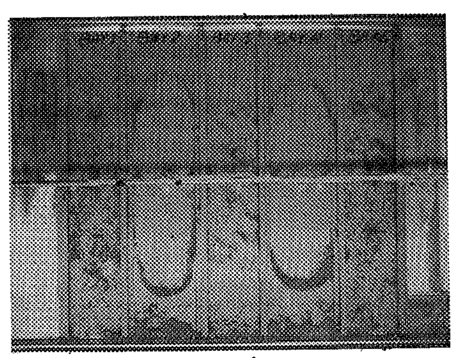


f = 117/121:B:5

f = 90/–:A:3

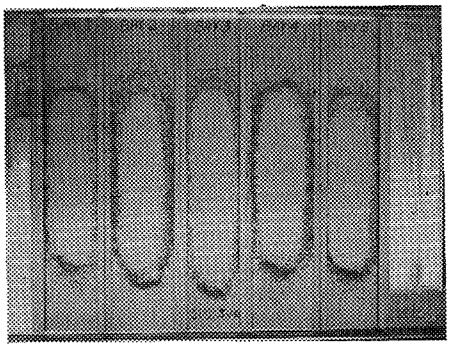


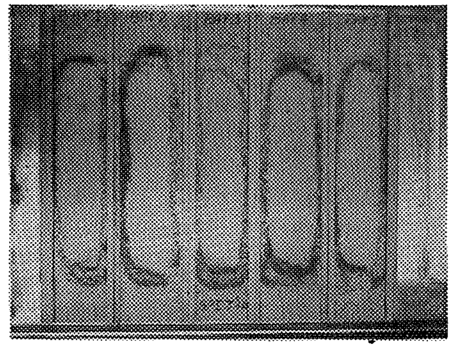
f = 101/100:A:3

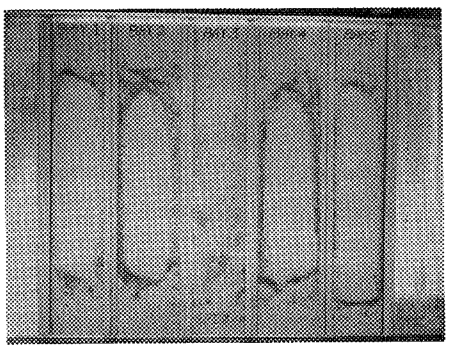


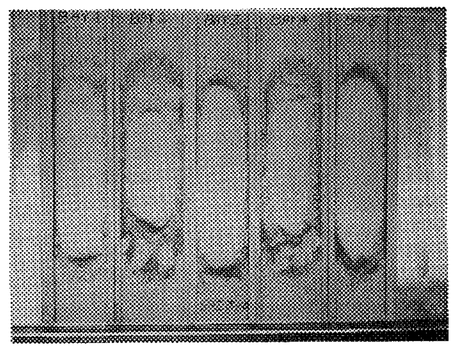
f = 117/150:B:3

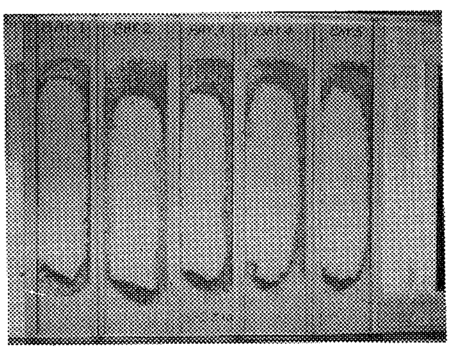
CHLADNI PATTERNS SPECIMEN SPI-3-1

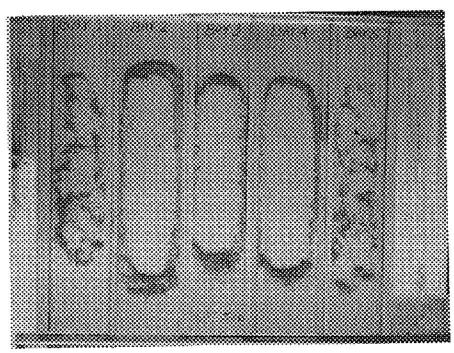

f = 105/:A:5

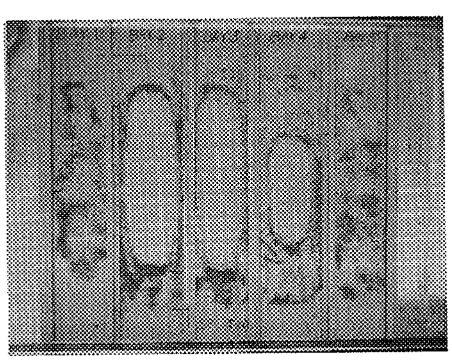

f = 109/:A:5

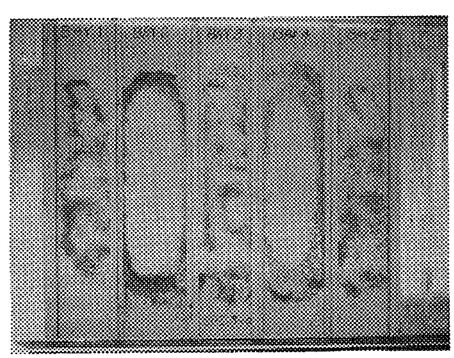

f = 115/:B:5


f = 127/:A:5

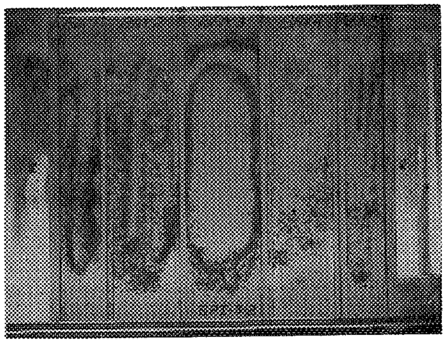

f = 134/:B:5


f = 106/:A:3


f = 122/:B:3

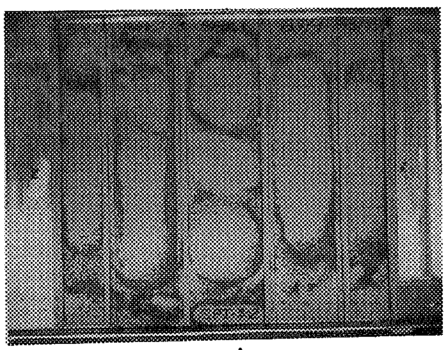

f = 135/:B:3

CHLADNI PATTERNS SPECIMEN SPI-3-1D

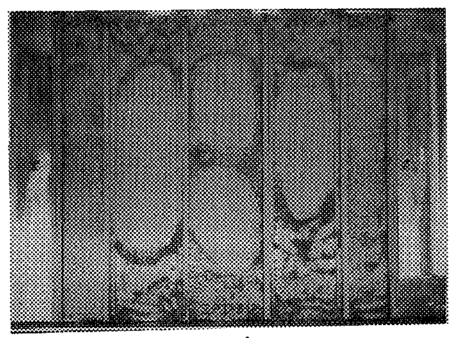


f = 54/–: A:5

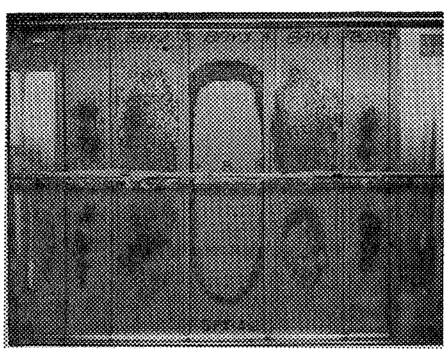
f = 62/74: A:5



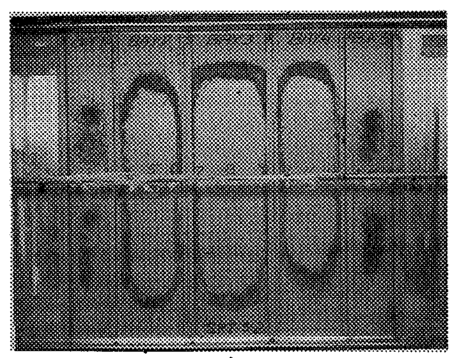
f = 72/–: A:5



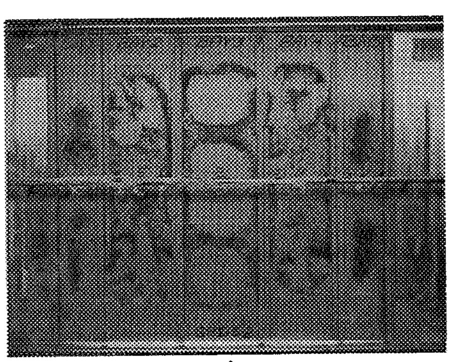
f = 111/–: A:5



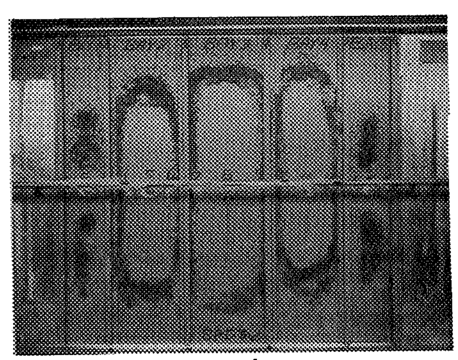
f = 62/–: A:3



f = 68/66: A:3

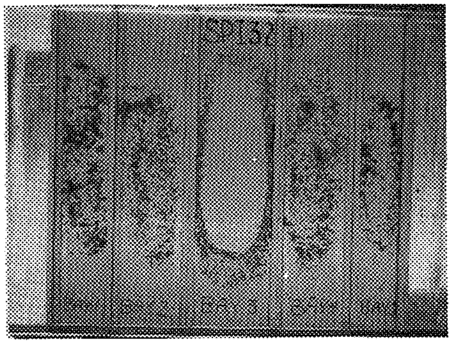


f = 74/–: A:3

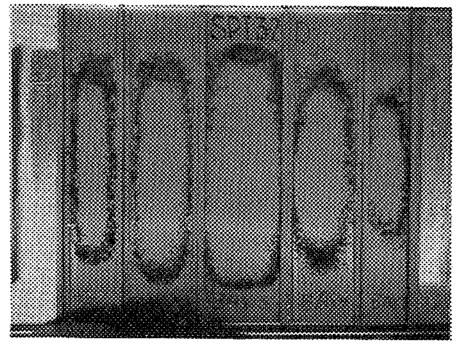


f = 101/–: A:3

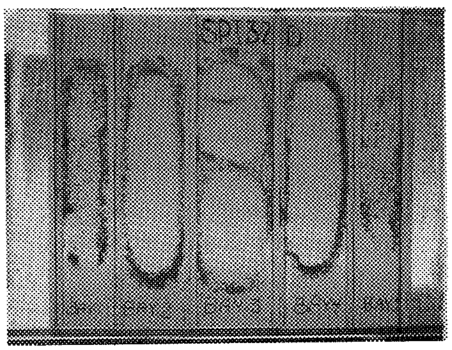
CHLADNI PATTERNS SPECIMEN SPI-3-2



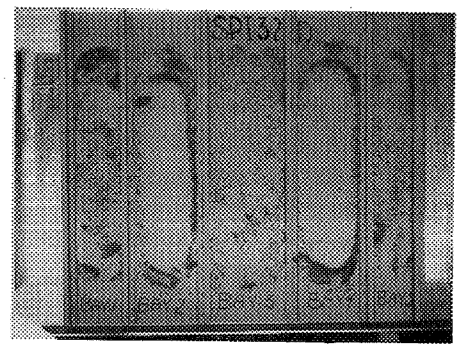
f = 63/–: A:5



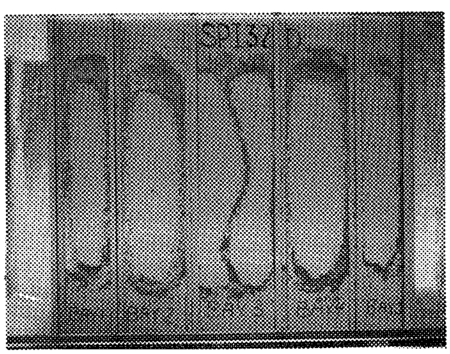
f = 74/71: A:5



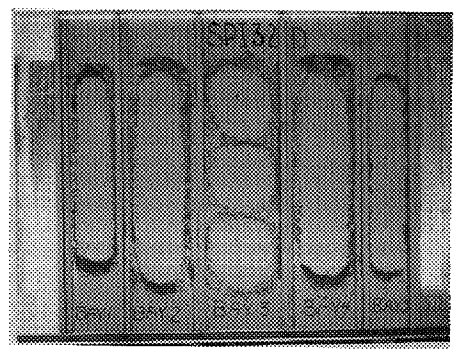
f = 93/–: A:5



f = 99/102: B:5

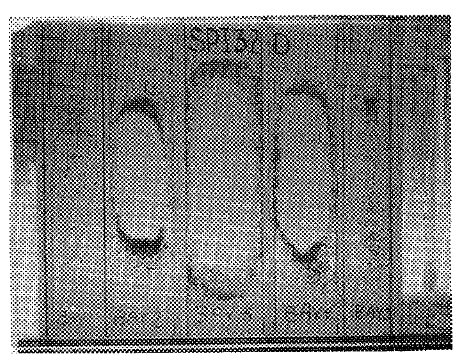


f = 107/128: B:5



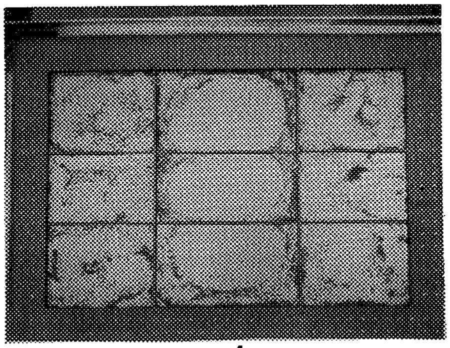
f = 125/–: A:5

f = 65/–: A:3

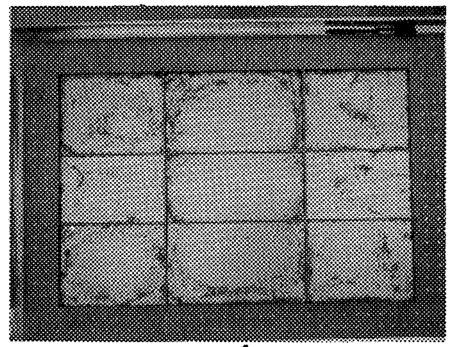


f = 71/65: C:3

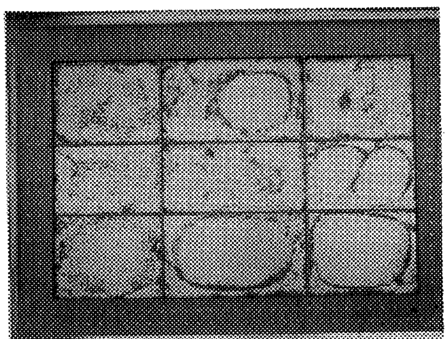
CHLADNI PATTERNS SPECIMEN SPI-3-2D



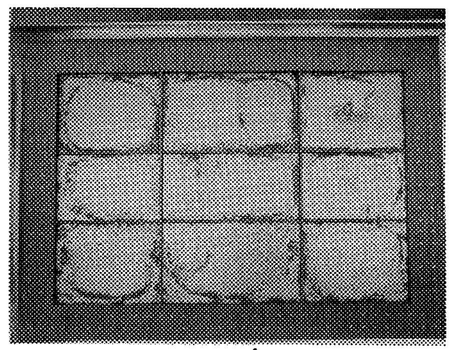
f = 88/82:A



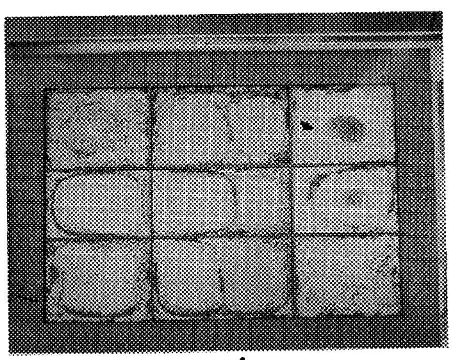
f = 94/112:A



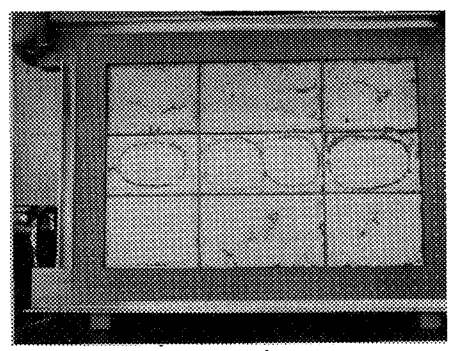
f = 123/125:A



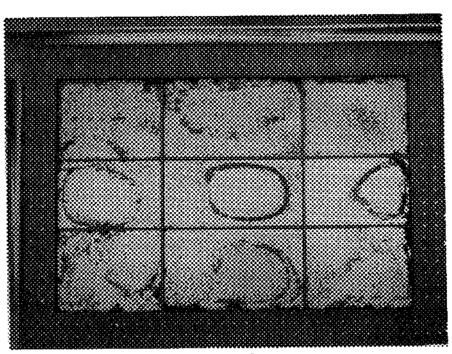
f = 148/135:A



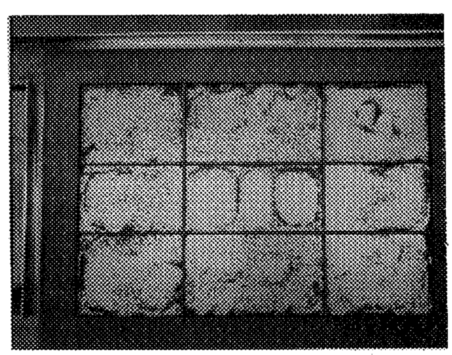
f = 70/–:A



f = 175/126:A

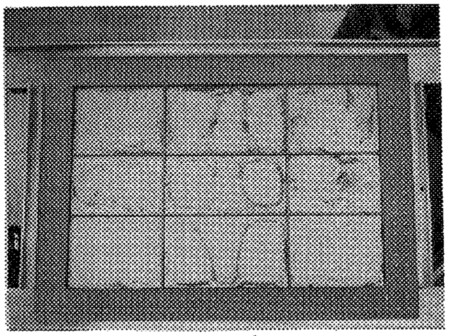


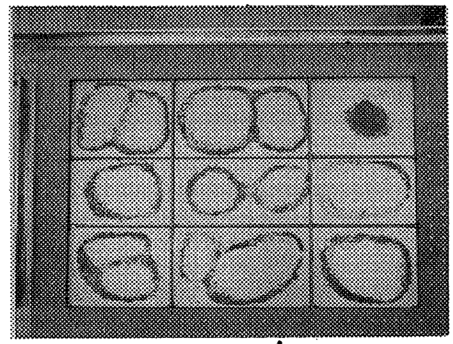
f = 188/197:A

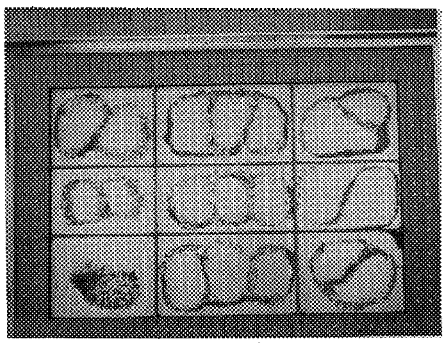


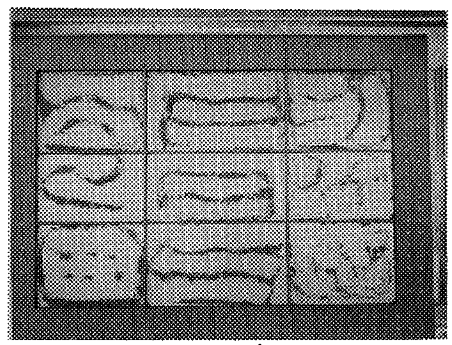
f = 270/–:A

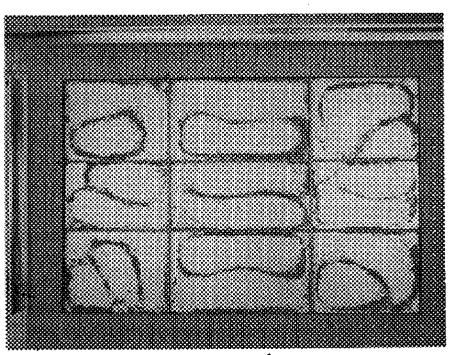
CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMEN

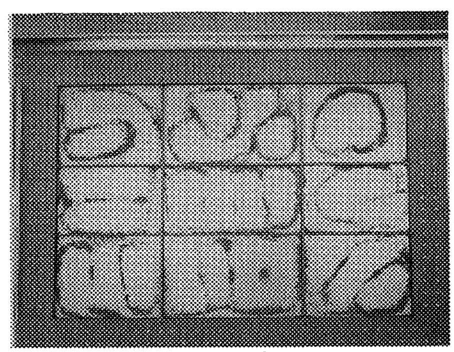

f = 279/–:A

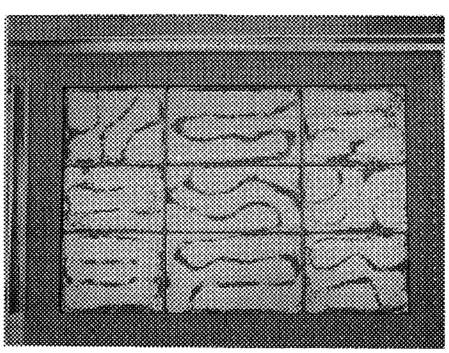

f = 139/–:B

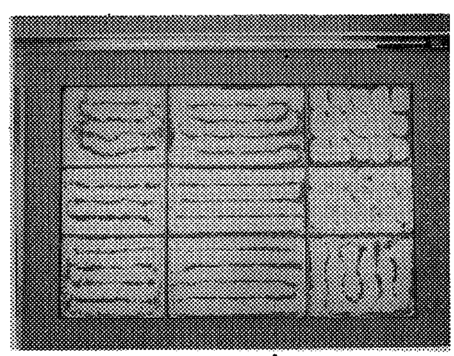

f = 264/–:B


f = 287/–:B

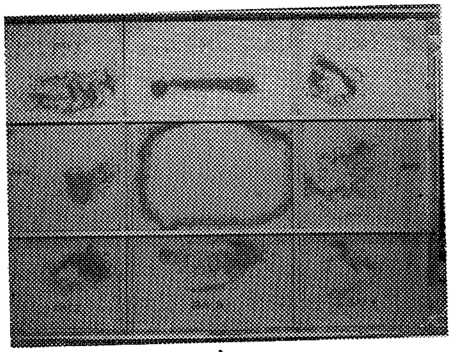

f = 346/–:C


f = 403/–:C

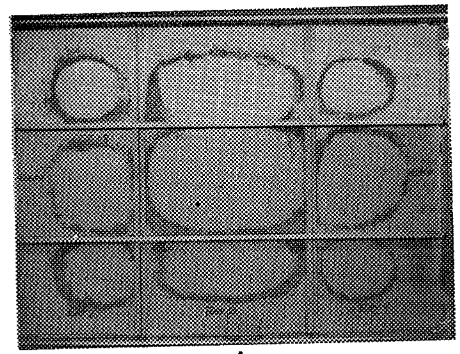

f = 697/–:C


f = 1502/–:C

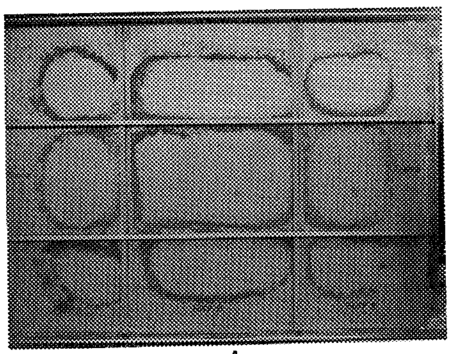
CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMEN



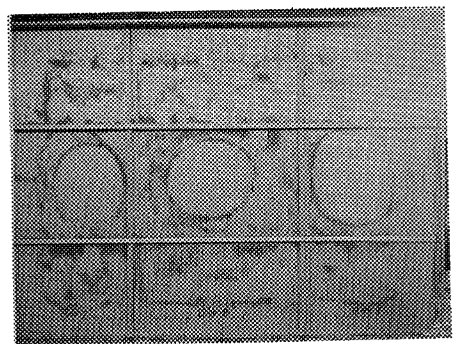
f = 74/82:A



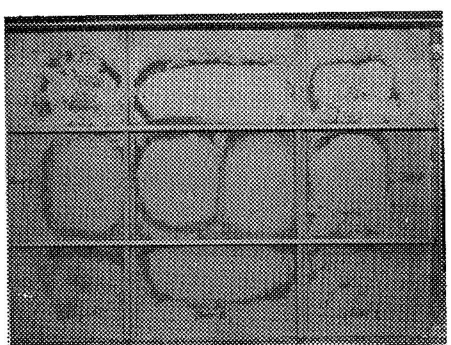
f = 82/87:A



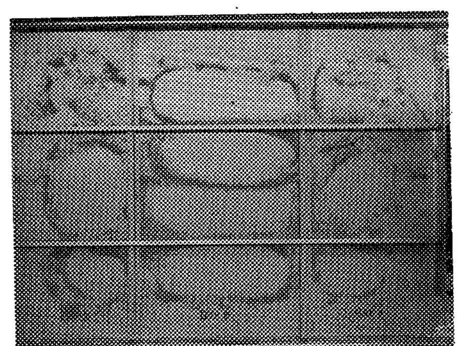
f = 110/88:A



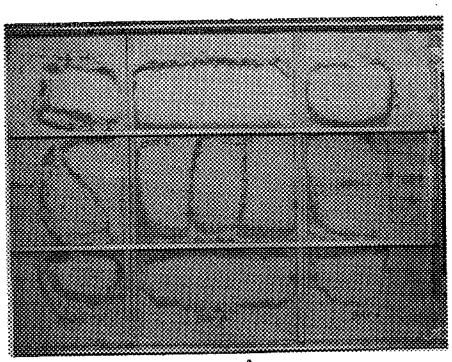
f = 127/–:B



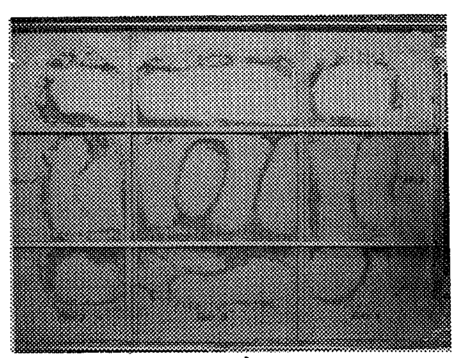
f = 138/–:A



f = 177/–:A

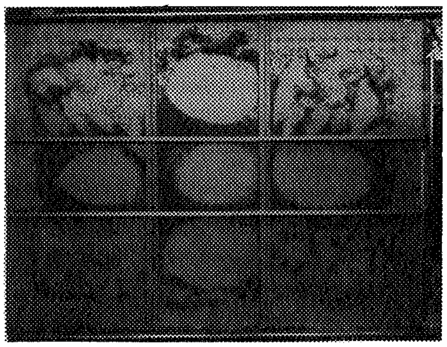


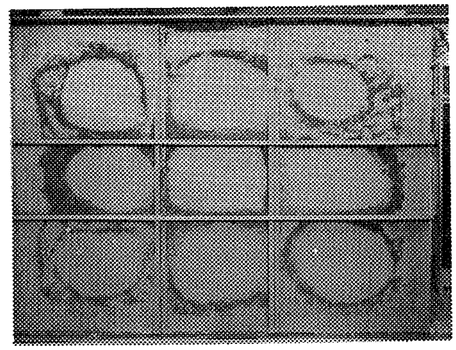
f = 220/–:A

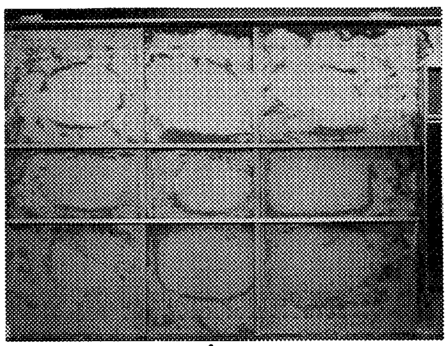


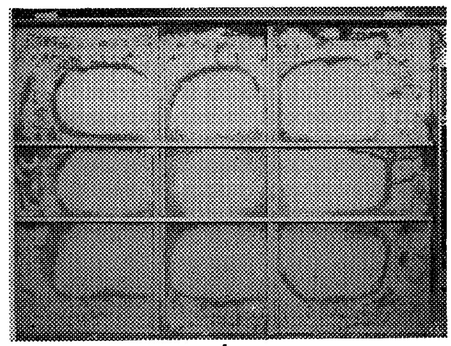
f = 309/–:A

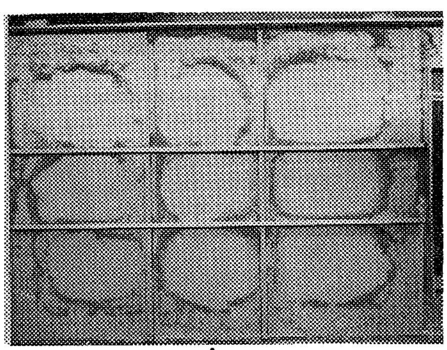
CHLADNI PATTERNS FOR 9 BAY SPECIMEN SPII-1

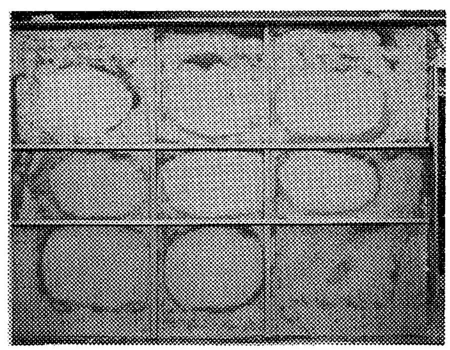

f = 90/89:A

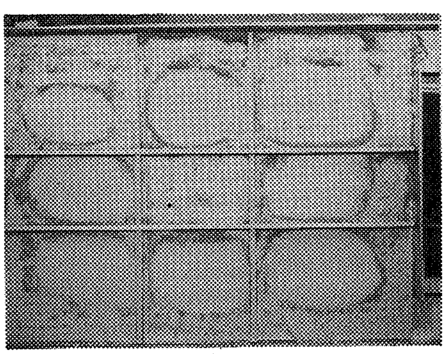

f = 97/112:A


f = 101/114:C


f = 107/115:D


f = 112/133:B


f = 134/-:B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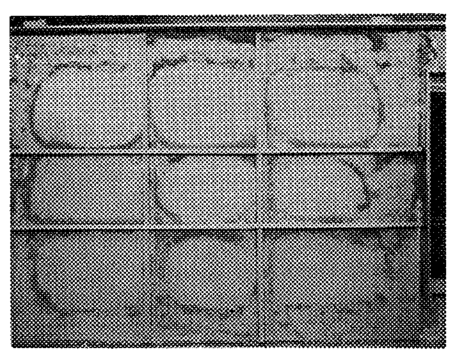
f = 168/211:B

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