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

F. F. Rudder, Jr.

Prepared under Contract No. NAS1-9526 by
LOCKHEED-GEORGIA COMPANY RESEARCH LABORATORY
Marietta, Georgia

for Langley Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 - Price
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 \( W \) (equation 23, ref. 1). The introduction of the coordinate \( W \) 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.
READ INPUT DATA

WRITE DATA CASE AND INPUT DATA

INITIALIZE PARAMETERS AND EDIT INPUT DATA AS REQ'D

COMPUTE FREE-FREE STIFFNESS, \( S(f) \), AND MASS, \( R(l) \), MATRICES

ARE ELASTIC SUPPORTS REQUIRED?

YES

ADD LUMPED SUPPORT DATA TO FREE-FREE STIFF. & MASS MATRICES

NO

NONDIMENSIONALIZE STIFFNESS AND MASS MATRICES

APPLY KINEMATIC CONSTRAINTS

FIGURE 1. FLOWCHART: PROGRAM BMPROP(MAIN)/ONE-DIMENSIONAL PANEL ARRAYS (CONTINUED)
FIGURE 1. FLOW CHART: PROGRAM BMPROP(MAIN)/ONE-DIMENSIONAL PANEL ARRAYS (CONCLUDED)
INITIALIZE
GEOMETRIC
PARAMETERS

SEGMENT 1
RDNWRT (1)

READ INPUT DATA
RDNWRT (1)

FILL CONSTRAINT VECTOR, NDEL(I)
FOR CLAMPED EDGES
COMPUTE LENGTH PARAMETER, TK
COMPUTE PLATE RIGIDITY, DP

PRINT EDITED
INPUT DATA
RDNWRT (2)

IOP = 1
(STIFFNESS
CALCULATIONS)

INITIALIZE
SUPER MATRIX, R
ZERO (R, N)

IOP = 1, 2

IOP = 2
(MASS
CALCULATIONS)

INITIALIZE
SUPER MATRIX, R
ZERO (R, N)

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)
STEP 17

STEP 18

STEP 19

STEP 20

STEP 21

STEP 22

FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)
FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONCLUDED)
FIGURE 3. TWO-DIMENSIONAL PANEL GEOMETRY AND ELEMENT NOMENCLATURE

FIGURE 4. PLATE AND RIB ELEMENT ASSEMBLY

**Plate elements**

**Rib elements**

**Twist coordinate, $\theta_{xy}$, not shown**
FIGURE 5. ACCELEROMETER AND STRAIN GAGE LOCATIONS
FOR ONE-DIMENSIONAL PANELS

*Note: Locations not indicated are sequentially spaced at one inch intervals.
FIGURE 6. ACCELEROMETER LOCATION FOR NINE-BAY MACHINED PANEL SPECIMENS
FIGURE 7. STRAIN GAGE LOCATION FOR MACHINED PANEL SPECIMENS (SEE TABLE 18)
STIFFENERS NOT SHOWN IN PLANVIEW FOR CLARITY

FIGURE 8. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-1
(SEE TABLE 18)
FIGURE 9. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-2
(SEE TABLE 18)
### TABLE 1
NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>82 Hz</td>
<td>SPI-1 A</td>
<td>0</td>
<td>0.20*</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>106 Hz</td>
<td>SPI-1 A</td>
<td>0.75</td>
<td>0.70</td>
<td>0.25*</td>
<td>-0.50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>119 Hz</td>
<td>SPI-1 A</td>
<td>0.25</td>
<td>0</td>
<td>0.15*</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>126 Hz</td>
<td>SPI-1 B</td>
<td>-0.05</td>
<td>0</td>
<td>0.40</td>
<td>-0.24</td>
<td>0.25</td>
<td>-0.18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Hz</td>
<td>SPI-1 A</td>
<td>0</td>
<td>0.95</td>
<td>1.00</td>
<td>-1.00</td>
<td>1.00</td>
<td>-1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127 Hz</td>
<td>SPI-1 B</td>
<td>-0.10</td>
<td>0</td>
<td>0.43</td>
<td>0.10*</td>
<td>0.55</td>
<td>-0.40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPI-1 B</td>
<td>0.25</td>
<td>0</td>
<td>0.63</td>
<td>0.19*</td>
<td>0.20</td>
<td>-0.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPI-1 B</td>
<td>0.75</td>
<td>0.61</td>
<td>1.00</td>
<td>0.27*</td>
<td>0.21*</td>
<td>-0.17</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPI-1 B</td>
<td>0.25</td>
<td>0</td>
<td>0.60</td>
<td>0.29*</td>
<td>0.25</td>
<td>-0.15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Hz</td>
<td>SPI-1 B</td>
<td>-0.10</td>
<td>0</td>
<td>0.42</td>
<td>0.35*</td>
<td>0.65</td>
<td>-0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Hz</td>
<td>SPI-1 B</td>
<td>0</td>
<td>1.00</td>
<td>0.90</td>
<td>0.81</td>
<td>1.00</td>
<td>0.43</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127 Hz</td>
<td>SPI-1 B</td>
<td>0</td>
<td>0</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Hz</td>
<td>SPI-1 B</td>
<td>0</td>
<td>0</td>
<td>0.45</td>
<td>0.31</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127 Hz</td>
<td>SPI-1 B</td>
<td>1.00</td>
<td>0.94</td>
<td>0.50</td>
<td>0.50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>127 Hz</td>
<td>SPI-1 B</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*90° Phase shift to reference
<table>
<thead>
<tr>
<th>Panel</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
<th>SPI-2-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>88 Hz</td>
<td>92 Hz</td>
<td>103 Hz</td>
<td>113 Hz</td>
<td>120 Hz</td>
<td>91 Hz</td>
<td>109 Hz</td>
</tr>
<tr>
<td>Speaker Cond.</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Position 1</td>
<td>0.01</td>
<td>-0.24</td>
<td>0.09</td>
<td>0.05</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.04</td>
<td>-0.24</td>
<td>0.21</td>
<td>0.01</td>
<td>-0.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.03</td>
<td>-0.43</td>
<td>-0.93</td>
<td>0.03</td>
<td>-0.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.03</td>
<td>-0.46</td>
<td>-0.75</td>
<td>0.01</td>
<td>-0.26</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>0.04</td>
<td>-0.37</td>
<td>-0.54</td>
<td>0.02</td>
<td>-0.13</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>0.03</td>
<td>-0.24</td>
<td>0.22</td>
<td>0.08</td>
<td>-0.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-0.02</td>
<td>-0.30</td>
<td>0.22</td>
<td>0.14</td>
<td>-0.10</td>
<td>0.10</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>-0.08</td>
<td>0.63</td>
<td>0.23</td>
<td>0.26</td>
<td>-0.10</td>
<td>0.26</td>
<td>0.57*</td>
</tr>
<tr>
<td>9</td>
<td>-0.40</td>
<td>0.22</td>
<td>0.23</td>
<td>0.42</td>
<td>-0.24</td>
<td>0.50</td>
<td>0.59</td>
</tr>
<tr>
<td>10</td>
<td>-0.67</td>
<td>0.21</td>
<td>0.23</td>
<td>0.47</td>
<td>-0.53</td>
<td>0.60</td>
<td>0.69</td>
</tr>
<tr>
<td>11</td>
<td>-0.50</td>
<td>0.28</td>
<td>0.25</td>
<td>0.35</td>
<td>-0.44</td>
<td>0.69</td>
<td>0.69</td>
</tr>
<tr>
<td>12</td>
<td>-0.13</td>
<td>0.81</td>
<td>0.24</td>
<td>0.25</td>
<td>-0.20</td>
<td>0.40</td>
<td>0.42*</td>
</tr>
<tr>
<td>13</td>
<td>-0.01</td>
<td>-0.35</td>
<td>0.20</td>
<td>0.25</td>
<td>0.19*</td>
<td>0.33</td>
<td>0.11*</td>
</tr>
<tr>
<td>14</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.10</td>
<td>0.26</td>
<td>0.28</td>
<td>0.54</td>
<td>0.14</td>
</tr>
<tr>
<td>15</td>
<td>0.18</td>
<td>0.07</td>
<td>0.05</td>
<td>0.28</td>
<td>0.36</td>
<td>0.82</td>
<td>0.36</td>
</tr>
<tr>
<td>16</td>
<td>0.20</td>
<td>0.15</td>
<td>0</td>
<td>0.26</td>
<td>0.36</td>
<td>1.00</td>
<td>0.46</td>
</tr>
<tr>
<td>17</td>
<td>0.18</td>
<td>0.12</td>
<td>0.05</td>
<td>0.21</td>
<td>0.30</td>
<td>0.74</td>
<td>0.36</td>
</tr>
<tr>
<td>18</td>
<td>0.11</td>
<td>-0.10</td>
<td>0.10</td>
<td>0.24</td>
<td>0.22</td>
<td>0.54</td>
<td>0.18</td>
</tr>
<tr>
<td>19</td>
<td>-0.01</td>
<td>-0.35</td>
<td>0.19</td>
<td>0.26</td>
<td>0.24</td>
<td>0.33</td>
<td>0.11*</td>
</tr>
<tr>
<td>20</td>
<td>-0.16</td>
<td>0.96</td>
<td>0.20</td>
<td>0.33</td>
<td>0.80</td>
<td>0.40</td>
<td>0.46*</td>
</tr>
<tr>
<td>21</td>
<td>-0.70</td>
<td>0.37</td>
<td>0.24</td>
<td>0.63</td>
<td>1.00</td>
<td>0.60</td>
<td>0.91</td>
</tr>
<tr>
<td>22</td>
<td>-1.00</td>
<td>0.36</td>
<td>0.21</td>
<td>1.00</td>
<td>0.85</td>
<td>0.60</td>
<td>1.00</td>
</tr>
<tr>
<td>23</td>
<td>-0.60</td>
<td>0.39</td>
<td>0.34</td>
<td>0.79</td>
<td>0.48</td>
<td>0.50</td>
<td>0.91</td>
</tr>
<tr>
<td>24</td>
<td>-0.14</td>
<td>1.00</td>
<td>0.19</td>
<td>0.40</td>
<td>0.48</td>
<td>0.28</td>
<td>0.50</td>
</tr>
<tr>
<td>25</td>
<td>-0.02</td>
<td>-0.30</td>
<td>0.26</td>
<td>0.12</td>
<td>0.31</td>
<td>0.14</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>0.05</td>
<td>-0.07</td>
<td>0.16</td>
<td>0.10</td>
<td>0.29</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>0.10</td>
<td>-0.03</td>
<td>-0.56</td>
<td>0.07</td>
<td>0.40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>0.106</td>
<td>-0.04</td>
<td>-0.75</td>
<td>0.07</td>
<td>0.49</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>29</td>
<td>0.110</td>
<td>-0.11</td>
<td>-1.00</td>
<td>0.08</td>
<td>0.54</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>0.09</td>
<td>-0.11</td>
<td>0.34</td>
<td>0.08</td>
<td>0.58</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Position 31</td>
<td>0.02</td>
<td>-0.08</td>
<td>0.20</td>
<td>0.09</td>
<td>0.14</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*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 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 - - - |
| 31 | -0.02 0.09 0.15 0.20 - - - |

*90° Phase shift to reference.
### TABLE 4
NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

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

*90° Phase shift to reference.
### TABLE 5
NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

<table>
<thead>
<tr>
<th>Panel</th>
<th>SPI-2-2D</th>
<th>SPI-2-2D</th>
<th>SPI-2-2D</th>
<th>SPI-2-2D</th>
<th>SPI-2-2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>55 Hz</td>
<td>59 Hz</td>
<td>68 Hz</td>
<td>96 Hz</td>
<td>64 Hz</td>
</tr>
<tr>
<td>Speaker Cond.</td>
<td>A</td>
<td>C</td>
<td>D</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.09 T</td>
<td>0.14</td>
<td>0.19</td>
<td>0.19</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>0.20</td>
<td>0.35</td>
<td>0.36</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>-0.04</td>
<td>-0.08</td>
<td>-0.07</td>
<td>-0.04</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0.07 T</td>
<td>-0.13</td>
<td>-0.19</td>
<td>-0.25</td>
<td>-0.23</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-0.21</td>
<td>-0.29</td>
<td>-0.35</td>
<td>-0.29</td>
</tr>
<tr>
<td></td>
<td>0.14</td>
<td>-0.14</td>
<td>-0.36</td>
<td>-0.40</td>
<td>-0.36</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>-0.15</td>
<td>0.06 T</td>
<td>-0.32</td>
<td>-0.50</td>
<td>-1.00</td>
</tr>
<tr>
<td></td>
<td>-0.23</td>
<td>0</td>
<td>0.38</td>
<td>0.44</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>-0.20</td>
<td>-0.06</td>
<td>0.22</td>
<td>0.89</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>-1.00</td>
<td>-0.63</td>
<td>-0.45</td>
<td>-0.25</td>
<td>0.11 T</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.50</td>
<td>0.38</td>
<td>0.21</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>-1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>-0.14</td>
<td>-0.14</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>0.15 T</td>
<td>0.20 T</td>
<td>0.23 T</td>
<td>0.20 T</td>
<td>0.10 T</td>
</tr>
<tr>
<td></td>
<td>-0.18</td>
<td>-0.29</td>
<td>-0.29</td>
<td>-0.29</td>
<td>-0.15</td>
</tr>
<tr>
<td></td>
<td>0.13*</td>
<td>0.18*</td>
<td>0.20*</td>
<td>0.20*</td>
<td>0.16*</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>0.06 T</td>
<td>0.10 T</td>
<td>0.13 T</td>
<td>0.10 T</td>
<td>0.10 T</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.12</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>-0.10</td>
<td>0.10</td>
<td>0.20</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>0.06 T</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*90° Phase shift to reference.

T response at twice frequency of reference.
<table>
<thead>
<tr>
<th>Panel</th>
<th>SPI-3-1</th>
<th>SPI-3-1</th>
<th>SPI-3-1</th>
<th>SPI-3-1</th>
<th>SPI-3-2</th>
<th>SPI-3-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>80 Hz</td>
<td>88 Hz</td>
<td>107 Hz</td>
<td>117 Hz</td>
<td>101 Hz</td>
<td>62 Hz</td>
</tr>
<tr>
<td>Speaker Cond.</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Position 1</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.30</td>
<td>0.60</td>
<td>1.00</td>
<td>0.77</td>
<td>-</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.38</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-0.40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-0.83</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.20</td>
</tr>
<tr>
<td>10</td>
<td>-1.00</td>
<td>-0.60</td>
<td>0.28</td>
<td>0.42</td>
<td>0.40</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>-0.80</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>-0.35</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>-0.06</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>0.39</td>
<td>-0.15</td>
<td>-0.18</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>17</td>
<td>0.24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>-0.15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>-0.40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>-0.70</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>-0.80</td>
<td>1.00</td>
<td>0.30</td>
<td>0.50</td>
<td>0.28</td>
<td>-</td>
</tr>
<tr>
<td>23</td>
<td>-0.68</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.58</td>
</tr>
<tr>
<td>24</td>
<td>-0.40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>-0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>26</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>0.18</td>
<td>-0.32</td>
<td>0.82</td>
<td>1.00</td>
<td>-</td>
<td>0.00</td>
</tr>
<tr>
<td>29</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Position 31</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
**TABLE 7**

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

<table>
<thead>
<tr>
<th>Panel</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
<th>SPI-3-1D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>105 Hz</td>
<td>105 Hz</td>
<td>109 Hz</td>
<td>127 Hz</td>
<td>134 Hz</td>
<td>106 Hz</td>
<td>139 Hz</td>
</tr>
<tr>
<td>Speaker Cond.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.09</td>
<td>0.15</td>
<td>0.01</td>
<td>0.13</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.18</td>
<td>0.08</td>
<td>0.36</td>
<td>0.61</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.56 T</td>
<td>0.28</td>
<td>0.20</td>
<td>0.31</td>
<td>0.81</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.20 T</td>
<td>0.25</td>
<td>0.35</td>
<td>0.27</td>
<td>0.91</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>0.22 T</td>
<td>0.23</td>
<td>0.27</td>
<td>0.30</td>
<td>0.76</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>0.25 T</td>
<td>0.20</td>
<td>0.15</td>
<td>0.36</td>
<td>0.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>0.35 T</td>
<td>0.43</td>
<td>-0.04</td>
<td>0.16</td>
<td>0.30</td>
<td>0.26</td>
<td>0.09</td>
</tr>
<tr>
<td>8</td>
<td>0.74</td>
<td>0.75</td>
<td>-0.30</td>
<td>0.26</td>
<td>0.44</td>
<td>0.63</td>
<td>0.25</td>
</tr>
<tr>
<td>9</td>
<td>0.87</td>
<td>1.00</td>
<td>1.00</td>
<td>0.36</td>
<td>0.36</td>
<td>1.00</td>
<td>0.62</td>
</tr>
<tr>
<td>10</td>
<td>0.94</td>
<td>1.00</td>
<td>0.59</td>
<td>0.38</td>
<td>0.96</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>11</td>
<td>1.00</td>
<td>1.00</td>
<td>0.63</td>
<td>0.38</td>
<td>0.96</td>
<td>1.00</td>
<td>0.49</td>
</tr>
<tr>
<td>12</td>
<td>0.81</td>
<td>0.85</td>
<td>-0.43</td>
<td>0.31</td>
<td>0.57</td>
<td>0.69</td>
<td>0.35</td>
</tr>
<tr>
<td>13</td>
<td>0.56</td>
<td>0.55</td>
<td>-0.07</td>
<td>0.27</td>
<td>0.52</td>
<td>0.47</td>
<td>0.12</td>
</tr>
<tr>
<td>14</td>
<td>0.22</td>
<td>0.30</td>
<td>0.71</td>
<td>-0.36</td>
<td>-0.09</td>
<td>0.40</td>
<td>0.08</td>
</tr>
<tr>
<td>15</td>
<td>0.17 T</td>
<td>0.15</td>
<td>0.25</td>
<td>-0.24</td>
<td>-0.21</td>
<td>0.60</td>
<td>0.09</td>
</tr>
<tr>
<td>16</td>
<td>0.17 T</td>
<td>0.15</td>
<td>0.25</td>
<td>-0.24</td>
<td>-0.18</td>
<td>0.74</td>
<td>0.12</td>
</tr>
<tr>
<td>17</td>
<td>0.17 T</td>
<td>0.15</td>
<td>0.25</td>
<td>-0.24</td>
<td>-0.12</td>
<td>0.60</td>
<td>0.13</td>
</tr>
<tr>
<td>18</td>
<td>0.22</td>
<td>0.25</td>
<td>0.11</td>
<td>-0.36</td>
<td>-0.12</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>19</td>
<td>0.47</td>
<td>0.55</td>
<td>-0.10</td>
<td>0.50</td>
<td>-0.27</td>
<td>0.33</td>
<td>-0.21</td>
</tr>
<tr>
<td>20</td>
<td>0.70</td>
<td>0.70</td>
<td>-0.33</td>
<td>0.37</td>
<td>-0.51</td>
<td>0.20</td>
<td>-0.44</td>
</tr>
<tr>
<td>21</td>
<td>0.88</td>
<td>0.80</td>
<td>-</td>
<td>0.67</td>
<td>-0.91</td>
<td>0.74</td>
<td>-0.80</td>
</tr>
<tr>
<td>22</td>
<td>0.92</td>
<td>0.75</td>
<td>-</td>
<td>0.74</td>
<td>-1.00</td>
<td>0.87</td>
<td>-1.00</td>
</tr>
<tr>
<td>23</td>
<td>0.87</td>
<td>0.80</td>
<td>0.20</td>
<td>0.61</td>
<td>-0.88</td>
<td>0.67</td>
<td>-0.78</td>
</tr>
<tr>
<td>24</td>
<td>0.67</td>
<td>0.75</td>
<td>0.11</td>
<td>0.49</td>
<td>-0.52</td>
<td>0.33</td>
<td>-0.35</td>
</tr>
<tr>
<td>25</td>
<td>0.15</td>
<td>0.20</td>
<td>0.20</td>
<td>0.25</td>
<td>-0.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>26</td>
<td>0.10 T</td>
<td>0.20</td>
<td>0.32</td>
<td>1.00</td>
<td>-0.64</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>0.10 T</td>
<td>0.25</td>
<td>0.38</td>
<td>0.30</td>
<td>-0.76</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>0.10 T</td>
<td>0.25</td>
<td>0.28</td>
<td>0.43</td>
<td>-0.67</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>29</td>
<td>0.10 T</td>
<td>0.25</td>
<td>0.13</td>
<td>0.25</td>
<td>-0.55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>0.10 T</td>
<td>0.25</td>
<td>0.13</td>
<td>0.25</td>
<td>-0.55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Position 31</td>
<td>0.10</td>
<td>0.15</td>
<td>0.03</td>
<td>0.10*</td>
<td>-0.15</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* T response at twice frequency of reference.
<table>
<thead>
<tr>
<th>Panel</th>
<th>SPI-3-2D</th>
<th>SPI-3-2D</th>
<th>SPI-3-2D</th>
<th>SPI-3-2D</th>
<th>SPI-3-2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>63 Hz</td>
<td>74 Hz</td>
<td>107 Hz</td>
<td>65 Hz</td>
<td>71 Hz</td>
</tr>
<tr>
<td>Speaker Cond.</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>Position 1</td>
<td>0.13 T</td>
<td>0.10 T</td>
<td>-0.08</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.10 T</td>
<td>0.16 T</td>
<td>-0.39</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.10 T</td>
<td>0.16 T</td>
<td>-0.69</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.10 T</td>
<td>0.10 T</td>
<td>-0.54</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>0.15 T</td>
<td>-0.13</td>
<td>-0.23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>0.45 T</td>
<td>-0.31</td>
<td>0.19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>0.50 *</td>
<td>-0.57</td>
<td>0.50</td>
<td>0.07</td>
<td>0.19 T</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>-0.72</td>
<td>0.85</td>
<td>0.07 T</td>
<td>-0.38</td>
</tr>
<tr>
<td>9</td>
<td>0.75</td>
<td>-0.61</td>
<td>1.00</td>
<td>0.10 T</td>
<td>-0.50</td>
</tr>
<tr>
<td>10</td>
<td>0.75</td>
<td>-0.36</td>
<td>1.00</td>
<td>-0.10</td>
<td>-0.50</td>
</tr>
<tr>
<td>11</td>
<td>0.35</td>
<td>-0.14</td>
<td>0.42</td>
<td>-0.10</td>
<td>-0.30</td>
</tr>
<tr>
<td>12</td>
<td>0.12</td>
<td>0.30</td>
<td>0.23</td>
<td>0.07</td>
<td>0.09 T</td>
</tr>
<tr>
<td>13</td>
<td>-0.10</td>
<td>0.68</td>
<td>0.31 *</td>
<td>0.25</td>
<td>0.33</td>
</tr>
<tr>
<td>14</td>
<td>-0.20</td>
<td>0.85</td>
<td>0.39 *</td>
<td>0.72</td>
<td>0.67</td>
</tr>
<tr>
<td>15</td>
<td>-0.25</td>
<td>1.00</td>
<td>0.39</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>16</td>
<td>-0.25</td>
<td>1.00</td>
<td>0.62</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>17</td>
<td>-0.30</td>
<td>0.82</td>
<td>0.58</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>18</td>
<td>-0.22</td>
<td>0.33</td>
<td>0.39</td>
<td>0.80</td>
<td>0.40</td>
</tr>
<tr>
<td>19</td>
<td>0.12 T</td>
<td>0.27</td>
<td>0.27</td>
<td>0.42</td>
<td>0.25</td>
</tr>
<tr>
<td>20</td>
<td>0.13</td>
<td>-0.10</td>
<td>0.31</td>
<td>0.17</td>
<td>0.08 T</td>
</tr>
<tr>
<td>21</td>
<td>0.36</td>
<td>-0.31</td>
<td>0.39 *</td>
<td>-0.17</td>
<td>-0.29</td>
</tr>
<tr>
<td>22</td>
<td>0.55</td>
<td>-0.63</td>
<td>0.58 *</td>
<td>-0.33</td>
<td>-0.50</td>
</tr>
<tr>
<td>23</td>
<td>0.63</td>
<td>-0.63</td>
<td>0.69 *</td>
<td>-0.33</td>
<td>-0.63</td>
</tr>
<tr>
<td>24</td>
<td>0.55</td>
<td>-0.56</td>
<td>0.69</td>
<td>-0.25</td>
<td>-0.48</td>
</tr>
<tr>
<td>25</td>
<td>0.30</td>
<td>-0.31</td>
<td>0.39 *</td>
<td>0.12 T</td>
<td>-0.25</td>
</tr>
<tr>
<td>26</td>
<td>0.13</td>
<td>-0.10</td>
<td>0.08 *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>0.05 T</td>
<td>-0.06</td>
<td>0.12 *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>0.08</td>
<td>-0.08</td>
<td>0.23 *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>29</td>
<td>0.10</td>
<td>-0.10</td>
<td>0.31 *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>0.08</td>
<td>0.06</td>
<td>0.15 *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Position 31</td>
<td>0.03</td>
<td>0.06</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*90° Phase shift to reference.

T response at twice frequency of reference.
TABLE 9
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
\( \bar{\varepsilon} = \text{NORMALIZING STRAIN, } \mu\text{ in/in} \)
SPECIMEN SPI-1

<table>
<thead>
<tr>
<th>Configuration</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, Hz</td>
<td>82</td>
<td>106</td>
<td>119</td>
<td>126</td>
<td>108</td>
<td>115</td>
<td>127</td>
</tr>
<tr>
<td>Strain Gage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>0.26</td>
<td>-0.50</td>
<td>0.40</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-0.87</td>
<td>-0.40</td>
<td>0.61</td>
<td>-1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-0.93</td>
<td>-0.40</td>
<td>0.56</td>
<td>-0.73</td>
<td>-0.56</td>
<td>-0.43</td>
<td>-0.20</td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
<td>0.40</td>
<td>0.28*</td>
<td>0.73</td>
<td>1.00</td>
<td>0.60</td>
<td>0.38</td>
</tr>
<tr>
<td>6</td>
<td>-0.80</td>
<td>-0.58</td>
<td>0.84</td>
<td>-0.77</td>
<td>-0.83</td>
<td>-0.50</td>
<td>-0.60</td>
</tr>
<tr>
<td>7</td>
<td>-0.67</td>
<td>-0.45</td>
<td>0.56</td>
<td>-0.77</td>
<td>-0.83</td>
<td>-0.50</td>
<td>-0.56</td>
</tr>
<tr>
<td>8</td>
<td>0.67</td>
<td>-0.40</td>
<td>-1.00</td>
<td>0.25</td>
<td>0.00</td>
<td>-1.00</td>
<td>0.40</td>
</tr>
<tr>
<td>9</td>
<td>-0.67</td>
<td>-0.32</td>
<td>0.70</td>
<td>0.50</td>
<td>-0.56</td>
<td>-0.63</td>
<td>0.56</td>
</tr>
<tr>
<td>10</td>
<td>-0.80</td>
<td>-0.32</td>
<td>0.70</td>
<td>0.40</td>
<td>-0.67</td>
<td>-0.68</td>
<td>0.46</td>
</tr>
<tr>
<td>11</td>
<td>0.00</td>
<td>-0.84</td>
<td>-0.42</td>
<td>-1.00</td>
<td>0.95</td>
<td>0.50</td>
<td>-1.00</td>
</tr>
<tr>
<td>12</td>
<td>-0.67</td>
<td>-0.47</td>
<td>0.20</td>
<td>0.94</td>
<td>-0.67</td>
<td>-0.38</td>
<td>0.60</td>
</tr>
<tr>
<td>13</td>
<td>-0.67</td>
<td>-0.40</td>
<td>0.20</td>
<td>0.94</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>0.67</td>
<td>1.00</td>
<td>-0.28</td>
<td>-0.67</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.60</td>
<td>-0.13</td>
<td>0.00</td>
<td>0.11T</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\( \bar{\varepsilon}, \mu\text{ in/in} \)
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

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

*90° Phase shift to reference.
TABLE 11
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
\( \bar{e} = \) NORMALIZING STRAIN, \( \mu \text{ in/in} \)
SPECIMEN SPI-2-1D

<table>
<thead>
<tr>
<th>Configuration</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, Hz</td>
<td>80</td>
<td>88</td>
<td>111</td>
<td>128</td>
<td>94</td>
<td>108</td>
<td>134</td>
</tr>
<tr>
<td>Strain Gage 1</td>
<td>-0.32</td>
<td>0.00</td>
<td>0.33</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 2</td>
<td>0.80</td>
<td>0.73</td>
<td>-0.67</td>
<td>0.55</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 3</td>
<td>-0.60</td>
<td>0.00</td>
<td>-0.33</td>
<td>-0.55</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 4</td>
<td>-0.52</td>
<td>0.00</td>
<td>-0.33</td>
<td>-0.55</td>
<td>0.50</td>
<td>-0.56</td>
<td>0.84</td>
</tr>
<tr>
<td>Strain Gage 5</td>
<td>0.40</td>
<td>-1.00</td>
<td>0.33</td>
<td>0.91</td>
<td>-0.57</td>
<td>0.63</td>
<td>-1.00</td>
</tr>
<tr>
<td>Strain Gage 6</td>
<td>-0.32</td>
<td>0.33</td>
<td>-0.60</td>
<td>-0.46</td>
<td>0.33</td>
<td>-0.63</td>
<td>0.67</td>
</tr>
<tr>
<td>Strain Gage 7</td>
<td>-0.28</td>
<td>0.33T</td>
<td>-0.74</td>
<td>-0.46</td>
<td>0.33</td>
<td>-0.63</td>
<td>0.56</td>
</tr>
<tr>
<td>Strain Gage 8</td>
<td>0.40</td>
<td>0.67</td>
<td>1.00</td>
<td>0.00</td>
<td>0.50*</td>
<td>1.00</td>
<td>0.56</td>
</tr>
<tr>
<td>Strain Gage 9</td>
<td>-0.44</td>
<td>-0.67</td>
<td>-0.60</td>
<td>0.55</td>
<td>0.33</td>
<td>-0.63</td>
<td>-0.45</td>
</tr>
<tr>
<td>Strain Gage 10</td>
<td>-0.60</td>
<td>-0.67</td>
<td>-0.47</td>
<td>0.55</td>
<td>0.67</td>
<td>-0.63</td>
<td>-0.67</td>
</tr>
<tr>
<td>Strain Gage 11</td>
<td>1.00</td>
<td>0.87</td>
<td>0.40</td>
<td>-1.00</td>
<td>-1.00</td>
<td>0.31</td>
<td>1.00</td>
</tr>
<tr>
<td>Strain Gage 12</td>
<td>-0.60</td>
<td>0.33</td>
<td>-0.40</td>
<td>0.82</td>
<td>0.83</td>
<td>-0.38</td>
<td>-0.56</td>
</tr>
<tr>
<td>Strain Gage 13</td>
<td>-0.56</td>
<td>0.47</td>
<td>-0.47</td>
<td>0.82</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 14</td>
<td>0.28</td>
<td>-0.80</td>
<td>-0.67</td>
<td>-0.73</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 15</td>
<td>0.28</td>
<td>0.47</td>
<td>0.27</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\( \bar{e}, \mu \text{ in/in} \) 105 125 312 92 125 67 75

*90° Phase shift to reference.
T Response at twice reference frequency.
<table>
<thead>
<tr>
<th>Configuration</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>57</td>
<td>61</td>
<td>68</td>
<td>61</td>
<td>51</td>
<td>67</td>
</tr>
<tr>
<td>Strain Gage 1</td>
<td>-0.13</td>
<td>-0.27</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.20</td>
<td>0.31</td>
<td>0.17</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.16</td>
<td>0.31</td>
<td>0.27</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.27</td>
<td>0.50</td>
<td>0.37</td>
<td>0.70</td>
<td>0.33</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>-0.55</td>
<td>-0.69</td>
<td>-0.50</td>
<td>-0.80</td>
<td>-0.33</td>
<td>-1.0</td>
</tr>
<tr>
<td>6</td>
<td>-0.36</td>
<td>-0.19</td>
<td>0.17</td>
<td>-0.30</td>
<td>-0.40</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>-0.65</td>
<td>-0.54</td>
<td>-0.20</td>
<td>-0.50</td>
<td>-0.80</td>
<td>-0.25</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>-0.69</td>
<td>-0.58</td>
<td>-0.27</td>
<td>-0.60</td>
<td>-0.83</td>
<td>-0.35</td>
</tr>
<tr>
<td>10</td>
<td>-0.44</td>
<td>-0.27</td>
<td>0.17</td>
<td>0.25*</td>
<td>-0.47</td>
<td>0.40</td>
</tr>
<tr>
<td>11</td>
<td>-0.44</td>
<td>-0.54</td>
<td>-0.37</td>
<td>-0.65</td>
<td>-0.33</td>
<td>-0.75</td>
</tr>
<tr>
<td>12</td>
<td>0.25</td>
<td>0.35</td>
<td>0.27</td>
<td>0.60</td>
<td>0.40</td>
<td>0.75</td>
</tr>
<tr>
<td>13</td>
<td>0.18</td>
<td>0.35</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>0.20</td>
<td>0.23</td>
<td>0.13</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 15</td>
<td>-0.09</td>
<td>0.15</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\bar{\varepsilon}$, $\mu$ in/in</td>
<td>230</td>
<td>108</td>
<td>125</td>
<td>83</td>
<td>125</td>
<td>167</td>
</tr>
</tbody>
</table>

*90° Phase shift to reference.
TABLE 13
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
\( \bar{\varepsilon} = \) NORMALIZING STRAIN, \( \mu \text{ in/in} \)
SPECIMEN SPI-2-2-D

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Strain Gage</th>
<th>Strain Gage</th>
<th>Strain Gage</th>
<th>Strain Gage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Frequency, Hz</td>
<td>5 Bay</td>
<td>5 Bay</td>
<td>5 Bay</td>
<td>3 Bay</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>68</td>
<td>96</td>
<td>64</td>
</tr>
<tr>
<td>Strain Gage</td>
<td>0.5</td>
<td>0.7</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.40</td>
<td>-0.8</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.55</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>-0.83</td>
<td>-1.0</td>
<td>-0.75</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td>-1.0</td>
<td>0.40</td>
<td>-1.0</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>-0.5</td>
<td>0.50</td>
<td>0.0</td>
<td>-0.8</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>-0.8</td>
</tr>
<tr>
<td></td>
<td>-0.83</td>
<td>-0.83</td>
<td>-0.75</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>-0.83</td>
<td>1.00</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>-0.5</td>
<td>0.0</td>
<td>-0.75</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>-0.50</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage</td>
<td>15</td>
<td>45</td>
<td>25</td>
<td>83</td>
</tr>
<tr>
<td>( \bar{\varepsilon}, \mu \text{ in/in} )</td>
<td>45</td>
<td>25</td>
<td>83</td>
<td>42</td>
</tr>
</tbody>
</table>
**TABLE 14**

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

\( \bar{\varepsilon} = \text{NORMALIZING STRAIN, } \mu \text{ in/in} \)

SPECIMEN SPI-3-1

<table>
<thead>
<tr>
<th>Configuration</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, Hz</td>
<td>80</td>
<td>88</td>
<td>92-93</td>
<td>107</td>
<td>117</td>
<td>90</td>
</tr>
<tr>
<td>Strain Gage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.13</td>
<td>0.0</td>
<td>-0.38</td>
<td>-0.25</td>
<td>-0.19</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>0.36*</td>
<td>0.35</td>
<td>0.94</td>
<td>1.00</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.36*</td>
<td>0.0</td>
<td>-1.00</td>
<td>-0.45</td>
<td>-0.93</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-0.39</td>
<td>0.25</td>
<td>-0.94</td>
<td>-0.42</td>
<td>-0.93</td>
<td>-0.83</td>
</tr>
<tr>
<td>5</td>
<td>0.71</td>
<td>-0.75</td>
<td>0.56</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>0.21*</td>
<td>0.50</td>
<td>-0.31</td>
<td>0.33</td>
<td>-0.55</td>
<td>-0.63</td>
</tr>
<tr>
<td>7</td>
<td>0.27*</td>
<td>0.40</td>
<td>-0.31</td>
<td>0.50</td>
<td>-0.44</td>
<td>-0.21</td>
</tr>
<tr>
<td>8</td>
<td>-0.71</td>
<td>0.50</td>
<td>0.0</td>
<td>-1.00</td>
<td>0.15</td>
<td>-0.42</td>
</tr>
<tr>
<td>9</td>
<td>0.21*</td>
<td>-0.75</td>
<td>-0.47</td>
<td>0.67</td>
<td>0.37</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>-0.64</td>
<td>-1.00</td>
<td>-0.63</td>
<td>0.50</td>
<td>0.37</td>
<td>-0.42</td>
</tr>
<tr>
<td>11</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.33</td>
<td>-0.74</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
<td>-0.50</td>
<td>-0.50</td>
<td>-0.78</td>
<td>-0.67</td>
<td>0.74</td>
<td>-0.63</td>
</tr>
<tr>
<td>13</td>
<td>0.27*</td>
<td>0.75</td>
<td>-0.78</td>
<td>-0.67</td>
<td>0.74</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>-0.72</td>
<td>-1.00</td>
<td>0.47</td>
<td>0.83</td>
<td>-0.55</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.30</td>
<td>0.50</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
</tr>
</tbody>
</table>

\( \bar{\varepsilon}, \mu \text{ in/in} \)

| 232 | 83 | 133 | 250 | 225 | 100 | 290 |

*90° Phase shift to reference.
### TABLE 15

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

\[ \hat{e} = \text{NORMALIZING STRAIN, } \mu \text{ in/in} \]

SPECIMEN SPI-3-2

<table>
<thead>
<tr>
<th>Configuration</th>
<th>5 Bay</th>
<th>5 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
<th>3 Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, Hz</td>
<td>54</td>
<td>62</td>
<td>62</td>
<td>68</td>
<td>101</td>
</tr>
<tr>
<td>Strain Gage 1</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.0</td>
<td>0.13</td>
<td>0.0</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.0</td>
<td>-0.50</td>
<td>0.0</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>-0.62</td>
<td>-0.30</td>
<td>-0.42</td>
<td>-0.36</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>-1.00</td>
<td>-0.85</td>
<td>-0.84</td>
<td>-0.89</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1.00</td>
<td>0.85</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>-0.93</td>
<td>-0.50</td>
<td>-0.88</td>
<td>-0.89</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>-0.54</td>
<td>-0.40</td>
<td>-0.50</td>
<td>-0.36</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>0.0</td>
<td>-1.00</td>
<td>-0.21</td>
<td>-0.27</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.0</td>
<td>0.50</td>
<td>0.0</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.0</td>
<td>0.65</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>0.0</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strain Gage 15</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>( \hat{e}, \mu \text{ in/in} )</td>
<td>54</td>
<td>167</td>
<td>100</td>
<td>233</td>
<td>75</td>
</tr>
</tbody>
</table>
### TABLE 16
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

\( \bar{\varepsilon} = \) NORMALIZING STRAIN, \( \mu \) in/in

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

<table>
<thead>
<tr>
<th>Configuration</th>
<th>SPI-3-1D</th>
<th>SPI-3-2D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 Bay</td>
<td>5 Bay</td>
</tr>
<tr>
<td>Frequency, Hz</td>
<td>105</td>
<td>115</td>
</tr>
<tr>
<td>Strain Gage 1</td>
<td>0.18*</td>
<td>0.17*</td>
</tr>
<tr>
<td>Strain Gage 2</td>
<td>0.42</td>
<td>0.83</td>
</tr>
<tr>
<td>Strain Gage 3</td>
<td>-0.58</td>
<td>-0.63</td>
</tr>
<tr>
<td>Strain Gage 4</td>
<td>-0.79</td>
<td>-1.00</td>
</tr>
<tr>
<td>Strain Gage 5</td>
<td>1.00</td>
<td>0.83</td>
</tr>
<tr>
<td>Strain Gage 6</td>
<td>-0.66</td>
<td>-0.42</td>
</tr>
<tr>
<td>Strain Gage 7</td>
<td>-0.53</td>
<td>-0.33</td>
</tr>
<tr>
<td>Strain Gage 8</td>
<td>0.50</td>
<td>-0.17</td>
</tr>
<tr>
<td>Strain Gage 9</td>
<td>-0.58</td>
<td>-0.63</td>
</tr>
<tr>
<td>Strain Gage 10</td>
<td>-0.63</td>
<td>0.58</td>
</tr>
<tr>
<td>Strain Gage 11</td>
<td>0.79</td>
<td>-0.75</td>
</tr>
<tr>
<td>Strain Gage 12</td>
<td>-0.66</td>
<td>0.83</td>
</tr>
<tr>
<td>Strain Gage 13</td>
<td>-0.53</td>
<td>0.79</td>
</tr>
<tr>
<td>Strain Gage 14</td>
<td>0.58</td>
<td>-0.63</td>
</tr>
<tr>
<td>Strain Gage 15</td>
<td>-0.36</td>
<td>0.33</td>
</tr>
<tr>
<td>( \bar{\varepsilon}, \mu ) in/in</td>
<td>158</td>
<td>200</td>
</tr>
</tbody>
</table>

*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)

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

*90° Phase shift to reference.
<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>88</th>
<th>94</th>
<th>148</th>
<th>175</th>
<th>188</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position 30</td>
<td>0.008</td>
<td>0.060*</td>
<td>0.011</td>
<td>0.167</td>
<td>-0.092</td>
</tr>
<tr>
<td>31</td>
<td>0.050</td>
<td>0.080</td>
<td>0.556</td>
<td>-0.108</td>
<td>-0.278</td>
</tr>
<tr>
<td>32</td>
<td>0.088</td>
<td>0.096</td>
<td>0.815</td>
<td>-0.108</td>
<td>-0.130</td>
</tr>
<tr>
<td>33</td>
<td>0.125</td>
<td>0.128</td>
<td>0.593</td>
<td>-0.733</td>
<td>-0.074</td>
</tr>
<tr>
<td>34</td>
<td>0.150</td>
<td>0.144</td>
<td>0.593</td>
<td>-0.733</td>
<td>0.093*</td>
</tr>
<tr>
<td>35</td>
<td>0.163</td>
<td>0.160</td>
<td>0.815</td>
<td>-0.750</td>
<td>0.148</td>
</tr>
<tr>
<td>36</td>
<td>0.163</td>
<td>0.160</td>
<td>0.704</td>
<td>0.517</td>
<td>0.315</td>
</tr>
<tr>
<td>37</td>
<td>0.150</td>
<td>0.160</td>
<td>0.269</td>
<td>0.383</td>
<td>0.482</td>
</tr>
<tr>
<td>38</td>
<td>0.150</td>
<td>0.220</td>
<td>0.133</td>
<td>0.267</td>
<td>0.482</td>
</tr>
<tr>
<td>39</td>
<td>0.225</td>
<td>0.290</td>
<td>0.222</td>
<td>0.517*</td>
<td>0.556</td>
</tr>
<tr>
<td>40</td>
<td>0.375</td>
<td>0.440</td>
<td>0.315</td>
<td>-0.800</td>
<td>0.407</td>
</tr>
<tr>
<td>41</td>
<td>0.500</td>
<td>0.600</td>
<td>0.296</td>
<td>-0.450</td>
<td>0.259</td>
</tr>
<tr>
<td>42</td>
<td>0.725</td>
<td>0.740</td>
<td>0.052*</td>
<td>-0.450</td>
<td>0.148</td>
</tr>
<tr>
<td>43</td>
<td>0.925</td>
<td>0.860</td>
<td>-0.185</td>
<td>-0.617</td>
<td>-0.667</td>
</tr>
<tr>
<td>44</td>
<td>1.000</td>
<td>1.000</td>
<td>-0.241</td>
<td>-0.750</td>
<td>-1.000</td>
</tr>
<tr>
<td>45</td>
<td>0.950</td>
<td>0.900</td>
<td>-0.370</td>
<td>0.750*</td>
<td>-0.482</td>
</tr>
<tr>
<td>46</td>
<td>0.800</td>
<td>0.900</td>
<td>-0.704</td>
<td>0.300</td>
<td>-0.259</td>
</tr>
<tr>
<td>47</td>
<td>0.550</td>
<td>0.780</td>
<td>-1.000</td>
<td>0.500</td>
<td>0.185*</td>
</tr>
<tr>
<td>48</td>
<td>0.300</td>
<td>0.560</td>
<td>-0.324</td>
<td>0.708</td>
<td>0.482</td>
</tr>
<tr>
<td>49</td>
<td>0.175</td>
<td>0.300</td>
<td>-0.185</td>
<td>1.000</td>
<td>0.704</td>
</tr>
<tr>
<td>50</td>
<td>0.158</td>
<td>0.260</td>
<td>-0.048</td>
<td>0.917</td>
<td>0.482</td>
</tr>
<tr>
<td>51</td>
<td>0.113</td>
<td>0.200</td>
<td>0.030</td>
<td>0.583</td>
<td>0.556</td>
</tr>
<tr>
<td>52</td>
<td>0.138</td>
<td>0.200</td>
<td>0.048</td>
<td>0.250</td>
<td>0.519</td>
</tr>
<tr>
<td>53</td>
<td>0.125</td>
<td>0.200</td>
<td>0.048</td>
<td>0.083*</td>
<td>0.250</td>
</tr>
<tr>
<td>54</td>
<td>0.113</td>
<td>0.160</td>
<td>0.052</td>
<td>-0.100</td>
<td>0.093</td>
</tr>
<tr>
<td>55</td>
<td>0.088</td>
<td>0.100</td>
<td>0.052</td>
<td>-0.217</td>
<td>-0.185</td>
</tr>
<tr>
<td>56</td>
<td>0.063</td>
<td>0.080</td>
<td>0.052</td>
<td>-0.333</td>
<td>-0.463</td>
</tr>
<tr>
<td>57</td>
<td>0.038</td>
<td>0.080*</td>
<td>0.059</td>
<td>-0.333</td>
<td>-0.648</td>
</tr>
<tr>
<td>Position 58</td>
<td>0.008</td>
<td>0.020*</td>
<td>0.044</td>
<td>-0.125</td>
<td>-0.222</td>
</tr>
</tbody>
</table>

*90° Phase shift to reference.
<table>
<thead>
<tr>
<th>Position</th>
<th>88</th>
<th>94</th>
<th>148</th>
<th>175</th>
<th>188</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>0.010</td>
<td>0.004</td>
<td>0.013</td>
<td>0.021</td>
<td>0.028</td>
</tr>
<tr>
<td>60</td>
<td>0.005</td>
<td>0.006</td>
<td>0.037</td>
<td>0.067</td>
<td>0.074</td>
</tr>
<tr>
<td>61</td>
<td>0.008</td>
<td>0.018</td>
<td>0.059</td>
<td>0.083</td>
<td>0.111</td>
</tr>
<tr>
<td>62</td>
<td>0.023</td>
<td>0.040</td>
<td>0.085</td>
<td>0.100</td>
<td>0.185</td>
</tr>
<tr>
<td>63</td>
<td>0.033</td>
<td>0.060</td>
<td>0.104</td>
<td>0.133</td>
<td>0.241</td>
</tr>
<tr>
<td>64</td>
<td>0.050</td>
<td>0.100</td>
<td>0.119</td>
<td>0.167</td>
<td>0.296</td>
</tr>
<tr>
<td>65</td>
<td>0.065</td>
<td>0.140</td>
<td>0.126</td>
<td>0.167</td>
<td>0.333</td>
</tr>
<tr>
<td>66</td>
<td>0.088</td>
<td>0.180</td>
<td>0.133</td>
<td>0.150</td>
<td>0.370</td>
</tr>
<tr>
<td>67</td>
<td>0.125</td>
<td>0.200</td>
<td>0.133</td>
<td>0.250</td>
<td>0.444</td>
</tr>
<tr>
<td>68</td>
<td>0.163</td>
<td>0.300</td>
<td>0.133</td>
<td>0.200</td>
<td>0.482</td>
</tr>
<tr>
<td>69</td>
<td>0.200</td>
<td>0.340</td>
<td>0.133</td>
<td>0.217</td>
<td>0.519</td>
</tr>
<tr>
<td>70</td>
<td>0.238</td>
<td>0.380</td>
<td>0.126</td>
<td>0.225</td>
<td>0.519</td>
</tr>
<tr>
<td>71</td>
<td>0.275</td>
<td>0.430</td>
<td>0.096</td>
<td>0.225</td>
<td>0.574</td>
</tr>
<tr>
<td>72</td>
<td>0.300</td>
<td>0.440</td>
<td>0.082</td>
<td>0.225</td>
<td>0.611</td>
</tr>
<tr>
<td>73</td>
<td>0.313</td>
<td>0.460</td>
<td>0.044</td>
<td>0.267</td>
<td>0.630</td>
</tr>
<tr>
<td>74</td>
<td>0.300</td>
<td>0.460</td>
<td>0.022</td>
<td>0.283</td>
<td>0.630</td>
</tr>
<tr>
<td>75</td>
<td>0.275</td>
<td>0.420</td>
<td>-0.030</td>
<td>0.299</td>
<td>0.630</td>
</tr>
<tr>
<td>76</td>
<td>0.250</td>
<td>0.400</td>
<td>-0.030</td>
<td>0.317</td>
<td>0.593</td>
</tr>
<tr>
<td>77</td>
<td>0.188</td>
<td>0.350</td>
<td>-0.030</td>
<td>0.333</td>
<td>0.574</td>
</tr>
<tr>
<td>78</td>
<td>0.163</td>
<td>0.300</td>
<td>-0.028</td>
<td>0.333</td>
<td>0.555</td>
</tr>
<tr>
<td>79</td>
<td>0.125</td>
<td>0.220</td>
<td>-0.037</td>
<td>0.267</td>
<td>0.463</td>
</tr>
<tr>
<td>80</td>
<td>0.100</td>
<td>0.180</td>
<td>-0.026</td>
<td>0.367</td>
<td>0.444</td>
</tr>
<tr>
<td>81</td>
<td>0.075</td>
<td>0.120</td>
<td>-0.022</td>
<td>0.333</td>
<td>0.407</td>
</tr>
<tr>
<td>82</td>
<td>0.063</td>
<td>0.086</td>
<td>-0.022</td>
<td>0.317</td>
<td>0.370</td>
</tr>
<tr>
<td>83</td>
<td>0.050</td>
<td>0.064</td>
<td>-0.020</td>
<td>0.300</td>
<td>0.333</td>
</tr>
<tr>
<td>84</td>
<td>0.025</td>
<td>0.040</td>
<td>-0.016</td>
<td>0.200</td>
<td>0.250</td>
</tr>
<tr>
<td>85</td>
<td>0.013</td>
<td>0.020</td>
<td>-0.011</td>
<td>0.138</td>
<td>0.120</td>
</tr>
<tr>
<td>86</td>
<td>0.005</td>
<td>0.008</td>
<td>-0.007</td>
<td>0.071</td>
<td>0.111</td>
</tr>
<tr>
<td>Position 87</td>
<td>0.008</td>
<td>0.004</td>
<td>-</td>
<td>0.042</td>
<td>0.046</td>
</tr>
</tbody>
</table>
TABLE 17
(CONTINUED)

| Frequency, Hz | Position 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | Position 119 |
|--------------|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|              | 0.003       | 0.013 | 0.045 | 0.063 | 0.088 | 0.108 | 0.125 | 0.138 | 0.145 | 0.150 | 0.100 | 0.095 | 0.063 | 0.1575 | 0.025 | 0.003 | 0.069 | 0.250 | 0.438 | 0.500 | 0.425 | 0.313 | 0.300 | 0.500 | 1.000 | 1.000 | 0.125 |
|              | 0.014       | 0.038 | 0.080 | 0.110 | 0.140 | 0.180 | 0.200 | 0.200 | 0.220 | 0.220 | 0.200 | 0.150 | 0.110 | 0.070 | 0.036 | 0.016 | 0.112* | 0.030 | 0.480 | 0.560 | 0.500 | 0.500 | 0.380 | 0.420 | 0.520 | 0.780 | 1.000 | 0.520 |
|              |             | 0.007 | 0.019 | 0.048 | 0.061 | 0.089 | 0.100 | 0.119 | 0.122 | 0.133 | 0.133 | 0.111 | 0.082 | 0.048 | 0.032 | 0.017 | -0.082 | -0.163 | -0.178 | -0.178 | -0.148 | -0.089 | -0.030 | -0.010 | -0.222 | -0.241 | 0.780 | 0.520 |
|              |             |       | 0.033 | 0.054 | 0.104 | 0.120 | 0.217 | 0.250 | 0.267 | 0.267 | 0.250 | 0.200 | 0.183 | 0.150 | 0.100 | 0.042 | -0.050 | -0.200 | -0.250 | -0.283 | 0.217* | 0.200 | 0.433 | -0.383 | -0.667 | -0.750 | 0.520 | 0.741 |
|              |             |       | 0.080 | 0.135 | 0.259 | 0.324 | 0.370 | 0.444 | 0.463 | 0.482 | 0.444 | 0.370 | 0.296 | 0.222 | 0.185 | 0.148 | 0.074 | -0.185 | -0.426 | -0.370 | -0.241 | 0.148* | 0.630 | 0.593 | - | - | -0.741 | -1.000 |
|              |             |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|              |             |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
*90° Phase shift to reference.
<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>88</th>
<th>94</th>
<th>148</th>
<th>175</th>
<th>188</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>0.003</td>
<td>0.016</td>
<td>-0.007</td>
<td>0.050</td>
<td>0.074</td>
</tr>
<tr>
<td>121</td>
<td>0.013</td>
<td>0.042</td>
<td>-0.009</td>
<td>0.104</td>
<td>0.111</td>
</tr>
<tr>
<td>122</td>
<td>0.045</td>
<td>0.080</td>
<td>-0.015</td>
<td>0.129</td>
<td>0.167</td>
</tr>
<tr>
<td>123</td>
<td>0.063</td>
<td>0.120</td>
<td>-0.022</td>
<td>0.183</td>
<td>0.222</td>
</tr>
<tr>
<td>124</td>
<td>0.088</td>
<td>0.160</td>
<td>-0.011</td>
<td>0.275</td>
<td>0.296</td>
</tr>
<tr>
<td>125</td>
<td>0.108</td>
<td>0.190</td>
<td>-0.037</td>
<td>0.308</td>
<td>0.333</td>
</tr>
<tr>
<td>21</td>
<td>0.125</td>
<td>0.230</td>
<td>-0.044</td>
<td>0.317</td>
<td>0.407</td>
</tr>
<tr>
<td>126</td>
<td>0.138</td>
<td>0.250</td>
<td>-0.044</td>
<td>0.333</td>
<td>0.444</td>
</tr>
<tr>
<td>127</td>
<td>0.145</td>
<td>0.260</td>
<td>-0.044</td>
<td>0.350</td>
<td>0.462</td>
</tr>
<tr>
<td>50</td>
<td>0.158</td>
<td>0.260</td>
<td>-0.048</td>
<td>0.367</td>
<td>0.482</td>
</tr>
<tr>
<td>128</td>
<td>0.158</td>
<td>0.260</td>
<td>-0.044</td>
<td>0.350</td>
<td>0.462</td>
</tr>
<tr>
<td>129</td>
<td>0.150</td>
<td>0.250</td>
<td>-0.037</td>
<td>0.267</td>
<td>0.444</td>
</tr>
<tr>
<td>79</td>
<td>0.125</td>
<td>0.220</td>
<td>-0.037</td>
<td>0.267</td>
<td>0.407</td>
</tr>
<tr>
<td>130</td>
<td>0.108</td>
<td>0.200</td>
<td>-0.030</td>
<td>0.183*</td>
<td>0.370</td>
</tr>
<tr>
<td>131</td>
<td>0.083</td>
<td>0.160</td>
<td>-0.026</td>
<td>0.167*</td>
<td>0.333</td>
</tr>
<tr>
<td>132</td>
<td>0.063</td>
<td>0.130</td>
<td>-0.015</td>
<td>0.117*</td>
<td>0.259</td>
</tr>
<tr>
<td>133</td>
<td>0.045</td>
<td>0.090</td>
<td>-0.013</td>
<td>0.100</td>
<td>0.185</td>
</tr>
<tr>
<td>134</td>
<td>0.025</td>
<td>0.048</td>
<td>-0.005</td>
<td>0.067</td>
<td>0.158</td>
</tr>
<tr>
<td>Position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>135</td>
<td>0.003</td>
<td>0.020</td>
<td>-0.007</td>
<td>0.042</td>
<td>0.074</td>
</tr>
</tbody>
</table>

*90° Phase shift to reference.
<table>
<thead>
<tr>
<th>SG</th>
<th>(x, y)</th>
<th>SG</th>
<th>(x, y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>(3.25, 18.0)</td>
<td>Y1</td>
<td>(13.0, 12.35)</td>
</tr>
<tr>
<td>X2</td>
<td>(6.40, 18.0)</td>
<td>Y2</td>
<td>(13.0, 16.25)</td>
</tr>
<tr>
<td>X3</td>
<td>(9.75, 18.0)</td>
<td>Y3</td>
<td>(13.0, 18.35)</td>
</tr>
<tr>
<td>X4</td>
<td>(10.25, 18.0)</td>
<td>Y4</td>
<td>(13.0, 19.85)</td>
</tr>
<tr>
<td>X5</td>
<td>(13.00, 18.0)</td>
<td>Y5</td>
<td>(13.0, 21.85)</td>
</tr>
<tr>
<td>X6</td>
<td>(14.25, 18.0)</td>
<td>Y6</td>
<td>(13.0, 23.75)</td>
</tr>
<tr>
<td>X7</td>
<td>(15.75, 18.0)</td>
<td>Y7</td>
<td>(13.0, 24.25)</td>
</tr>
<tr>
<td>X8</td>
<td>(16.25, 18.0)</td>
<td>Y8</td>
<td>(13.0, 27.10)</td>
</tr>
<tr>
<td>X9</td>
<td>(19.60, 18.0)</td>
<td>X10</td>
<td>(22.80, 18.0)</td>
</tr>
</tbody>
</table>

SPII-1

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

SPII-2

<table>
<thead>
<tr>
<th>SG</th>
<th>(x, y)</th>
<th>SG</th>
<th>(x, y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>(6.7, 18.5)</td>
<td>Y1</td>
<td>(13.5, 8.5)</td>
</tr>
<tr>
<td>X2</td>
<td>(8.2, 18.5)</td>
<td>Y2</td>
<td>(13.5, 10.75)</td>
</tr>
<tr>
<td>X3</td>
<td>(9.7, 18.5)</td>
<td>Y3</td>
<td>(13.5, 13.00)</td>
</tr>
<tr>
<td>X4</td>
<td>(10.7, 18.5)</td>
<td>Y4</td>
<td>(13.5, 14.10)</td>
</tr>
<tr>
<td>X5</td>
<td>(13.5, 18.5)</td>
<td>Y5</td>
<td>(13.5, 18.5)</td>
</tr>
<tr>
<td>X6</td>
<td>(16.3, 18.5)</td>
<td>Y6</td>
<td>(13.5, 23.0)</td>
</tr>
<tr>
<td>X7</td>
<td>(17.2, 18.5)</td>
<td>Y7</td>
<td>(13.5, 24.0)</td>
</tr>
<tr>
<td>X8</td>
<td>(18.6, 18.5)</td>
<td>Y8</td>
<td>(13.5, 26.25)</td>
</tr>
<tr>
<td>X9</td>
<td>(20.1, 18.5)</td>
<td>Y9</td>
<td>(13.5, 28.50)</td>
</tr>
</tbody>
</table>
### TABLE 19
NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS
NINE-BAY PANEL SPECIMENS SPII-1 AND SPII-2

<table>
<thead>
<tr>
<th>Specimen SPII-1</th>
<th>Frequency, Hz</th>
<th>90</th>
<th>97</th>
<th>101</th>
<th>107</th>
<th>112</th>
<th>134</th>
<th>144</th>
<th>168</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Number 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.25</td>
<td>0.20</td>
<td>0.23</td>
<td>-0.23</td>
<td>-0.38</td>
<td>-</td>
<td>-0.40</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>0.20</td>
<td>0.20</td>
<td>0.30</td>
<td>-0.19</td>
<td>-0.38</td>
<td>-</td>
<td>0.27</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>-1.00</td>
<td>-0.27</td>
<td>0.33</td>
<td>-0.23</td>
<td>-0.38</td>
<td>0.25</td>
<td>0.67</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.19</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.70</td>
<td>-</td>
<td>-</td>
<td>0.85</td>
</tr>
<tr>
<td>6</td>
<td>-0.25</td>
<td>-0.20</td>
<td>-0.27</td>
<td>-0.31</td>
<td>-0.54</td>
<td>-0.65</td>
<td>0.27</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>0.23</td>
<td>0.20</td>
<td>0.30</td>
<td>0.23</td>
<td>0.38</td>
<td>-</td>
<td>-1.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>8</td>
<td>-0.85</td>
<td>-0.23</td>
<td>0.30</td>
<td>0.27</td>
<td>0.31</td>
<td>-0.30</td>
<td>-0.33</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>Bay Number 9</td>
<td>-</td>
<td>0.20</td>
<td>0.27</td>
<td>0.15</td>
<td>0.38</td>
<td>-</td>
<td>0.40</td>
<td>-0.70</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specimen SPII-2</th>
<th>Frequency, Hz</th>
<th>74</th>
<th>77</th>
<th>82</th>
<th>110</th>
<th>112</th>
<th>126</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Number 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.57</td>
<td>-1.00</td>
<td>-1.00</td>
<td>0.86</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.57</td>
<td>-0.19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.27</td>
<td>0.35</td>
<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.71</td>
<td>-0.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>0.20</td>
<td>-0.74</td>
<td>-0.27</td>
<td>-</td>
<td>-</td>
<td>-0.37</td>
</tr>
<tr>
<td>Bay Number 9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Measurements taken at center of each panel bay.

*90° Phase shift to reference.
TABLE 20
NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION
\( \bar{\varepsilon} = \text{NORMALIZING STRAIN, } \mu \text{ in/in} \)
NINE BAY MACHINED PANEL SPECIMEN
(See Table 18 and Figure 7)

<table>
<thead>
<tr>
<th>Strain Gage</th>
<th>88/A</th>
<th>94/A</th>
<th>123/A</th>
<th>148/A</th>
<th>170/A</th>
<th>188/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>-0.79</td>
<td>-0.80</td>
<td>0.09</td>
<td>0.76</td>
<td>0.00</td>
<td>-0.40</td>
</tr>
<tr>
<td>X2</td>
<td>0.48</td>
<td>0.40</td>
<td>-0.09</td>
<td>0.00</td>
<td>0.00</td>
<td>0.32</td>
</tr>
<tr>
<td>X3</td>
<td>-0.79</td>
<td>-0.80</td>
<td>0.09</td>
<td>0.51</td>
<td>0.00</td>
<td>-0.40</td>
</tr>
<tr>
<td>X4</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-0.86</td>
<td>-0.51</td>
<td>-0.61</td>
<td>-1.00</td>
</tr>
<tr>
<td>X5</td>
<td>0.79</td>
<td>0.80</td>
<td>0.86</td>
<td>0.51</td>
<td>0.72</td>
<td>1.00</td>
</tr>
<tr>
<td>X6</td>
<td>0.31</td>
<td>0.36</td>
<td>0.57</td>
<td>0.25</td>
<td>0.40</td>
<td>0.00</td>
</tr>
<tr>
<td>X7</td>
<td>0.79</td>
<td>-0.80</td>
<td>-0.86</td>
<td>-0.51</td>
<td>1.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>X8</td>
<td>0.00</td>
<td>-0.60</td>
<td>0.57</td>
<td>-0.25</td>
<td>-0.40</td>
<td>-0.40</td>
</tr>
<tr>
<td>X9</td>
<td>-0.63</td>
<td>0.50</td>
<td>-0.57</td>
<td>0.25</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>X10</td>
<td>-0.79</td>
<td>-0.60</td>
<td>1.00</td>
<td>-0.51</td>
<td>0.00</td>
<td>-0.61</td>
</tr>
<tr>
<td>Y1</td>
<td>-0.48</td>
<td>-0.50</td>
<td>-0.57</td>
<td>-1.00</td>
<td>0.80</td>
<td>-0.61</td>
</tr>
<tr>
<td>Y2</td>
<td>0.22</td>
<td>0.10</td>
<td>0.29</td>
<td>0.51</td>
<td>-0.40</td>
<td>0.61</td>
</tr>
<tr>
<td>Y3</td>
<td>0.16</td>
<td>0.30</td>
<td>0.46</td>
<td>0.25</td>
<td>0.61</td>
<td>0.20</td>
</tr>
<tr>
<td>Y4</td>
<td>0.00</td>
<td>0.00</td>
<td>0.29</td>
<td>-0.25</td>
<td>0.40</td>
<td>-0.20</td>
</tr>
<tr>
<td>Y5</td>
<td>0.00</td>
<td>-0.10</td>
<td>0.00</td>
<td>-0.25</td>
<td>0.00</td>
<td>-0.20</td>
</tr>
<tr>
<td>Y6</td>
<td>-0.16</td>
<td>-0.40</td>
<td>-0.43</td>
<td>0.25</td>
<td>-0.61</td>
<td>0.00</td>
</tr>
<tr>
<td>Y7</td>
<td>0.00</td>
<td>-0.10</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>Y8</td>
<td>0.00</td>
<td>0.10</td>
<td>0.00</td>
<td>-0.51</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>( \bar{\varepsilon} )</td>
<td>132</td>
<td>208</td>
<td>146</td>
<td>83</td>
<td>104</td>
<td>104</td>
</tr>
</tbody>
</table>
TABLE 21
NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION
\( \bar{\epsilon} = \) NORMALIZING STRAIN, \( \mu \text{ in/in} \)
NINE BAY PANEL SPECIMEN SPII-1
(See Table 18 and Figure 8)

<table>
<thead>
<tr>
<th>Strain Gage</th>
<th>90/A</th>
<th>97/A</th>
<th>112/B</th>
<th>134/B</th>
<th>144/B</th>
<th>168/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>0.14</td>
<td>0.16</td>
<td>0.00</td>
<td>-0.51</td>
<td>0.84</td>
<td>0.79</td>
</tr>
<tr>
<td>X2</td>
<td>0.12</td>
<td>-0.16</td>
<td>-0.17</td>
<td>-0.35</td>
<td>0.66</td>
<td>0.33</td>
</tr>
<tr>
<td>X3</td>
<td>-0.24</td>
<td>-0.37</td>
<td>-0.34</td>
<td>0.35</td>
<td>-1.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>X4</td>
<td>-0.26</td>
<td>-0.95</td>
<td>-0.86</td>
<td>-0.76</td>
<td>-0.42</td>
<td>-1.00</td>
</tr>
<tr>
<td>X5</td>
<td>0.22</td>
<td>0.95</td>
<td>0.74</td>
<td>0.76</td>
<td>0.00</td>
<td>0.67</td>
</tr>
<tr>
<td>X6</td>
<td>-0.38</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-0.34</td>
<td>-0.92</td>
</tr>
<tr>
<td>X7</td>
<td>-0.76</td>
<td>-0.39</td>
<td>-0.43</td>
<td>-0.60</td>
<td>0.00</td>
<td>-0.46</td>
</tr>
<tr>
<td>X8</td>
<td>0.28</td>
<td>-0.47</td>
<td>-0.17</td>
<td>-0.25</td>
<td>0.00</td>
<td>-0.33</td>
</tr>
<tr>
<td>X9</td>
<td>0.86</td>
<td>-0.37</td>
<td>0.17</td>
<td>0.35</td>
<td>0.00</td>
<td>0.33</td>
</tr>
</tbody>
</table>

| 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
\( \varepsilon = \text{NORMALIZING STRAIN}, \ \mu \text{in/in} \)
NINE BAY PANEL SPECIMEN SPII-2
(See Table 18 and Figure 9)

<table>
<thead>
<tr>
<th>Strain Gage</th>
<th>(74/A)</th>
<th>(77/B)</th>
<th>(77/C)</th>
<th>(81/D)</th>
<th>(82/A)</th>
<th>(110/A)</th>
<th>(112/D)</th>
<th>(126/B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X1)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.25</td>
<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(X2)</td>
<td>-0.50</td>
<td>-0.52</td>
<td>-0.50</td>
<td>0.00</td>
<td>-0.39</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(X3)</td>
<td>-1.00</td>
<td>-0.76</td>
<td>-0.79</td>
<td>-0.72</td>
<td>-0.75</td>
<td>-0.69</td>
<td>0.00</td>
<td>-0.46</td>
</tr>
<tr>
<td>(X4)</td>
<td>0.50</td>
<td>0.39</td>
<td>0.50</td>
<td>0.72T</td>
<td>0.45</td>
<td>0.40</td>
<td>0.64</td>
<td>0.46</td>
</tr>
<tr>
<td>(X5)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.72</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.46</td>
</tr>
<tr>
<td>(X6)</td>
<td>0.50</td>
<td>0.52</td>
<td>0.50</td>
<td>0.72T</td>
<td>0.50</td>
<td>0.48</td>
<td>0.64</td>
<td>0.33</td>
</tr>
<tr>
<td>(X7)</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-0.79</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-0.60</td>
<td>-0.52</td>
<td>-0.33</td>
</tr>
<tr>
<td>(X8)</td>
<td>0.57</td>
<td>-0.64</td>
<td>-0.50</td>
<td>0.00</td>
<td>-0.39</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(X9)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.42</td>
<td>-0.50</td>
<td>-0.52</td>
<td>0.00</td>
</tr>
<tr>
<td>(Y1)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.39</td>
<td>-0.36</td>
<td>-0.52</td>
<td>1.00</td>
</tr>
<tr>
<td>(Y2)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.25</td>
<td>0.36</td>
<td>0.52</td>
<td>-0.86</td>
</tr>
<tr>
<td>(Y3)</td>
<td>-0.72</td>
<td>-0.76</td>
<td>-0.60</td>
<td>0.00</td>
<td>-0.60</td>
<td>0.00</td>
<td>0.64</td>
<td>0.46</td>
</tr>
<tr>
<td>(Y4)</td>
<td>0.50</td>
<td>0.00</td>
<td>0.50</td>
<td>0.00</td>
<td>0.35</td>
<td>0.50</td>
<td>0.64</td>
<td>-0.67</td>
</tr>
<tr>
<td>(Y5)</td>
<td>0.50</td>
<td>0.76</td>
<td>0.60</td>
<td>0.72</td>
<td>0.50</td>
<td>0.50</td>
<td>0.64</td>
<td>0.46</td>
</tr>
<tr>
<td>(Y6)</td>
<td>0.36</td>
<td>0.00</td>
<td>0.40</td>
<td>0.00</td>
<td>0.20</td>
<td>-0.50</td>
<td>-0.64</td>
<td>0.67</td>
</tr>
<tr>
<td>(Y7)</td>
<td>-1.00</td>
<td>-0.76</td>
<td>-0.60</td>
<td>0.00</td>
<td>-0.55</td>
<td>0.50</td>
<td>-0.64</td>
<td>-0.67</td>
</tr>
<tr>
<td>(Y8)</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.50</td>
<td>0.00</td>
<td>0.20</td>
<td>0.50</td>
<td>0.64</td>
<td>0.33</td>
</tr>
<tr>
<td>(Y9)</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.69</td>
<td>0.00</td>
<td>-0.25</td>
<td>-0.69</td>
<td>-0.76</td>
<td>-0.46</td>
</tr>
</tbody>
</table>

\(\varepsilon\) 58 33 42 29 84 42 33 63
<table>
<thead>
<tr>
<th>Specimen</th>
<th>Number of Bays</th>
<th>Frequency (Hz)</th>
<th>Strain Gage No.</th>
<th>Damping Ratio (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>82</td>
<td>X10</td>
<td>1.1</td>
</tr>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>119</td>
<td>X11</td>
<td>1.3</td>
</tr>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>126</td>
<td>X10</td>
<td>1.3</td>
</tr>
<tr>
<td>SPI-1</td>
<td>3</td>
<td>108</td>
<td>X5/X11</td>
<td>3.0/1.6</td>
</tr>
<tr>
<td>SPI-1</td>
<td>3</td>
<td>127</td>
<td>X11</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>88</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>103</td>
<td>X5</td>
<td>2.7</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>120</td>
<td>X5</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>3</td>
<td>91</td>
<td>X8</td>
<td>3.0</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>88</td>
<td>X5</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>111</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>5</td>
<td>57</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>5</td>
<td>61</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>3</td>
<td>51</td>
<td>X8</td>
<td>2.7</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>3</td>
<td>61</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>68</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>80</td>
<td>X5</td>
<td>1.0</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>88</td>
<td>X5</td>
<td>2.9</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>107</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>117</td>
<td>X5</td>
<td>1.0</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>3</td>
<td>101</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-3-2</td>
<td>5</td>
<td>62</td>
<td>X11</td>
<td>1.8</td>
</tr>
<tr>
<td>SPI-3-2</td>
<td>3</td>
<td>68</td>
<td>X8</td>
<td>1.6</td>
</tr>
<tr>
<td>SPI-3-2D</td>
<td>5</td>
<td>74</td>
<td>X8</td>
<td>1.6</td>
</tr>
<tr>
<td>SPI-3-2D</td>
<td>3</td>
<td>71</td>
<td>X8</td>
<td>1.5</td>
</tr>
</tbody>
</table>
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 (αₓ, αᵧ) 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:

\[
\begin{bmatrix}
P \\
M_x \\
M_y \\
M_{xy}
\end{bmatrix}_i \quad \left\{ \begin{array}{l}
\text{shear in the z direction} \\
\text{bending moment about the x-axis} \\
\text{bending moment about the y-axis} \\
\text{twisting moment}
\end{array} \right.
\]

\[
\begin{bmatrix}
d \\
\theta_x \\
\theta_y \\
\theta_{xy}
\end{bmatrix}_i \quad \left\{ \begin{array}{l}
\text{displacement in the z direction} \\
\text{rotation about the x-axis} \\
\text{rotation about the y-axis} \\
\text{twist}
\end{array} \right.
\]

The composite beam stiffness matrix has the form:

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

\[
\{ \mathbf{P} \}_2 = [K_{12}]^T \{ \mathbf{d} \}_1 + [K_{22}] \{ \mathbf{d} \}_2
\]
where, for ribs parallel to the $x$-axis ($\alpha_x = 1; \alpha_y = 0$) and for ribs parallel to the $y$-axis ($\alpha_x = 0; \alpha_y = 1$)

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

\[
[K_{11}]_x = \begin{bmatrix}
12\beta_{yy} & -12\tau_1 & -6R_y & -6r_L \\
-12\tau_1 & 12\tau_1 & 6R_y & 6\tau_2 \\
6\beta_{yy} & -6R_y & 4\beta_y L^2 & 4r_L^2 \\
6r_L & -6\tau_2 & 2r_L^2 & 4\gamma_4
\end{bmatrix}
\]

(symmetric)

\[
[K_{12}]_x = \begin{bmatrix}
12\beta_{yy} & 12\tau_1 & -6R_y & -6r_L \\
-12\tau_1 & 12\tau_1 & 6R_y & 6\tau_2 \\
6\beta_{yy} & -6R_y & 2\beta_y L^2 & 2r_L^2 \\
6r_L & -6\tau_2 & 2r_L^2 & 2\gamma_4
\end{bmatrix}
\]

\[
[K_{22}]_x = \begin{bmatrix}
12\beta_{yy} & -12\tau_1 & 6R_y & -6r_L \\
-12\tau_1 & 12\tau_1 & 6R_y & 6\tau_2 \\
6\beta_{yy} & -6R_y & 4\beta_y L^2 & 4r_L^2 \\
6r_L & -6\tau_2 & 4r_L^2 & 4\gamma_4
\end{bmatrix}
\]

(symmetric)

\[
[K_{11}]_y = \begin{bmatrix}
12\beta_{xx} & 6\beta_{yy} & 12\tau_1 & 6r_L \\
6\beta_{xx} & 4\beta_y L^2 & 6R_y & 4r_L^2 \\
4\beta_{xx} & 6r_L & 12\tau_1 & -6\tau_2 \\
12\tau_1 & -6\tau_2 & 4\gamma_4
\end{bmatrix}
\]

(symmetric)
\[ [K_{12}]_y = \begin{bmatrix}
-12 \beta_{xx} & 6 \beta_{xx} L & -12 \gamma_1 & 6 \gamma_2 \\
-6 \beta_{xx} L & 2 \beta_{xx} L^2 & -6 \gamma_1 L & 2 \gamma_2 L^2 \\
-12 \gamma_1 & 6 \gamma_1 L & -12 \gamma_2 & -6 \gamma_2 \\
-6 \gamma_1 L & 2 \gamma_1 L^2 & 6 \gamma_2 & 2 \gamma_4 \\
\end{bmatrix} \]

\[ [K_{22}]_y = \begin{bmatrix}
12 \beta_{xx} & -6 \beta_{xx} L & 12 \gamma_1 & -6 \gamma_2 \\
-6 \beta_{xx} L & 2 \beta_{xx} L^2 & 6 \gamma_1 & 4 \gamma_2 L^2 \\
\end{bmatrix} \]

\[(\text{symmetric})\]

\[ \beta_{ij} = E I_x / L^3 \]
\[ \gamma_1 = E T / L^3 + G J / 10 L \]
\[ \gamma_2 = E T / L^2 + G J / 60 \]

\[ \gamma_3 = \gamma_3 = E T / L + G J / 30 \]

\[ \gamma_4 = E T / L - G J / 60 \]

for ribs parallel to the x-axis

\[ \tau_1 = \gamma_1 + S \beta_{zz} - 2 S \beta_{yz} + S \beta_{yy} - 2 (S r_x - S r_z) \]
\[ \tau_2 = \gamma_2 - (S r_z - S r_z) L \]

for ribs parallel to the y-axis

\[ \tau_1 = \gamma_1 + S \beta_{zz} - 2 S \beta_{yz} + S \beta_{yy} - 2 (S r_x - S r_z) \]
\[ \tau_2 = \gamma_2 - (S r_z - S r_z) L \]

The composite beam mass matrix has the form

\[ \{\ddot{p}\}_1 = [M_{11}] \{\ddot{a}\} + [M_{12}] \{\ddot{a}\}_2 \]
Appendix A

\[
\{\p\}_2 = [M_{12}^T \{a\}]_1 + [M_{22}] \{d\}_2
\]

where \([M_{ij}] = \alpha_x \{K_{ij}\} \times \alpha_y \{K_{ij}\}\)

\[
[M_{11}]_x = M
\]

\[
\begin{bmatrix}
13/35 & 13e/35 & -11L/210 \\
\frac{L^2}{105} & & 0 \\
\end{bmatrix}
\]

(symmetric)

\[
[M_{12}]_x = M
\]

\[
\begin{bmatrix}
9/70 & 9e/70 & 13L/420 \\
9e/70 & 9L^2/70 & -13e L/420 \\
-13L/420 & -13e L/420 & -L^2/140 \\
0 & -13L^3 x/210 & 0 \\
\end{bmatrix}
\]

\[
[M_{22}]_x = M
\]

\[
\begin{bmatrix}
13/35 & 13e/35 & 11L/210 \\
13L^2 /35 & 11e L/210 & -11L^3 x/210 \\
\frac{L^2}{105} & & 0 \\
\end{bmatrix}
\]

(symmetric)

\[
[M_{11}]_y = M
\]

\[
\begin{bmatrix}
13/35 & 11L /210 & -13e/35 \\
\frac{L^2}{105} & -11e L/210 & 13L^2 /35 \\
\end{bmatrix}
\]

(symmetric)
\[ \begin{bmatrix} 9/70 & -13L^2/420 & -9e_x/70 & 0 \\ 13L^2/420 & -L^2/140 & -13e_xL/420 & 0 \\ -9e_x/70 & 13e_xL/420 & 9L^2/70 & 13L^3I^*/420 \\ 0 & 0 & -13L^3I^*/420 & -L^4I^*/140 \end{bmatrix} \]

\[ \begin{bmatrix} 13/35 & -11L^2/210 & -13e_x/35 & 0 \\ -11L^2/210 & L^2/105 & 13e_xL/210 & 0 \\ 13L^2I^*/35 & 11L^3I^*/210 & L^4I^*/105 & 0 \end{bmatrix} \]

For ribs parallel to the x-axis

\[
M = pA_L \quad e_x = C - S_y \quad e_z = C - S_z \\
\begin{bmatrix} 2 \cr r^2 = (e_y^2 + e_z^2)/L_x^2 \cr I^*_{\text{p}} = (I_{yy} + I_{zz})/(A_L L^2) \cr I_{\text{p}} = r^2 + I^*_{\text{p}} \end{bmatrix}
\]

and for ribs parallel to the y-axis

\[
M = pA_L \quad e_y = C - S_x \quad e_z = C - S_z \\
\begin{bmatrix} 2 \cr r^2 = (e_x^2 + e_z^2)/L_y^2 \cr I^*_{\text{p}} = (I_{xx} + I_{zz})/(A_L L^2) \cr I_{\text{p}} = r^2 + I^*_{\text{p}} \end{bmatrix}
\]
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

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

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

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

\[
\left\{ \bar{P} \right\}_i = \frac{D}{ab} \left[ \begin{array}{c} \{ K_{ij} \} + \{ \overline{K}_{ij} \} \end{array} \right] \left\{ \bar{d} \right\}_i \quad \left\{ W_o \right\}_i
\]

\[ D = \frac{Eh^3}{12(1 - \nu^2)} \]

where \( P_o \) is the generalized force in the \( W_o \) direction. The matrix \( \{ \overline{K}_{ij} \} \) has the form

\[
\{ \overline{K}_{ij} \} = \begin{bmatrix} \overline{K}_{11} & \overline{K}_{12} & \overline{K}_{13} & \overline{K}_{14} \\ \overline{K}_{21} & \overline{K}_{22} & \overline{K}_{23} & \overline{K}_{24} \\ \overline{K}_{31} & \overline{K}_{32} & \overline{K}_{33} & \overline{K}_{34} \\ \overline{K}_{41} & \overline{K}_{42} & \overline{K}_{43} & \overline{K}_{44} \end{bmatrix}
\]

\[
\{ \overline{K}_{ij} \} \text{ (symmetric)}
\]

53
where

\[
[K_{11}] = \begin{bmatrix}
k/16 & kb/64 & -ka/64 & 8k_1ab \\
kb^2/256 & -kab/256 & 2k_1ab^2 & \\
\text{(symmetric)} & & & \\
\end{bmatrix}
\]

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

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

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

\[
[K_{22}] = \begin{bmatrix}
k/16 & kb/64 & ka/64 & -8k_1ab \\
kb^2/256 & kab/256 & -2k_1ab^2 & \\
\text{(symmetric)} & & & \\
\end{bmatrix}
\]
$$[\bar{K}_{23}] = \begin{bmatrix} 
\frac{k}{16} & -\frac{kb}{64} & -\frac{ka}{64} & -8k_1ab \\
\frac{kb}{64} & -\frac{kb^2}{256} & -\frac{kab}{256} & -2k_1ab^2 \\
\frac{ka}{64} & -\frac{kab}{256} & -\frac{k^2}{256} & -2k_1a^2b \\
-8k_1ab & 2k_1ab^2 & 2k_1a^2b & k_2a^2b^2 
\end{bmatrix}$$

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

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

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

$$[\bar{K}_{44}] = \begin{bmatrix} 
\frac{k}{16} & -\frac{kb}{64} & \frac{ka}{64} & 8k_1ab \\
\frac{kb^2}{256} & -\frac{kab}{256} & -2k_1ab^2 \\
\frac{ka}{64} & -\frac{kab}{256} & \frac{k^2}{256} & 2k_1a^2b \\
\text{(symmetric)} & & & 
\end{bmatrix}$$
$k = \frac{C_2^2}{C_{11}^2}
\left[ (b/a)^2 + (a/b)^2 + 2C_{11}^2(C_{31} - 2)^2 \right]
$

$k_1 = k/2048 - C_0 C_{11}^2
k_2 = k/4096 - C_0 C_{11}^2
$

$C_0 = 1/(1.58815)^2
\alpha_1 = 0.98250222
$

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

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

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

$$\{K_{ci}\} = \begin{bmatrix}
K_{c1} \\
K_{c2} \\
K_{c3} \\
K_{c4}
\end{bmatrix}$$

where

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

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

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

$$\begin{pmatrix}
\bar{p}_i \\
\bar{p}_o
\end{pmatrix} = \bar{\rho} \bar{a} \bar{b}
\begin{bmatrix}
[M_{ij}] + [\bar{M}_{ij}] & \frac{M_{ci}}{C_0} \\
\frac{M_{ci}^T}{C_0^2} & \frac{[d] [\bar{W}_o]}{W_o}
\end{bmatrix}
\begin{pmatrix}
d \\
\bar{W}_o
\end{pmatrix}$$
The matrix \( \tilde{\mathbf{M}}_{ij} \) has the form

\[
\begin{bmatrix}
\tilde{M}_{11} & \tilde{M}_{12} & \tilde{M}_{13} & \tilde{M}_{14} \\
\tilde{M}_{21} & \tilde{M}_{22} & \tilde{M}_{23} & \tilde{M}_{24} \\
\tilde{M}_{31} & \tilde{M}_{32} & \tilde{M}_{33} & \tilde{M}_{34} \\
\tilde{M}_{41} & \tilde{M}_{42} & \tilde{M}_{43} & \tilde{M}_{44}
\end{bmatrix}
\]

where

\[
\begin{bmatrix}
r_1 & r_2 b & -r_2^a & r_4 a b \\
r_2 b & r_3 b^2 & -r_3 a b & r_5 a^2 b \\
-r_2^a & -r_3 a b & r_3 a^2 & -r_5 a^2 b \\
r_4 a b & r_5 a^2 b & r_5 a^2 b & -r_6 a^2 b^2
\end{bmatrix}
\]

\[
\begin{bmatrix}
r_1 & r_2 b & r_2^a & -r_4 a b \\
r_2 b & r_3 b^2 & r_3 a b & -r_5 a^2 b^3 \\
-r_2^a & -r_3 a b & r_3 a^2 & r_5 a^2 b \\
r_4 a b & r_5 a^2 b & r_5 a^2 b & -r_6 a^2 b^2
\end{bmatrix}
\]

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

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

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

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

\[ [\tilde{\mathbf{M}}_{33}] = \begin{bmatrix} r_1 & -r_2 b & -r_2 a & -r_4 a b \\ r_3 b^2 & r_3 a b & r_5 a b^2 \\ (symmetric) & r_3 a^2 & r_5 a^2 b & r_6 a^2 b^2 \end{bmatrix} \]
The coupling matrix, \{ M_{ci} \}, has the form

\[
\begin{pmatrix}
M_{c1} \\
M_{c2} \\
M_{c3} \\
M_{c4}
\end{pmatrix}
\]

where

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

\[
M_{44} = \begin{bmatrix}
r_1 & -r_2 b & r_2 a & r_4 ab \\
-r_2 b & r_3 b^2 & -r_3 ab & -r_5 ab^2 \\
-r_2 a & r_3 a b & -r_3 a^2 & -r_5 a^2 b \\
-r_4 ab & r_5 a b^2 & -r_5 a^2 b & -r_6 a^2 b^2
\end{bmatrix}
\]

\( r_1 = C_o (C_o/16 - 2C_{11}^2) \)

\( r_2 = C_o (C_o/64 - C_{11}(C_{21} + C_{11}/4)) \)

\( r_3 = C_o (C_o/128 - C_{11}C_{21})/2 \)

\( r_4 = C_o (C_o/256 - C_{21}^2 - C_{11}^2/16) \)

\( r_5 = C_o (C_o/256 - C_{21}^2 - C_{21}C_{11}/4)/4 \)

\( r_6 = C_o (C_o/512 - C_{21}^2)/8 \)

\( C_{21} = C_{11}/C_{31} \)
\[ \begin{align*}
\{M_{c1}\} &= \begin{\bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix} \\
\{M_{c2}\} &= \begin{\bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix} \\
\{M_{c3}\} &= \begin{\bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix} \\
\{M_{c4}\} &= \begin{\bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix}
\end{align*} \]

\[r_7 = 2C_o(C_o/16 - C_{11}^2)\]

\[r_8 = 2C_o(C_o/64 - C_{11}C_{21})\]

\[r_9 = 2C_o(C_o/256 - C_{21}^2)\]
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), EL(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\textsuperscript{th} coordinate is unconstrained; if NDEL(J) = 1, the J\textsuperscript{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(ΣNEL(I) + 1) ≤ 38, NBAY ≤ 5.

SIZE: 005152
PROGRAM BMPROP (INPUT, OUTPUT, TAPES=INPUT, TAPE6=OUTPUT)

DIMENSION BL(5), NEL(5), NDEL(38), R(741), S(741)


DIMENSION SI(4), S2(4), S3(4), NCP(6)

DIMENSION EI(5), NU(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

CASE=1

READ(IN,120) NCASE

READ(IN,120) NCASE

100 READ(IN,120) NCASE, 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

NC0=2*NGP

NUP=NC0*(NC0+1)/2

DO 240 IOP=1, 2

DO 210 I=1, NUP

R(I)=R(I)

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
IICS=ICN+2
CALL ASSY(NCO,ICN,ICS,R,S1,S2,S3,2)

220 CONTINUE
IF(10P=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=NCPI(I)
K=J+1
JJ=J+(J*J-J)/2
JK=J+(K*K-K)/2
S(JJ)=S(JJ)+SL(I)
S(JK)=S(JK)+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+1
IT=IT+1
255 CONTINUE
TL=TL/FLOAT(NCT)
TK=TK/FLOAT(NCT)
IM=TM/FLOAT(NCT)
CALL NONDIM(S,NCO,TL,TK)
CALL NONDIM(R,NCO,TL,TM)
C APPLY CONSTRAINTS
NDEL=0
DO 261 J=1,NCO
261 CONTINUE
IF(IUL) 264,264,262
262 NDEL(1)=1
NDEL(2)=1
DO 263 I=1,NSUP
NCPI(I)=NCPI(I)-2
263 CONTINUE
264 IF(IUR) 270,270,265
265 IC=NCO-1
NDEL(1C)=1
NDEL(NCO)=1
CALL ORDER(S,NDEL,NGP,NDL)
CALL ORDER(R,NDEL,NGP,NDL)
270 NCU=NCO-NDEL
NUP=NCO*(NCO+1)/2
IF(IOUT=1) 315,275,275
275 WRITE(10,280)
WRITE(10,285) NCO,TK,TL
WRITE(10,290) (S(I),I=1,NUP)
WRITE(10,300)
WRITE(10,305) NCO,TM,TL
WRITE(10,290) (R(I),I=1,NUP)

PROGRAM BMPROP: CARD IMAGE LISTING 2/3
Appendix C

C COMPUTE EIGENVALUES AND EIGENVECTORS

315 WRITE(10,320) TL,TK,TM
CALL FREQ(S,K,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(15,i6,13)
125 FORMAT(3X,2E12.5)
130 FORMAT(3X,3E12.5)
140 FORMAT(3X,3E12.5)
145 FORMAT(1H,7X,4TH FREE VIBRATION OF A ONE DIMENSIONAL PANEL ARRAY)
150 FORMAT(25X,9HDATA CASE,I4)
155 FORMAT(15X,9HNUMBER OF BAYS=,I3,19X,19HNUMBER OF SUPPORTS=,I3)
160 FORMAT(15X,9HPANEL WIDTH=,E12.5,7X,16HPOISSON'S RATIO=,E12.5)
165 FORMAT(15X,9HNUMBER OF 3X7BENDING,6X,10HWEIGHT PER,18X3HBAY)
170 FORMAT(15X,9HNAY,3X,8HELEMENTS,4X,8HRIGIDITY,5X,19HUNIT AREA,6X,6HLENGTH/)
180 FORMAT(15X,9H5X13,7X,13,5X,E12.5,1X,E12.5,3X,E12.5)
182 FORMAT(15X,9HINPUT COORDINATE=,I3)
183 FORMAT(4X,4HKZ=,E12.5,2X,8KZTHETA=,E12.5,2X,7HTHETA=,E12.5)
184 FORMAT(4X,4HI=,E12.5,2X,8IZTHETA=,E12.5,2X,7ITHETA=,E12.5)
280 FORMAT(1H,4X,16HSTIFFNESS MATRIX)
285 FORMAT(15X,9HNCO=,I4,2X,3HTK=,E12.5,2X,3HTL=,E12.5/)
290 FORMAT(8E12.5)
300 FORMAT(1H1X,E12.5)
305 FORMAT(15X,9H5X4HNCO=,I4,2X,3HTK=,E12.5,2X,3HTL=,E12.5/)
310 FORMAT(6E11.4)
320 FORMAT(3E12.5)

END
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

El(I) - Bending rigidity of element

WB(I) - Weight percent length of element

BL(I) - Length of element

RESTRICTIONS: None

SIZE: 000152

REFERENCE: Reference 1, pp. 9 - 11.
BEGIN

A = LENGTH OF ELEMENT IN ITH BAY OF PANEL

YES

D = MASS COEFFICIENT OF ITH BAY OF PANEL
STATEMENT NO. 15

NO

IOP > 1

D = STIFFNESS COEFFICIENT OF ITH BAY OF PANEL
STATEMENT NO. 10

CÔMPUTE THE PARTITIONED CONSISTENT MASS MATRIX FOR THE ELEMENT

CÔMPUTE THE PARTITIONED STIFFNESS MATRIX FOR THE ELEMENT

RETURN

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(1)
AS = A*A
IF (IOP - 1) = 10: 10, 10, 15
10 B = EI(I)/(A*AS)
11 B1(1) = 12.0*D
12 B1(2) = 6.0*D*A
13 B1(3) = 4.0*D*AS
14 B2(1) = -12.0*D
15 B2(2) = -6.0*D*A
16 B2(3) = 6.0*D*A
17 B2(4) = 2.0*D*AS
18 B3(1) = 12.0*D
19 B3(2) = -6.0*D*A
20 B3(3) = 4.0*D*AS
RETURN
21 D = WB(1)*A/386.0
22 B1(1) = 13.0*D/35.0
23 B1(2) = 11.0*D*A/210.0
24 B1(3) = 9.0*D/70.0
25 B2(1) = 13.0*D*A/420.0
26 B2(2) = -13.0*D*A/420.0
27 B2(3) = -13.0*D*A/420.0
28 B2(4) = -13.0*D*A/420.0
29 B3(1) = 13.0*D/35.0
30 B3(2) = 11.0*D*A/210.0
31 B3(3) = 0.0*D*A/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
BEGIN

SET ROW NUMBER (K) AND COLUMN NUMBER (L) FOR PARTITIONED ELEMENT MATRICES

STEP 4.1

COMPUTE SUBSCRIPTS FOR SYMMETRIC ELEMENT MATRICES E1 AND E3 [(K, L) -> KLS] AND FOR GENERAL ELEMENT MATRIX E2 [(K, L) -> KLG] SUBROUTINE LOC

STEP 4.2

STEP 4.3

COMPUTE INITIAL ROW NUMBER (INK) AND COLUMN NUMBER (INL) TO LOCATE ELEMENT MATRIX E1(KLS) IN THE ASSEMBLED MATRIX A

STEP 4.4

COMPUTE SUBSCRIPT FOR THE LOCATION (INK, INL) -> NKL IN THE ASSEMBLED MATRIX A SUBROUTINE LOC

STEP 4.5

COMPUTE SECONDARY ROW NUMBER (ISK) AND COLUMN NUMBER (ISL) TO LOCATE ELEMENT MATRIX E3(KLS) IN THE ASSEMBLED MATRIX A

STEP 4.6

COMPUTE SUBSCRIPT FOR THE LOCATION (ISK, ISL) -> IKL IN THE ASSEMBLED MATRIX A SUBROUTINE LOC

FLÖW CHART: SUBPRÖGRAM ASSY (N, ICN, ICS, A, E1, E2, E3, NLM)
Appendix C

ADD (ASSEMBLE) ELEMENT MATRICES $E_1(KLS)$ & $E_3(KLS)$ TO $A(NKL)$ AND $A(IKL)$, RESPECTIVELY

ADD ELEMENT MATRIX $E_2(KLG)$ TO ASSEMBLED MATRIX $A(IKS)$

IS ELEMENT ROW AND COLUMN COUNT FINISHED?

RETURN

GØ TO STEP 4.1

FLOW CHART: SUBPROGRAM 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) GT 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

REFERENCES: Reference 3
Appendix C

FLOW CHART: SUBPROGRAM LOC(I, J, IR, N, MS)
SUBROUTINE LOC(I,J,IR,N,MS)

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

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+(IX*IX-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,TK)

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
Appendix C

BEGIN

STEP 6.1

SET INDEX FOR ROTATION COORDINATE (I) AT GRID POINT

STEP 6.2

COMPUTE INDICES FOR TRANSLATION COORDINATE (II) AT GRID POINT AND TRANSLATION AND ROTATION COORDINATES (I2 AND I3, RESPECTIVELY) AT NEXT GRID POINT

STEP 6.3

COMPUTE SUBSCRIPTS FOR TRANSLATION AND COUPLING COORDINATES (I11 AND I11) FOR GRID POINT

STEP 6.4

MULTIPLY ELEMENTS OF MATRIX A BY THE LENGTH PARAMETER, TL

STEP 6.5

YES

STEP 6.6

NO

I ≥ N

YES

STEP 6.7

NO

I ≥ N

STEP 6.8

GOTO STEP 6.1

DIVIDE ALL ELEMENTS IN MATRIX A BY THE PARAMETER TK

RETURN

FLOW CHART: SUBPROGRAM NØNDIM (A, N, TL, TK)
SUBROUTINE NONDIM(A,N,TL,TK)
DIMENSION A(N)

DO 3 I=2,N,2
   I1=I-1
   I2=I+1
   I3=I+2
   I11=I1+(II*II-I1)/2
   I11=I1+(I-I)/2
   A(I11)=TL*TL*A(I11)
   A(I11)=TL*A(I11)

   IF(I=3,3)
   I2=I1+(II*II-I2)/2
   I2=I1+(II*II-I2)/2
   A(I12)=TL*TL*A(I12)
   A(I12)=TL*A(I12)

   CONTINUE

DO 4 I=1,N
   DO 4 J=I,N
   CALL LOC(I,J,IJ,N,1)
   A(IJ)=A(IJ)/TK

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
Appendix C

BEGIN
INITIALIZE DATA
SELECT GRID POINT, IC
COMPUTE SUBSCRIPTS FOR COORDINATES AT GRID POINT IC
TRANSLATION SUBSCRIPT, J
ROTATION SUBSCRIPT, II

STEP 7.1
STEP 7.2
STEP 7.3

STEP 7.4
STEP 7.5

STEP 7.6
STEP 7.7

STEP 7.8
STEP 7.9

FLOW CHART: SUBPROGRAM ORDER (A, NDEL, NGP, NDL)
Appendix C

SELECT COORDINATE, M, TO BE DELETED

COMPUTE CURRENT SIZE, N, OF MATRIX A

SET TO ZERO ALL ELEMENTS (ROW AND COLUMN) FOR COORDINATE M IN SYMMETRIC MATRIX, A

SUBROUTINE DELETE

BEGINNING WITH COORDINATE M REPLACE ROW AND COLUMN LOCATIONS OF M BY COORDINATE (M+1), (M+1) BY (M+2), ETC., UNTIL FINAL COORDINATE IS ENCOUNTERED

REORDER COORDINATES, NC(I), TO BE DELETED

STEP 7.10

STEP 7.11

STEP 7.12

STEP 7.13

STEP 7.14

NO TO STEP 7.9

STEP 7.15

STEP 7.16

RETURN

FLOW CHART: SUBPROGRAM ORDER (A, NDEL, NGP, NDL)
SUBROUTINE DELETE (A, N, J)

PURPOSE: To delete (set to zero) all elements in the $J^{\text{th}}$ 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
SUBROUTINE ORDER(A*NDEL,NGP,NDL)
DIMENSION A(N),NDEL(1),NC(38)

NDL=0
NC0=2*NGP
DO I=1,NC0
NC(1)=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(I)) 5,5,4
4 NDL=NDL+1
NC(NDL)=I1
5 CONTINUE
DO 11 K=1,NDL
M=NC(K)
ML=NC0-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,I1,N,1)
IF(I-J) 7,6,7
6 J1=J+1
CALL LOC(I1,J1+1,J1,N,1)
GO TO 8
7 CALL LOC(I1,J,J1,N,1)
8 A(I,J)=A(I,J1)
9 CONTINUE
DO 11 I=1,NDL
10 NC(I)=NC(I)-1
11 CONTINUE
M=NC0-NDL+1
DO 12 K=M,NC0
CALL DELETE(A,NC0,K)
12 CONTINUE
RETURN
END

SUBROUTINE DELETE(A,N,J)
DIMENSION A(N)

DO 1 K=1,N
CALL LOC(K,J,K,J,N,1)
A(K,J)=0.0
1 CONTINUE
RETURN
END
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) - Dimensionless 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 ≤ 19

ACCURACY: See NROOT and EIGEN

SIZE: 000256_B
BEGIN

WRITE DATA SET IDENTIFICATION NUMBER

FILL COMPLETE STIFFNESS, S(I), AND MASS, R(I), MATRICES (STORAGE MODE 0) WITH SYMMETRIC STIFFNESS, SS(I) AND MASS, RR(I), MATRICES (STORAGE MODE 1)

COMPUTE EIGENVALUES, EVL(I), AND EIGENVECTORS, EVC(I), SUBROUTINE NR00T

IN THE ORDER OF DECREASING MAGNITUDE, WRITE THE EIGENVALUE (UNITS - Hz) AND THE EIGENVECTOR FOR EACH COORDINATE OF THE SYSTEM

RETURN

FLOW CHART: SUBPROGRAM FREQ (SS, RR, TL, TK, TM, NCASE, N)
SUBROUTINE FREQ(SS, RR, TL, TK, TM, NCASE, N)
  DIMENSION SS(1), RR(1), EVL(3H), EVC(1156)
  DIMENSION S(1156), R(1156), DUM1(342)
  DIMENSION IDUM1(11), DUM2(17)
  COMMON EVL, EVC, DUM1, DUM2, SS, RR
  IO=6
  NUP=N*(N+1)/2
  WRITE(IO, 120)
  WRITE(IO, 125) NCASE
  DO 205 I=1, N
    DO 210 J=1, N
      CALL LOC(I, J, IJ, N, N)
    CALL LOC(I, J, IJS, N, N)
    S(IJ)=SS(IJS)
    R(IJ)=RR(IJS)
  CONTINUE
  CALL NROOT(N, S, R, EVL, EVC)
  IF(EVL(I) .LE. 0.159155*SQR(TK*EVL(I)/TM))
  EVL(I)=ABS(EVL(I))
  WRITE(IO, 210) EVL(I)
  WRITE(IO, 215) EVL(I)=0.159155*SQR(TK*EVL(I)/TM)
  WRITE(IO, 220) EVL(I)
  WRITE(IO, 225) EVL(I)
  WRITE(IO, 230) IY=N*(I-1)+1
  WRITE(IO, 235) (EVC(J), J=IX, IY)
  CONTINUE
RETURN
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: 0003128

REFERENCES: References 3 and 4
SUBROUTINE NRROT (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
ARE PREMULTIPLIED BY THE ASSOCIATED EIGENVECTORS.
L=0
DO 110 J=1, M
L=L+J
110 XL(J)=1.0/SGRT(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 NRROT: CARD IMAGE LISTING 1/2
L = M * (J-1) + 1
A(L) = 0.0
DO 150 K = 1 * M
N1 = N1 + 1
N2 = N2 + 1
150 A(L) = A(L) + B(N1) * X(N2)
L = 0
K = 0
DO 130 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
SUBROUTINE EIGEN (A, R, N, MV)

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

SUBPROGRAMES 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

REFERENCES:  References 3 and 4
SUBROUTINE EIGEN(A,R,N,MV)
DIMENSION A(1),R(1)
C GENERATE IDENTITY MATRIX
5 RANGE=1.0E-6
10 I=1
20 J=1,N
30 R(I,J)=0.0
40 CONTINUE
C COMPUTE INITIAL AND FINAL NORMS (ANORM AND ANORMX)
25 ANORM=0.0
35 CONTINUE
IF(I-J) 165,165,40
40 ANORM=1.414*SQRT(ANORM)
ANORMX=ANORM*RANGE/FLOAT(N)
C INITIALIZE INDICATORS AND COMPUTE THRESHOLD, THR
IND=0
THR=ANORM
50 L=1
55 M=L+1
C COMPUTE SIN AND COS
60 MQ=(M*M-M)/2
70 LG=(L*L-L)/2
80 LM=L+MQ
90 IF(ABS(A(LM))-THR) 130,65,65
100 IND=1
110 LL=L+LG
120 MM=M+MQ
130 X=0.5*(A(LL)-A(MM))
140 Y=-A(LM)/SQRT(A(LM)*A(LM)+X*X)
150 IF(X) 70,75,75
160 Y=-Y
170 SINX=Y/SQRT(2.0*(1.0+(SQRT(1.0-Y*Y))))
180 SINX2=SINX*SINX
190 COSX=SQRT(1.0-SINX2)
200 COSX2=COSX*COSX
210 SINCS=SINX*COSX
C ROTATE L AND M COLUMNS
ILQ=N*(L-1)
220 IMQ=N*(M-1)
230 DO 125 I=1,N
240 IF(I-I-M) 85,115,80
250 IF(I-L) 80,115,80
260 IF(I-M) 85,115,90
270 IF(I-I-M) 85,115,90
280 CONTINUE
C END OF LISTING
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 ≤ 38, NBAY ≤ 5, NSUP ≤ 6, NINT ≤ 5.

ACCURACY: (See NROOT and EIGEN)

SIZE: 0011148

REFERENCE: Reference 1, pp. 9 - 11.
Appendix C

BEGIN

STEP 10.1

C0MPUTE INTERVAL SIZE, STP, AND NUMBER OF POINTS, NINT, FOR COMPUTING VALUES ALONG ELEMENT

STEP 10.2

SET MODE NUMBER, I
ONLY LOWER FREQUENCY MODES I ≤ 15 ARE COMPUTED

STEP 10.3

C0MPUTE INDEX FOR EIGENVALUE
C0MPUTE SUBSCRIPT LIMITS FOR EIGENVECTOR
WRITE EIGEN VALUE

STEP 10.4

STEP 10.5

STEP 10.6

STEP 10.7

STEP 10.8

STEP 10.9

YES

IS THIS THE FIRST BAY? J=1

YES

IS THE FIRST BAY CLAMPED AT THE L.H. END?

C0MPUTE C00RDINATE NUMBERS FOR R.H. END OF ELEMENT AND ASSIGN C00RDINATE VALUES.
SET LA = 1

NO

NO

NO

YES

GO TO STEP 10.14

GO TO STEP 10.14

GO TO STEP 10.14

GO TO STEP 10.14

FLOW CHART: SUBPR0GRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)
Appendix C

A)

COMPUTE PARTITIONED STIFFNESS MATRIX FOR ELEMENT SUBROUTINE ELEM

STEP 10.10

COMPUTE INITIAL VALUES OF SHEAR, SHRI, AND BENDING MOMENT, BNDI, DUE TO ELASTIC DEFORMATION

STEP 10.11

COMPUTE PARTITIONED MASS MATRIX FOR ELEMENT SUBROUTINE ELEM

STEP 10.12

COMPUTE INERTIA RELIEF FOR SHEAR AND BENDING MOMENT AND ADD TO PREVIOUS VALUES OF SHEAR AND BENDING MOMENT

STEP 10.13

INITIALIZE PARAMETERS
SET LC = LA

STEP 10.14

SET ELEMENT NUMBER WITHIN BAY K = 1, NLMT

STEP 10.15

YES

K ≤ 1

NO

STEP 10.16

XS = X1(CNT+1)

YES

LA = 1

NO

STEP 10.17

GΩ TO STEP 10.21.1

STEP 10.18

COMPUTE COORDINATE NUMBERS FOR ELEMENT

B

FLOW CHART: SUBPROGRAM SSBM (NCΩ, NBAY, NSUP, IBL, NINT, NDATA)
Appendix C

STEP 10.19.1
THE LAST GRID POINT HAS BEEN ENCOUNTERED. SET COORDINATE VALUES AT R.H. END OF ELEMENT.

STEP 10.19.2
SET COORDINATE VALUES AT EACH END OF THE ELEMENT

STEP 10.20
IS THE COORDINATE POINT ELASTICALLY SUPPORTED?

STEP 10.21.1
COMPUTE SUPPORT (POINT) SHEAR AND BENDING MOMENT IMPEDANCE AND ADD TO CURRENT VALUES

STEP 10.21.2
SET POINT SHEAR AND BENDING MOMENT EQUAL TO CURRENT VALUES

BEGIN INTERPOLATION OVER ELEMENT JJ = 1, NINT

SET INDEX, CNT
SET DIMENSIONLESS COORDINATE, ZE
SET LOCAL COORDINATE, X
X1 = X + XS

COMPUTE VALUES OF
W(CNT) EQN. 16*
DW(CNT) EQN. 16*
SHR(CNT) EQN. 17*
BND(CNT) EQN. 18*

SET LA = 0
CURRENT VALUE OF SHEAR = SHR(CNT)
CURRENT VALUE OF BENDING MOM. = BND(CNT)

*Reference 1, p. 10

FLOW CHART: SUBPROGRAM SSBM (NC0, NBAY, NSUP, IBL, NINT, NDATA)
STEP 10.26

STEP 10.27

STEP 10.28

STEP 10.29

STEP 10.30

STEP 10.31

STEP 10.32

STEP 10.33

STEP 10.34

FLOW CHART: SUBPROGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)
SUBROUTINE SSBM(NCO, 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 XI(180), WB(180), BLMT(180), BND(180)
COMMON EVL, EVC, DUM1, WB, BLMT, BND, DUM2
COMMON TL, SL, SC, SR, RL, RC, RR, NEL, NCP
COMMON DUM3, S1, S2, S3, XI, WB, BLMT, BND

INTEGER CNT
IO=6
STP=1. /FLOAT(NINT)
NINT=NINT+1
DO 929 I=1,15
WRITE(10,100)
WRITE(10,101) NDATA
SHR=0.
BNDP=0.
SHP=0.
BNDP=0.
NLMAX=0
CNT=0
NN=NCO+I-1
WRITE(10,102) EVL(NN)
NFL=NN*NCO-1
OM=6.28316*EVL(NN)
OMS=OM*OM
NCUR=0
LA=0
DO 921 J=1, NSUP
NLMT=NEL(J)
NLMAX=NLMAX+NLMT
BMM=OMS*WB(J)/386.
1 (J-1) 901, 901
901 IF(IBL-I) 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
1 (K-1) 903, 903, 904
903 X5=X1(CNT+1)
904 X5=X1(CNT)
905 IF(1-LA) 908, 914, 908
IC=NCUR+2*K-2*LC-1
K1=NC0*(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(T(KK)=-IC) 912,913,912
912 CONTINUE
GO TO 914
913 SHRIP=(OMS*RL(KK)/386.-SC(KK))**TL*D1+
2*(OMS*RC(KK)/386.-SL(KK))*D2*SHRI
BNDRP=(SC(KK)-OMS*RC(KK)/386.)*TL*D1+
2*(SR(KK)-OMS*RR(KK)/386.)*D2*BNDR
GO TO 915
914 SHRIP=SHRI
BNDRP=BNDR
915 CONTINUE
DO 920 JJ=1,NINT
CNT=CNT+1
ZE=STP*FLOAT(JJ-1)
X=ZE*BLMT(J)
X1(CNT)=X+X5
ZES=ZE*ZE
ZEC=ZE*ZES
W(CNT)=(ZE**ZEC-3**ZES+1.)**TL*D1+X*(ZE**ZES-2**ZE+1.)*D2-
2*ZE**ZEC-3.)*TL*D3+X*ZE**ZES-2**ZE+1.)*D4
Dw(CNT)=6.*ZE**(ZEC-1.)*TLS**D1/BLMT(J)+(3.*ZES-4**ZE+1.)*D2-
26.*ZEC**ZEC-1.)*TLS**D3/BLMT(J)+(3.*ZES-2.)*D4
SHRIP(CNT)=SHRIP+BNDRP+X**ZEC**(5.*ZEC=ZES+1.)*TLS**D1+
2BNDRP**X**ZEC**(25.*ZES-2**ZE+3.**1.5.)*D2-
3BNDRP**X**ZES**(5.*ZEC-1.)*TLS**D3+
4BNDRP**X**ZES**(25.*ZE-1.3.)*TLS**D4
BNDRP(CNT)=BNDRP+SHRIP+BNDRP+X**ZEC**(5.*ZEC-1.)*TLS**D1+
2BNDRP**X**ZES**(5.*ZES-2**ZE+3.**1.5.)*TLS**D2-
3BNDRP**X**ZES**(5.*ZEC-1.)*TLS**D3+
4BNDRP**X**ZEC**(5.*ZEC-1.12.)*TLS**D4
LA=0
SHRIP=SHRIP(CNT)
BNDRP=BNDRP(CNT)
920 CONTINUE
NCUR=IC+1
921 CONTINUE
WMAX=0.
WMAX=0.
SHRIP=WMAX.
BNDRP=WMAX.
LIM=NLIM=NINT
DO 924 IW=1,LIM
IF(ABS(W(IW))=WMAX) 916,916,917
SUBPROGRAM SSBM: CARD IMAGE LISTING 2/3
iAppendix C

917 \[ W_{\text{MAX}} = \text{ABS}(w(iW)) \]
916 \[ \text{IF}(\text{ABS}(Dw(iW)) - D_{\text{MAX}}) \quad 918, 918, 919 \]
919 \[ D_{\text{MAX}} = \text{ABS}(Dw(iW)) \]
918 \[ \text{IF}(\text{ABS}(SHR(iW)) - SHR_{\text{MAX}}) \quad 922, 922, 923 \]
923 \[ SHR_{\text{MAX}} = \text{ABS}(SHR(iW)) \]
922 \[ \text{IF}(\text{ABS}(BND(iW)) - BND_{\text{MAX}}) \quad 924, 924, 925 \]
925 \[ BND_{\text{MAX}} = \text{ABS}(BND(iW)) \]
924 CONTINUE

DO 926 IM = 1, LIM
926 \[ W(IM) = W(IM)/W_{\text{MAX}} \]
926 \[ Dw(IM) = Dw(IM)/D_{\text{MAX}} \]
926 \[ SHR(IM) = SHR(IM)/SHR_{\text{MAX}} \]
926 \[ BND(IM) = BND(IM)/BND_{\text{MAX}} \]
926 CONTINUE

LIM = 1
DO 928 J = 1, NBAY
928 \[ \text{WRITE}(I0, 998) \]
928 \[ \text{WRITE}(I0, 997) \]
928 \[ LIMM = LIM + NINT * NEL(J) - 1 \]
928 \[ DO 927 IR = LIM, LIMM \]
927 \[ \text{WRITE}(I0, 999) \]
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, 3HCBAR, I2)
998 FORMAT(/, 9X, 1HX, 10X, 1HW, 8X, 5HDW/DX, 9X, 1HV, 11X, 1HM)
999 FORMAT(5X, F7.3, 2X, 4E12.5)
RETURN
END.
Appendix C

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

EVL(I) - Array of eigenvalues
Appendix C

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: 0063718

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,PLSTF)
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),
COMMON R(2701), A(3), B(3)
COMMON NCASE, EP, HP, PR, RHO, DP, TL, TK, TM, NCO
DIMENSION NDEL(73), S1(36), S2(64), S3(36), SC(17),
    SF(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/
100 READ(5,105) NDATA
105 FORMAT(5X,I3)
110 M=4
    N=4
    NPC=4
    MBAY=M-1
    NBAY=N-1
    NCP=M*N
    NU1=NCP*NP
    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/ (1 + 12*(1-PR*PR))
   CALL RDNWRT (2)
   RHO=RHO*HP/386.
   D0.305 IOP=1,2
   NCO=NU1+MBAY*NBAY
   CALL ZEROQR(2,701)
   IF(IOP=1) 200,200,210
C   COMPUTE AND ASSEMBLE FREE FREE PLATE STIFFNESS MATRIX
   200   ANAME(1)=4HSEG2
   ANAME(2)=0
   CALL RNMIV(1)
   CALL RNMIV(2)
   CALL RNMIV(3)
   CALL RNMIV(4)

PROGRAM PLTVIB: CARD IMAGE LISTING 1/3
Appendix C

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 ASSYPR(R,S1,S2,S3,SC,IM,J,N,NCP)
205 CONTINUE

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,RHO,PR,S1,S2,S3,SC)
CALL ASSYPR(R,S1,S2,S3,SC,IM,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,SM,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,SM,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
I11=I1+(I1*11-I1)/2
II=I+(I-I-I)/2
TR=TR+R(I11)*R(II)
275 CONTINUE
ANAME(1)=4HSEG6
ANAME(2)=0
CALL SEGMENT(LFILE,1,ANAME)
IF(IOF-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(IOF-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
SUBROUTINE RDNWRT (IT0)

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: IT0

= 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 ≤ IT0 ≤ 4

ACCURACY: Not Applicable

SIZE: 001026

REFERENCES: None
FLOW CHART: SUBROUTINE RDNWRT(ITO)
Appendix C

SUBROUTINE RDNWRT (IT0)
COMMON ER(4), GR(4), RH0(4), SR2(4), C2(4), SR3(4), C3(4),
A2(I), A22(I), A23(I), A33(I), SJ(I), RE2(I), RE3(I), GM(I)
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) IT0
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), RH0(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)
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, HP, RHOP, DP
WRITE(IO, 650)
DC 140 I=1, 4
GO TO (130, 130, 135, 135) I
130 WRITE(IO, 655)
WRITE(IO, 660) I, ER(I), GR(I), RH0(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), RH0(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)
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(TM*EVL(I)/TM)
WRITE(IO, 710) EVL(I), FREQ
WRITE(IO, 715) IY=NCO*(I-1)+1
IY=NCO*I
WRITE(IO, 720) (EVC(J), J=IX, IY)
CONTINUE
FORMAT(5X, 14)
SUBPROGRAM RDNWRT: CARD IMAGE LISTING 1/2
FORMATA(4X,3E12.5)
610 FORMAT(A4X,4E12.5)
615 FORMAT(A4X,4I2)
620 FORMAT(A1H1,28X,9HDATA_CASE,5).
625 FORMAT(A/28X,19HFREE VIBRATION OF A/19X,
13YHINE_BAY,ORTHOGONALLY STIFFENED_PANEL/28X,
210HSTRUCTURAL GEOMETRY/)
630 FORMAT(A15X,3HA1=,E12.5,2X,3HA2=,E12.5,2X,3HA3=,E12.5/)
635 FORMAT(A15X,3HB1=,E12.5,2X,3HB2=,E12.5,2X,3HB3=,E12.5/)
640 FORMAT(A30X,16HCOVER_SHEET_DATA/)
645 FORMAT(A5X,16HYOUNG'S MODULUS=,E12.5,15X,16HPOISSON'S RATIO=,
1E12.5,5X,16HTHICKNESS=,E12.5,5X,16WEIGHT/VOLUME=,
2E12.5,24X,17HBENDING RIGIDITY=,E12.5/)
650 FORMAT(A31X,14HSTIFFENER_DATA/)
655 FORMAT(A24X,29HSTIFFENERS PARALLEL TO x-AXIS)
660 FORMAT(A5X,13HSTIFFENER_NO.,12X,4HE=,E12.5,2X,4HG=,E12.5,
12X,6HRHO=,E12.5)
665 FORMAT(A5X,3HSY=,E12.5,2X,4HCY=,E12.5,2X,4HSZ=,E12.5,2X,
16HCZ=,E12.5)
670 FORMAT(A5X,3SHA=,E12.5,2X,4HIYY=,E12.5,2X,4HIYZ=,E12.5,2X,
16HIZ=,E12.5)
675 FORMAT(A5X,3SHJ=,E12.5,2X,4HREY=,E12.5,2X,4HREZ=,E12.5,2X,
16HGAMMA=,E12.5/)
680 FORMAT(A24X,29HSTIFFENERS PARALLEL TO y-AXIS)
685 FORMAT(A5X,3HSX=,E12.5,2X,4HCX=,E12.5,2X,4HSZ=,E12.5,2X,
16HCZ=,E12.5)
690 FORMAT(A5X,3SHA=,E12.5,2X,4HIXX=,E12.5,2X,4HIYZ=,E12.5,2X,
16HIZ=,E12.5)
695 FORMAT(A5X,3SHJ=,E12.5,2X,4HREX=,E12.5,2X,4HREZ=,E12.5,2X,
16HGAMMA=,E12.5/)
700 FORMAT(A23X,29HNDIMENSIONALIZING CONSTANTS)
705 FORMAT(A13X,3HTK=,E12.5,2X,3HTL=,E12.5,2X,3HTM=,E12.5)
710 FORMAT(A5X,11HEIGENVALUE=,E12.5,19X,10HFREQUENCY=,E12.5,4H,Hz.)
715 FORMAT(A33X,11HEIGENVECTOR)

RETURN
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 ≠ 0, B ≠ 0

ACCURACY: See References below

SIZE: 002220

REFERENCES: o Reference 1, pp. 12 - 15


BEGIN

COMPUTE ASPECT RATIO PARAMETERS

FILL ARRAY S1(I)*
\[ S1(I) = \begin{bmatrix} K_{11} & K_{12} \\ \text{sym.} & K_{22} \end{bmatrix} \]

FILL ARRAY S2(I)*
\[ S2(I) = \begin{bmatrix} K_{13} & K_{14} \\ K_{23} & K_{24} \end{bmatrix} \]

FILL ARRAY S3(I)*
\[ S3(I) = \begin{bmatrix} K_{33} & K_{34} \\ \text{sym.} & K_{44} \end{bmatrix} \]

FILL ARRAY SC(I)*
\[ SC(I) = \begin{bmatrix} K_{c1} \end{bmatrix} \]
\[ SC(17) = k \]

MULTIPLY ALL VALUES BY D/ab

RETURN

*SEE APPENDIX B

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


**DIMENSION S1(2), S2(2), S3(2), S4(2)**

**AB** = 

\[
F = \frac{B \cdot B}{(A \cdot A)}
\]

\[
G = \frac{A \cdot A}{(-B \cdot B)}
\]

\[
R = \frac{F + G}{2}
\]

\[
C_0 = \frac{3.9647605}{10^6}
\]

\[
C_1 = \frac{2.0771538}{10^6}
\]

\[
C_2 = \frac{0.0469616}{10^6}
\]

\[
C_3 = \frac{4.6472757}{10^6}
\]

\[
\Phi = R + 2 \cdot C_1 \cdot C_1 \cdot (C_1 - 2) \cdot (C_1 - 2)
\]

\[
S = \frac{C_0 \cdot \Phi}{(C_1 \cdot C_1)}
\]

\[
S \cdot S = \frac{SM}{2048} = C_0 \cdot C_1 \cdot C_1
\]

\[
S \cdot S = \frac{SM}{4096} = C_0 \cdot C_1 \cdot C_1
\]

\[
S_1(1) = \frac{156 \cdot R/35 \cdot +2 \cdot 88 \cdot 0.0625}{SM}
\]

\[
S_1(2) = \frac{(2 \cdot F + 78 \cdot G)/35 \cdot +1 \cdot 2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot B
\]

\[
S_1(3) = \frac{(4 \cdot F + 52 \cdot G)/35 \cdot +32 \cdot 0.0390625}{SM} \cdot B \cdot B
\]

\[
S_1(4) = \frac{(78 \cdot F + 22 \cdot G)/35 \cdot +1 \cdot 2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A
\]

\[
S_1(5) = \frac{(11 \cdot F/35 \cdot +0.2 \cdot (2 \cdot P) \cdot 0.0390625}{SM} \cdot A \cdot B
\]

\[
S_1(6) = \frac{(52 \cdot F + 4 \cdot G)/35 \cdot +32 \cdot 0.0390625}{SM} \cdot A \cdot A
\]

\[
S_1(7) = \frac{(11 \cdot F/35 \cdot +0.2 \cdot (2 \cdot P) \cdot 0.0390625}{SM} \cdot A \cdot B
\]

\[
S_1(8) = \frac{(2 \cdot F + 22 \cdot G)/35 \cdot +1 \cdot 2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A \cdot B
\]

\[
S_1(9) = \frac{(2 \cdot F/3 \cdot +2 \cdot G)/35 \cdot +1 \cdot 2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A \cdot A
\]

\[
S_1(10) = \frac{(4 \cdot R/105 \cdot +2 \cdot 88 \cdot 0.0625}{SM}
\]

\[
S_1(11) = \frac{(196 \cdot F/54 \cdot +2 \cdot 88 \cdot 0.0625}{SM}
\]

\[
S_1(12) = \frac{(122 \cdot F - 27 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot B
\]

\[
S_1(13) = \frac{(78 \cdot F - 13 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A
\]

\[
S_1(14) = \frac{(6 \cdot F - 6 \cdot G)/35 \cdot +1 \cdot (2 \cdot P) \cdot R \cdot 0.0390625}{SM} \cdot A \cdot B
\]

\[
S_1(15) = \frac{S_1(1)}{S_1(1)}
\]

\[
S_1(16) = \frac{S_1(12)}{S_1(12)}
\]

\[
S_1(17) = \frac{(4 \cdot F - 18 \cdot G)/35 \cdot +32 \cdot 0.0390625}{SM} \cdot A \cdot B
\]

\[
S_1(18) = \frac{(11 \cdot F - 6 \cdot G)/35 \cdot +1 \cdot (2 \cdot P) \cdot 0.0390625}{SM} \cdot A \cdot A
\]

\[
S_1(19) = \frac{(2 \cdot F - 13 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A \cdot B
\]

\[
S_1(20) = \frac{S_1(1)}{S_1(1)}
\]

\[
S_1(21) = \frac{S_1(13)}{S_1(13)}
\]

\[
S_1(22) = \frac{S_1(14)}{S_1(14)}
\]

\[
S_1(23) = \frac{S_1(18)}{S_1(18)}
\]

\[
S_1(24) = \frac{(26 \cdot F - 3 \cdot G)/35 \cdot +8 \cdot 0.0390625}{SM} \cdot A \cdot A
\]

\[
S_1(25) = \frac{(11 \cdot F - 3 \cdot G)/35 \cdot +1 \cdot (2 \cdot P) \cdot 0.0390625}{SM} \cdot B
\]

\[
S_1(26) = \frac{S_1(4)}{S_1(4)}
\]

\[
S_1(27) = \frac{S_1(5)}{S_1(5)}
\]

\[
S_1(28) = \frac{S_1(6)}{S_1(6)}
\]

\[
S_1(29) = \frac{S_1(7)}{S_1(7)}
\]

\[
S_1(30) = \frac{S_1(15)}{S_1(15)}
\]

\[
S_1(31) = \frac{S_1(25)}{S_1(25)}
\]

\[
S_1(32) = \frac{(2 \cdot F - 3 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot B
\]

\[
S_1(33) = \frac{S_1(7)}{S_1(7)}
\]

\[
S_1(34) = \frac{S_1(8)}{S_1(8)}
\]

\[
S_1(35) = \frac{S_1(9)}{S_1(9)}
\]

\[
S_1(36) = \frac{S_1(10)}{S_1(10)}
\]

\[
S_2(1) = \frac{(54 \cdot F - 156 \cdot G)/35 \cdot +2 \cdot 88 \cdot 0.0625}{SM}
\]

\[
S_2(2) = \frac{(13 \cdot F - 78 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot B
\]

\[
S_2(3) = \frac{(27 \cdot F - 22 \cdot G)/35 \cdot +1 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A
\]

\[
S_2(4) = \frac{(6.5 \cdot F - 11 \cdot G)/35 \cdot +1 \cdot (2 \cdot P) \cdot R \cdot 0.0390625}{SM} \cdot A \cdot B
\]

\[
S_2(5) = \frac{54 \cdot R/35 \cdot +2 \cdot 88 \cdot 0.0625}{SM}
\]

\[
S_2(6) = \frac{(13 \cdot F - 27 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot B
\]

\[
S_2(7) = \frac{(127 \cdot F - 13 \cdot G)/35 \cdot +2 \cdot (2 \cdot P) \cdot 0.015625}{SM} \cdot A
\]

\[
S_2(8) = \frac{(6.5 \cdot R/35 \cdot +2 \cdot 88 \cdot 0.0390625}{SM} \cdot A \cdot B
\]
\[ S_2(9) = -S_2(2) \]
\[ S_2(10) = -(3.*F-26.*G)/35.+2./25.+0.0390625*SM)*B*B \]
\[ S_2(11) = (6.5*F-11.*G)/35.-.1*(.2+P)+0.0390625*SM)*AB \]
\[ S_2(12) = -(1.5*F-11.*G/3.)/35.+(.2+P)/30.+2.*SM*AB \]
\[ S_2(13) = S_2(6) \]
\[ S_2(14) = (13.*F+9.*G)/35.+.08-.00390625*SM)*B*B \]
\[ S_2(15) = (6.5*R/35.-.02-.00390625*SM)*AB \]
\[ S_2(16) = -(1.5*F+13.*G/6.)/35.+1./150.-2.*SM*AB \]
\[ S_2(17) = S_2(3) \]
\[ S_2(18) = -S_2(11) \]
\[ S_2(19) = (18.*F-4.*G)/35.-.32+.00390625*SM)*A*A \]
\[ S_2(20) = -(13.*F/3.-2.*G)/35.-2./75.+2.*SM*AB \]
\[ S_2(21) = S_2(7) \]
\[ S_2(22) = S_2(15) \]
\[ S_2(23) = (19.*F+3.*G)/35.+.08-.00390625*SM)*A*A \]
\[ S_2(24) = -(13.*F/6.+1.5*G)/35.+1./150.-2.*SM*AB \]
\[ S_2(25) = S_2(4) \]
\[ S_2(26) = S_2(12) \]
\[ S_2(27) = S_2(20) \]
\[ S_2(28) = ((F-2.*G/3.)-35.+2./225.+SM)*AB*AB \]
\[ S_2(29) = S_2(8) \]
\[ S_2(30) = S_2(16) \]
\[ S_2(31) = -S_2(24) \]
\[ S_2(32) = -(R/70.+1./450.-SM)*AB*AB \]
\[ S_2(33) = S_2(5) \]
\[ S_2(34) = S_2(6) \]
\[ S_2(35) = S_2(7) \]
\[ S_2(36) = S_2(8) \]
\[ S_2(37) = S_2(1) \]
\[ S_2(38) = S_2(2) \]
\[ S_2(39) = S_2(3) \]
\[ S_2(40) = S_2(4) \]
\[ S_2(41) = S_2(13) \]
\[ S_2(42) = S_2(14) \]
\[ S_2(43) = -S_2(15) \]
\[ S_2(44) = S_2(16) \]
\[ S_2(45) = S_2(9) \]
\[ S_2(46) = S_2(10) \]
\[ S_2(47) = S_2(11) \]
\[ S_2(48) = S_2(12) \]
\[ S_2(49) = S_2(35) \]
\[ S_2(50) = S_2(43) \]
\[ S_2(51) = S_2(23) \]
\[ S_2(52) = S_2(24) \]
\[ S_2(53) = S_2(17) \]
\[ S_2(54) = S_2(18) \]
\[ S_2(55) = S_2(19) \]
\[ S_2(56) = S_2(20) \]
\[ S_2(57) = S_2(29) \]
\[ S_2(58) = S_2(30) \]
\[ S_2(59) = S_2(31) \]
\[ S_2(60) = S_2(32) \]
\[ S_2(61) = S_2(25) \]
\[ S_2(62) = S_2(26) \]
\[ S_2(63) = S_2(27) \]
\[ S_2(64) = S_2(28) \]
\[ S_3(1) = S_1(1) \]
\[ S_3(2) = -S_1(2) \]
\[ S_3(3) = S_1(3) \]
Appendix C

| 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) |
| S3(37) = | S1(37) |
| S3(38) = | S1(38) |
| S3(39) = | S1(39) |
| S3(40) = | S1(40) |
| S3(41) = | S1(41) |
| S3(42) = | S1(42) |
| S3(43) = | S1(43) |
| S3(44) = | S1(44) |
| S3(45) = | S1(45) |
| S3(46) = | S1(46) |
| S3(47) = | S1(47) |
| S3(48) = | S1(48) |
| S3(49) = | S1(49) |
| S3(50) = | S1(50) |
| S3(51) = | S1(51) |
| S3(52) = | S1(52) |
| S3(53) = | S1(53) |
| S3(54) = | S1(54) |
| S3(55) = | S1(55) |

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

REFERENCES: See References for subroutine PLTSTF
Appendix C

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=.39647605
C11=.20771538
C21=.04469616
C31=.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+R2)*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)
### Appendix C

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_2(1)$</td>
<td>$C_1C_4+R_1$</td>
</tr>
<tr>
<td>$S_2(2)$</td>
<td>$(C_1C_5+R_2)*B$</td>
</tr>
<tr>
<td>$S_2(3)$</td>
<td>$-(C_2C_4+R_2)*A$</td>
</tr>
<tr>
<td>$S_2(4)$</td>
<td>$(C_2C_5+R_4)*AB$</td>
</tr>
<tr>
<td>$S_2(5)$</td>
<td>$C_4C_4+R_1$</td>
</tr>
<tr>
<td>$S_2(6)$</td>
<td>$(C_4C_5+R_2)*B$</td>
</tr>
<tr>
<td>$S_2(7)$</td>
<td>$(C_4C_5+R_2)*A$</td>
</tr>
<tr>
<td>$S_2(8)$</td>
<td>$-(C_5C_5+R_4)*AB$</td>
</tr>
<tr>
<td>$S_2(9)$</td>
<td>$-S_2(2)$</td>
</tr>
<tr>
<td>$S_2(10)$</td>
<td>$-(C_1C_6+R_3)<em>B</em>B$</td>
</tr>
<tr>
<td>$S_2(11)$</td>
<td>$-(C_2C_5+R_3)*AB$</td>
</tr>
<tr>
<td>$S_2(12)$</td>
<td>$-(C_2C_6+R_5)<em>AB</em>B$</td>
</tr>
<tr>
<td>$S_2(13)$</td>
<td>$-S_2(6)$</td>
</tr>
<tr>
<td>$S_2(14)$</td>
<td>$(C_4C_6+R_3)<em>B</em>B$</td>
</tr>
<tr>
<td>$S_2(15)$</td>
<td>$(C_5C_5+R_3)*AB$</td>
</tr>
<tr>
<td>$S_2(16)$</td>
<td>$(C_5C_6+R_5)<em>AB</em>B$</td>
</tr>
<tr>
<td>$S_2(17)$</td>
<td>$S_2(3)$</td>
</tr>
<tr>
<td>$S_2(18)$</td>
<td>$-S_2(11)$</td>
</tr>
<tr>
<td>$S_2(19)$</td>
<td>$(C_3C_4+R_3)<em>A</em>A$</td>
</tr>
<tr>
<td>$S_2(20)$</td>
<td>$(C_3C_5+R_5)<em>A</em>AB$</td>
</tr>
<tr>
<td>$S_2(21)$</td>
<td>$-S_2(7)$</td>
</tr>
<tr>
<td>$S_2(22)$</td>
<td>$-S_2(15)$</td>
</tr>
<tr>
<td>$S_2(23)$</td>
<td>$(C_4C_6+R_3)<em>A</em>A$</td>
</tr>
<tr>
<td>$S_2(24)$</td>
<td>$(C_5C_6+R_5)<em>A</em>AB$</td>
</tr>
<tr>
<td>$S_2(25)$</td>
<td>$-S_2(4)$</td>
</tr>
<tr>
<td>$S_2(26)$</td>
<td>$-S_2(12)$</td>
</tr>
<tr>
<td>$S_2(27)$</td>
<td>$-S_2(20)$</td>
</tr>
<tr>
<td>$S_2(28)$</td>
<td>$(C_3C_6+R_6)<em>AB</em>AB$</td>
</tr>
<tr>
<td>$S_2(29)$</td>
<td>$S_2(8)$</td>
</tr>
<tr>
<td>$S_2(30)$</td>
<td>$-S_2(16)$</td>
</tr>
<tr>
<td>$S_2(31)$</td>
<td>$-S_2(24)$</td>
</tr>
<tr>
<td>$S_2(32)$</td>
<td>$(C_5C_6+R_6)<em>AB</em>AB$</td>
</tr>
<tr>
<td>$S_2(33)$</td>
<td>$S_2(5)$</td>
</tr>
<tr>
<td>$S_2(34)$</td>
<td>$S_2(6)$</td>
</tr>
<tr>
<td>$S_2(35)$</td>
<td>$-S_2(7)$</td>
</tr>
<tr>
<td>$S_2(36)$</td>
<td>$-S_2(8)$</td>
</tr>
<tr>
<td>$S_2(37)$</td>
<td>$S_2(1)$</td>
</tr>
<tr>
<td>$S_2(38)$</td>
<td>$S_2(2)$</td>
</tr>
<tr>
<td>$S_2(39)$</td>
<td>$-S_2(3)$</td>
</tr>
<tr>
<td>$S_2(40)$</td>
<td>$-S_2(4)$</td>
</tr>
<tr>
<td>$S_2(41)$</td>
<td>$S_2(13)$</td>
</tr>
<tr>
<td>$S_2(42)$</td>
<td>$-S_2(14)$</td>
</tr>
<tr>
<td>$S_2(43)$</td>
<td>$-S_2(15)$</td>
</tr>
<tr>
<td>$S_2(44)$</td>
<td>$-S_2(16)$</td>
</tr>
<tr>
<td>$S_2(45)$</td>
<td>$S_2(9)$</td>
</tr>
<tr>
<td>$S_2(46)$</td>
<td>$-S_2(10)$</td>
</tr>
<tr>
<td>$S_2(47)$</td>
<td>$-S_2(11)$</td>
</tr>
<tr>
<td>$S_2(48)$</td>
<td>$-S_2(12)$</td>
</tr>
<tr>
<td>$S_2(49)$</td>
<td>$-S_2(21)$</td>
</tr>
<tr>
<td>$S_2(50)$</td>
<td>$-S_2(22)$</td>
</tr>
<tr>
<td>$S_2(51)$</td>
<td>$S_2(23)$</td>
</tr>
<tr>
<td>$S_2(52)$</td>
<td>$-S_2(24)$</td>
</tr>
<tr>
<td>$S_2(53)$</td>
<td>$-S_2(17)$</td>
</tr>
<tr>
<td>$S_2(54)$</td>
<td>$-S_2(18)$</td>
</tr>
<tr>
<td>$S_2(55)$</td>
<td>$S_2(19)$</td>
</tr>
<tr>
<td>$S_2(56)$</td>
<td>$S_2(20)$</td>
</tr>
<tr>
<td>$S_2(57)$</td>
<td>$-S_2(29)$</td>
</tr>
<tr>
<td>$S_2(58)$</td>
<td>$-S_2(30)$</td>
</tr>
<tr>
<td>$S_2(59)$</td>
<td>$-S_2(31)$</td>
</tr>
</tbody>
</table>

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 2/4
\[ S_2(60) = S_2(32) \]
\[ S_2(61) = S_2(25) \]
\[ S_2(62) = S_2(26) \]
\[ S_2(63) = S_2(27) \]
\[ S_2(64) = S_2(28) \]
\[ S_3(1) = S_1(1) \]
\[ S_3(2) = S_1(2) \]
\[ S_3(3) = S_1(3) \]
\[ S_3(4) = S_1(4) \]
\[ S_3(5) = S_1(5) \]
\[ S_3(6) = S_1(6) \]
\[ S_3(7) = S_1(7) \]
\[ S_3(8) = S_1(8) \]
\[ S_3(9) = S_1(9) \]
\[ S_3(10) = S_1(10) \]
\[ S_3(11) = S_1(11) \]
\[ S_3(12) = S_1(12) \]
\[ S_3(13) = S_1(13) \]
\[ S_3(14) = S_1(14) \]
\[ S_3(15) = S_1(15) \]
\[ S_3(16) = S_1(16) \]
\[ S_3(17) = S_1(17) \]
\[ S_3(18) = S_1(18) \]
\[ S_3(19) = S_1(19) \]
\[ S_3(20) = S_1(20) \]
\[ S_3(21) = S_1(21) \]
\[ S_3(22) = S_1(22) \]
\[ S_3(23) = S_1(23) \]
\[ S_3(24) = S_1(24) \]
\[ S_3(25) = S_1(25) \]
\[ S_3(26) = S_1(26) \]
\[ S_3(27) = S_1(27) \]
\[ S_3(28) = S_1(28) \]
\[ S_3(29) = S_1(29) \]
\[ S_3(30) = S_1(30) \]
\[ S_3(31) = S_1(31) \]
\[ S_3(32) = S_1(32) \]
\[ S_3(33) = S_1(33) \]
\[ S_3(34) = S_1(34) \]
\[ S_3(35) = S_1(35) \]
\[ S_3(36) = S_1(36) \]
\[ S_3(37) = S_1(37) \]
\[ S_3(38) = S_1(38) \]
\[ S_3(39) = S_1(39) \]
\[ S_3(40) = S_1(40) \]
\[ S_3(41) = S_1(41) \]
\[ S_3(42) = S_1(42) \]
\[ S_3(43) = S_1(43) \]
\[ S_3(44) = S_1(44) \]
\[ S_3(45) = S_1(45) \]
\[ S_3(46) = S_1(46) \]
\[ S_3(47) = S_1(47) \]
\[ S_3(48) = S_1(48) \]
\[ S_3(49) = S_1(49) \]
\[ S_3(50) = S_1(50) \]
\[ S_3(51) = S_1(51) \]
\[ S_3(52) = S_1(52) \]
\[ S_3(53) = S_1(53) \]
\[ S_3(54) = S_1(54) \]
\[ S_3(55) = S_1(55) \]
\[ S_3(56) = S_1(56) \]
\[ S_3(57) = S_1(57) \]
\[ S_3(58) = S_1(58) \]
\[ S_3(59) = S_1(59) \]
\[ S_3(60) = S_1(60) \]

Do 25 I=1,64

SUBPROGRAM PLTMAS: CARD IMAGE LISTING 3/4
IF(I-17)  5,10
  5 SC(I) = R*SC(I)*AB
10 IF(I-36) 15,15,20
  15 S1(I) = R*S1(I)*AB
  20 S3(I) = R*S3(I)*AB
  25 CONTINUE
  RETURN
  END
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

REFERENCES: None
Appendix C

BEGIN

COMPUTE INITIAL PARAMETERS

BEGIN COORDINATE COUNT AT GRID POINT

COMPUTE ELEMENT LOCATION IN ARRAYS S1, S2, S3 LOC

COMPUTE ELEMENT LOCATION IN SUPERMATRIX, A LOC

IS ROW COUNT EQ. TO OR GTR. THAN COL. COUNT?

A(NKL) = A(NKL) + S1(KLS)
A(IKL) = A(IKL) + S3(KLS)

A(IKS) = A(IKS) + S2(KLG)

HAVE ALL COORDINATES BEEN CONSIDERED?

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

COMPUTE COLUMN LOCATION OF GEN. COORDINATE OF PANEL BAY, ICL

BEGIN ROW COUNT FOR GEN. COORDINATE

YES

K > 4

NO

ICR = ICN + K - 1

YES

K > 8

NO

ICR = ICK + NCP + K - 5

YES

K > 12

NO

ICR = ICS + K - 9

YES

K > 16

NO

ICR = ICL

ICR = ICS + NCP + K - 13

COMPUTE SUBSCRIPT, ICC, IN SUPER MATRIX, A

A(ICC) = A(ICC) + SC(K)

YES

IS ROW COUNT COMPLETE?

NO

RETURN

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)
NL = 2 * NCP
NGP = M * (J - 1) + 1
NOBAY = (M - 1) * (J - 1) + 1
INC = NCP * (NGP - 1) + 1
ICS = INC + 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 = INC + K - 1
INL = INC + 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
A(NKL) = A(NKL) + S1(KLS)
A(IKL) = A(IKL) + S3(KLS)
10 A(IKS) = A(IKS) + S2(KLG)
20 CONTINUE
INL = NCP * M * N + NOBAY
DO 70 K = 1, 17
IF(K - 4) 25, 25, 30
25 ICR = INC + K - 1
GO TO 65
30 IF(K - 8) 35, 35, 40
35 ICR = INC + 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, IOP, 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)
IOP - IOP = 1, stiffness matrix is computed
       IOP = 2, consistent mass matrix is computed
D - Length of beam element
S1, S2, S3 - Partitioned stiffness on mass matrix (see Flow Chart)

RESTRICTIONS: D ≠ 0

ACCURACY: See Reference 1, p. 8

SIZE: 001175

REFERENCES: Reference 1, pp. 5 - 11
BEGIN

INITIALIZE ARRAYS
S1, S2, S3
ZERO

YES

1 < 3

RIB PARALLEL TO X-AXIS
SET AX = 1.0

AY = 1.0 - AX

YES

IOP ≤ 1

COMPUTE STIFF. PARAMETERS
FILL ARRAYS
S1(I) = K11
S2(I) = K12
S3(I) = K22
SEE APPENDIX A

RETURN

NO

NO

RIB PARALLEL TO Y-AXIS
SET AX = 0.0

COMPUTE MASS. PARAMETERS
FILL ARRAYS
S1(I) = M11
S2(I) = M12
S3(I) = M22
SEE APPENDIX A

RETURN

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

DIMENSION ER(4), GR(4), RH0(4), SR2(4), C2(4), SR3(4), C3(4),

COMMON ER, GR, RH0, SR2, C2, SR3, C3,
1AR, A22, A23, A33, SJ, RE2, RE3, GM

CALL ZERO(S1, 36)
CALL ZERO(S2, 64)
CALL ZERO(S3, 36)

IF (I = 3) 5, 10, 10

5

Ax = 1.0
G0 TO 15

10

Ax = 0.0

15

AY = 1.0 - Ax

D2 = D * D

D3 = D * D2

IF (IO = 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) / D30.

G3 = ER(I) * GM(I) / D2 + GR(I) * SJ(I) * D / 30.

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 * (SR3(I) * R3 - SR2(I) * R2) * D

T2Y = G2 + (SR3(I) * R3 - SR2(I) * R2) * D

S1(I) = 12 * B22

S1(2) = 6 * (AY * B22 * D2 - 2 * AX * RY)

S1(3) = 4 * (AY * B22 * D2 + 3 * AX * T1X)

S1(4) = 6 * (2 * AX * RY = AX * B22 * D)

S1(5) = 6 * (AY * RX * D + AX * RY * D)

S1(6) = 4 * (3 * AX * T1Y + AX * B22 * D2)

S1(7) = 6 * (AY - AX) * R2 * D

S1(8) = 2 * (2 * AX * RX - AX * B22 * D2)

S1(9) = 2 * (9 * AX * RX * T2X)

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 * D2 + 2 * AX * RY)

S2(6) = 2 * (AY * B22 * D2 - 6 * AX * T1X)

S2(7) = -6 * (AX * RX * D - AX * RX * D)

S2(8) = 2 * (AY * R2 * D2 - 3 * AX * T2X)

S2(9) = -6 * (2 * AX * RX + AX * B22 * D)

S2(10) = -6 * (AY * RX * D - AX * RY * D)

S2(11) = 2 * (AX * B22 * D2 - 6 * AX * T1Y)

S2(12) = 2 * (AX * R2 * D2 + 3 * AX * T2Y)

S2(13) = S1(7)

S2(14) = 2 * (AY * R2 * D2 + 3 * AX * T2X)
Appendix C

\begin{align*}
S2(15) &= -2 \times (3 \times AY \times T2Y - AX \times R2 \times D2) \\
S2(16) &= 2 \times G4 \\
S3(1) &= S1(1) \\
S3(2) &= -6 \times (AY \times B22 \times D + 2 \times AX \times RY) \\
S3(3) &= S1(3) \\
S3(4) &= 6 \times (2 \times AX \times AY \times RY + AX \times B22 \times D) \\
S3(5) &= -S1(5) \\
S3(6) &= S1(6) \\
S3(7) &= -S1(7) \\
S3(8) &= 2 \times (2 \times AX \times R2 \times D2 - 3 \times AX \times T2Y) \\
S3(9) &= 2 \times (3 \times AX \times T2Y + 2 \times AX \times R2 \times D2) \\
S3(10) &= 4 \times G3
\end{align*}

RETURN

25 \quad RM = RH0(I) \times AR(I) \times D / 386. \\
E2 = C2(I) - SR2(I) \\
E3 = C3(I) - SR3(I) \\
R = (E2 \times E2 + E3 \times E3) / D \\
RP = (A22(I) + A33(I)) / (AR(I) \times D2) \\
P1 = 13. / 35. \\
P2 = 11. / 210. \\
P3 = 1. / 105. \\
P4 = 9. / 70. \\
P5 = 13. / 420. \\
P6 = 1. / 140. \\
S1(1) = P1 \times RM \\
S1(2) = (P1 \times AX \times E2 + P2 \times AY \times D) \times RM \\
S1(3) = (P1 \times AX \times (R \times RP) + P3 \times AY) \times RM \times D2 \\
S1(4) = (P2 \times AX \times D + P1 \times AY \times E2) \times RM \\
S1(5) = -P2 \times E2 \times RM \times D \\
S1(6) = (P3 \times AX + P1 \times AY \times (R \times RP)) \times RM \times D2 \\
S1(8) = P2 \times AX \times RM \times D3 \times RP \\
S1(9) = P2 \times AY \times RM \times D3 \times RP \\
S1(10) = P3 \times RM \times D \times D3 \times RP \\
S2(1) = P4 \times RM \\
S2(2) = (P4 \times AX \times E2 + P5 \times AY \times D) \times RM \\
S2(3) = -(P5 \times AX \times D + P4 \times AY \times E2) \times RM \\
S2(5) = (P4 \times AX \times E2 - P5 \times AY \times D) \times RM \\
S2(6) = (P4 \times AX \times (R \times RP) - P6 \times AY) \times RM \times D2 \\
S2(7) = -P5 \times (AX - AY) \times E2 \times RM \times D \\
S2(8) = P5 \times AX \times RM \times D3 \times RP \\
S2(9) = (P5 \times AX \times D - P4 \times AY \times E2) \times RM \\
S2(10) = -S2(7) \\
S2(11) = -(P6 \times AX - P4 \times AY \times (R \times RP)) \times RM \times D2 \\
S2(12) = -P5 \times AY \times RM \times D3 \times RP \\
S2(14) = -P5 \times AX \times RM \times D3 \times RP \\
S2(15) = P5 \times AY \times RM \times D3 \times RP \\
S2(16) = -P6 \times RM \times D \times D3 \times RP \\
S3(1) = S1(1) \\
S3(2) = (P1 \times AX \times E2 - P2 \times AY \times D) \times RM \\
S3(3) = S1(3) \\
S3(4) = (P2 \times AX \times D - P1 \times AY \times E2) \times RM \\
S3(5) = -S1(5) \\
S3(6) = S1(6) \\
S3(8) = -S1(8) \\
S3(9) = -S1(9) \\
S3(10) = S1(10)
\end{align*}

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 ≤ 4, N ≤ 4

ACCURACY: Not Applicable

SIZE: 000207

REFERENCES: None
Appendix C

BEGIN

COMPUTE LOGIC NO. AY, SIZE OF SUPERMATRIX, A, AND COORDINATE POINTS OF THE RIB ELEMENT, ICN, ICS

BEGIN COORDINATE COUNT

COMPUTE ELEMENT INDEX FOR ARRAYS S1, S2, AND S3 LOC

COMPUTE ELEMENT LOCATION IN SUPERMATRIX, A LOC

IS ROW COUNT EQL. OR GTR. THAN COL. COUNT

YES

A(NKL) = A(NKL) + S1(KLS)
A(IKL) = A(IKL) + S3(KLS)
A(IKS) = A(IKS) + S2(KLG)

HAVE ALL COORDINATES BEEN CONSIDERED?

YES

RETURN

NO

FLOW CHART: SUBROUTINE ASSYR (A, S1, S2, S3, I, M, J, N, NCP, AX)
SUBROUTINE ASSYR(A,S1,S2,S3,I,M,N,NCP,AX)
DIMENSION A(2),S1(2),S2(2),S3(2)
AY=1.0
NCO=NCP*M*N*(M-1)*(N-1)
NGP=M*(J-1)+1
KCP=NGP*(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,KLS,NCO,1)
CALL LOC(INK,ISL,IKL,NCO,1)
IF(K=L) 15,10,10
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 ≠ 0, TL ≠ 0

ACCURACY: Not Applicable

SIZE: 000444

REFERENCES: None
Appendix C

BEGIN

COMPUTE INITIAL PARAMETERS

BEGIN GRID POINT COUNT
IC = NCP, NCI, NCP

BEGIN COORDINATE COUNT
FOR EACH GRID POINT
COMPUTE ROW AND COLUMN INDICES: IROW, ICOL
COMPUTE LOCATION IN SUBMATRIX: IJ

COMPUTE SUBSCRIPT, IR, OF ELEMENT IN SUPERMATRIX, A

LOC

COMPUTE NONDIMENSIONALIZING PARAMETER, CL, AND MULTIPLY A(IR) BY CL

HAVE ALL COORDINATES BEEN CONSIDERED AT GRID POINT?

YES

HAVE ALL GRID POINTS BEEN CONSIDERED

YES

NO

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

FLOW CHART: SUBROUTINE NONDIM (A, M, N, TK, TL)
BEGIN COORDINATE COUNT FOR GEN. COORDINATES

COMPUTE COLUMN LOCATION OF COUPLING TERMS, ICOL

BEGIN GRID POINT COUNT FOR COUPLING TERMS, L

COMPUTE ROW LOCATION OF COUPLING TERM FOR EACH COORDINATE

COMPUTE LOCATION OF ELEMENT IN SUPERMATRIX, AIRC

COMPUTE NONDIMENSIONALIZING PARAMETER, CL, AND MULTIPLY A(IRC) BY CL

HAVE ALL COORDINATES BEEN CONSIDERED?

HAVE ALL GRID POINTS BEEN CONSIDERED?

NONDIMENSIONALIZE GENERALIZED COORDINATES

RETURN

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)
NL=M*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 J=1,NCP
   IROW=I1+J-1
   DO 35 J=1,NCP
   ICOL=I1+J-1
   IJ=I+J*(J-1)/2
   CAL LOC(IROW,ICOL,ICP,1)
   GO TO (5,10,15,10,15,15,20,20,25),IJ

5      CL=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
40     IF(IC=NCI) 40,100,100
   IC=IC+1
45     NBAND=NBAND-NCP+1
50     NU=IC+NBAND
55     DO 95 JC=IC1,NU,NCP
      IF(JC=NCI) 55,95,95
55     DO 90 J=1,NCP
      ICOL=JC+J-1
      IC=IC+1
      IROW=I1+J-1
      CALL LOC(IROW,ICOL,IR,NCO,1)
      IJ=1+NCP*(J-1)
      GO TO (60,65,65,70,65,70,70,75,65,70,70,75,70,75,80),IJ
60     CL=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 I CC=IC
GO TO 125
110 I CC=IC+NCP
GO TO 125
115 I CC=IC+NCP*M
GO TO 125
125 DO 150 K=1,NCP
IRR=IC+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(I)=CL*A(I)
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

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

REFERENCES: See Subroutine LOC
BEGIN

YES MS < 0

RETURN

NO

YES MS = 0

RETURN

NO

COMPUTE SUBSCRIPT FOR SYMMETRIC ARRAY B: IJS

LOC

COMPUTE SUBSCRIPT FOR GENERAL ARRAY A: IJG

LOC

FILL ARRAY A WITH ELEMENTS OF ARRAY B

HAVE ALL ELEMENTS OF A BEEN FILLED

YES

NO

RETURN

COMPUTE UPPER LIMIT, NUP, FOR SYMMETRIC ARRAYS A AND B

FILL ARRAY A WITH ELEMENTS OF ARRAY B

RETURN

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

SUBROUTINE FILL(A, B, N, MS)
DIMENSION A(2), B(2)
IF(MS) 25, 5, 15
5 DO 10 I = 1, N
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, NJ, 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

REFERENCES: None
BEGIN

INITIALIZE PARAMETERS
NDL, NGP, NCO

INITIALIZE ARRAY, NC(I)

BEGIN GRID POINT COUNT, IC

BEGIN COORDINATE COUNT AT GRID POINT, J

YES

NDEL(I1) = 1

NO

INCREASE COUNT OF DELETED COORDINATES BY ONE: NDL = NDL + 1

PUT INDEX OF DELETED COORDINATE IN ARRAY NC

YES

J > NCP

NO

IC > NGP

YES

NO

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

Flow Chart: Subroutine ORDER (A, NDEL, NCP, MI, NI, NDL)
Appendix C

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, NI, NC, 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
4 IF(NDL).GT.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(I1,J,I1,J,N,1)
IF(I-J).LT.4,5
4 J1=J+1
CALL LOC(I1,J1,I1,J1,N,1)
GO TO 6
5 CALL LOC(I1,J1,I1,J1,N,1)
6 A(I1J1)=A(I1J1)
7 CONTINUE
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 performed 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)
Appendix D

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 Ith panel bay

EI(I)  Bending rigidity of Ith panel bay (see equation 21, reference 1, p. 11), lb.-in.2

WB(I)  Weight per unit length of Ith panel bay (see equation 22, reference 1, p. 11), lb./in.

BL(I)  Length of Ith panel bay (dimension a., figure D-1)

NCP(I)  Translation coordinate number for locating Ith elastic support in structure NCP(I) will be an odd number

SL(I)  Lumped spring constant, Kzz, for the Ith elastic support (see equation 20a, reference 1, p. 11)

SC(I)  Lumped spring constant, Kzz, for the Ith elastic support (see equation 20a, reference 1, p. 11)

SR(I)  Lumped spring constant, Kzz, for the Ith elastic support (see equation 20a, reference 1, p. 11)

RL(I)  Lumped mass constant, lzz, for the Ith elastic support (see equation 20b, reference 1, p. 11)
Appendix D

RC(I) Lumped mass constant, \( l^*_{z0} \), for the \( I \)th elastic support (see equation 20b, reference 1, p. 11)

RR(I) Lumped mass constant, \( l_{z0}^* \), 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)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(I5)</td>
<td>NCASE</td>
</tr>
</tbody>
</table>

DATA CASE INPUT FORMAT

CARD 1 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(I5)</td>
<td>NDATA</td>
</tr>
<tr>
<td>6(I3)</td>
<td>NBAY</td>
</tr>
<tr>
<td>9(I3)</td>
<td>NSUP</td>
</tr>
<tr>
<td>12(I3)</td>
<td>IOUT</td>
</tr>
<tr>
<td>16(I3)</td>
<td>IBL</td>
</tr>
<tr>
<td>18(I3)</td>
<td>IBR</td>
</tr>
<tr>
<td>21(I3)</td>
<td>NINT</td>
</tr>
</tbody>
</table>

CARD 2 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>4(E12.5)</td>
<td>BW</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>PR</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(I3)</td>
<td>NEL(I)</td>
</tr>
<tr>
<td>4(E12.5)</td>
<td>E1(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>WB(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>BL(I)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(I3)</td>
<td>NCP(I)</td>
</tr>
<tr>
<td>5(E12.5)</td>
<td>SL(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>SC(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>SR(I)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5(E12.5)</td>
<td>RL(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>RC(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>RR(I)</td>
</tr>
</tbody>
</table>
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

$$K_{zz} = 630.02$$  
$$I_{zz}^* = 0.074299$$

$$K_{z\theta} = 14.271$$  
$$I_{z\theta}^* = 0.0$$

$$K_{\theta\theta} = 118.30$$  
$$I_{\theta\theta}^* = 0.0074605$$

Since the cover sheet is uniform, the lumped data are

$$EI(I) = 313.34$$  
$$WB(I) = 0.03232$$

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
Appendix D

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)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>6(I3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>NDATA</td>
</tr>
</tbody>
</table>

CARD 1 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>6(I4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>NCASE</td>
</tr>
</tbody>
</table>

CARD 2 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>A(1)</td>
<td>A(2)</td>
<td>A(3)</td>
</tr>
</tbody>
</table>

CARD 3 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>B(1)</td>
<td>B(2)</td>
<td>B(3)</td>
</tr>
</tbody>
</table>

CARD 4 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
<th>41(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>EP</td>
<td>HP</td>
<td>PR</td>
<td>RHOP</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>ER(I)</td>
<td>GR(I)</td>
<td>RHO(I)</td>
</tr>
</tbody>
</table>

**See comment on page 6 of reference 1.
CARDS 6, 10, 14, 18 (ONE EACH PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
<th>41(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>SR2(I)</td>
<td>C2(I)</td>
<td>SR3(I)</td>
<td>C3(I)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
<th>41(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>AR(I)</td>
<td>A22(I)</td>
<td>A23(I)</td>
<td>A33(I)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>5(E12.5)</th>
<th>17(E12.5)</th>
<th>29(E12.5)</th>
<th>41(E12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>SJ(I)</td>
<td>RE2(I)</td>
<td>RE3(I)</td>
<td>GM(I)</td>
</tr>
</tbody>
</table>

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(l) x B(l)) 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:

- $E_R(I) = 10.3 \times 10^6$, lbf./in.$^2$
- $G_R(I) = 3.9 \times 10^6$, lbf./in.$^2$
- $\text{RHO}(I) = 0.101$, lbf./in.$^3$
- $\text{SR}2(I) = 0.0$, in.
- $\text{C}2(I) = 0.0$, in.
- $\text{SR}3(I) = 0.27191$, in.
- $\text{C}3(I) = 0.80525$, in.
- $\text{AR}(I) = 0.120$, in.$^2$
- $\text{A}22(I) = 0.018389$, in.$^4$
- $\text{A}23(I) = 0.0$, in.$^4$
- $\text{A}33(I) = 0.022298$, in.$^4$
- $\text{SJ}(I) = 4.08 \times 10^{-5}$, in.$^4$
- $\text{RE}2(I) = 0.0$, in.$^5$
- $\text{RE}3(I) = 0.0$, in.$^5$
- $\text{GM}(I) = 2.4445 \times 10^{-3}$, in.$^6$
Appendix D

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

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

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

<table>
<thead>
<tr>
<th>BAY</th>
<th>NUMBER OF ELEMENTS</th>
<th>BENDING RIGIDITY</th>
<th>WEIGHT PER UNIT AREA</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>0.31334E+03</td>
<td>0.32320E-01</td>
<td>0.60000E+01</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.31334E+03</td>
<td>0.32320E-01</td>
<td>0.60000E+01</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0.31334E+03</td>
<td>0.32320E-01</td>
<td>0.60000E+01</td>
</tr>
</tbody>
</table>

SUPPORT NO. 1

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

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

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
-0.26394E-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
-0.43900E-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-01 0.55555E+00
-0.47718E-01 0.56086E+00 0.19684E-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
<table>
<thead>
<tr>
<th>Mode Shape</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.14314E+04 Hz.</td>
</tr>
</tbody>
</table>

**Mode Shape**

<table>
<thead>
<tr>
<th>0.20075E-01</th>
<th>0.47805E+00</th>
<th>0.39897E-01</th>
<th>0.41477E+00</th>
<th>0.26459E-01</th>
<th>0.56646E-01</th>
<th>0.22139E-01</th>
<th>0.35479E+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.22984E-01</td>
<td>0.35350E+00</td>
<td>0.25855E-01</td>
<td>0.45883E-01</td>
<td>0.42503E-01</td>
<td>0.38016E+00</td>
<td>0.18416E-01</td>
<td>0.43094E+00</td>
</tr>
</tbody>
</table>

**Frequency**: 0.10779E+04 Hz.

**Mode Shape**

<table>
<thead>
<tr>
<th>0.42889E-01</th>
<th>0.29934E+00</th>
<th>0.29080E-01</th>
<th>0.34273E+00</th>
<th>0.19237E-01</th>
<th>0.51959E-00</th>
<th>0.91371E-01</th>
<th>0.85631E-01</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.92372E-01</td>
<td>0.57464E-01</td>
<td>0.15062E-01</td>
<td>0.51746E+00</td>
<td>0.29636E-01</td>
<td>0.35522E+00</td>
<td>0.44298E-01</td>
<td>0.30882E+00</td>
</tr>
</tbody>
</table>

**Frequency**: 0.91226E+03 Hz.

**Mode Shape**

<table>
<thead>
<tr>
<th>0.02173E-01</th>
<th>0.22241E+00</th>
<th>0.55437E-01</th>
<th>0.24407E+00</th>
<th>0.93691E-02</th>
<th>0.47409E+00</th>
<th>0.68465E-02</th>
<th>0.39075E+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21049E-02</td>
<td>0.38760E+00</td>
<td>0.17145E-01</td>
<td>0.47678E+00</td>
<td>0.58187E-01</td>
<td>0.26047E+00</td>
<td>0.55314E-1</td>
<td>0.23547E+00</td>
</tr>
</tbody>
</table>

**Frequency**: 0.61498E+03 Hz.

**Mode Shape**

<table>
<thead>
<tr>
<th>0.29406E+00</th>
<th>0.39500E+00</th>
<th>0.32425E+00</th>
<th>0.41994E-01</th>
<th>0.17535E+00</th>
<th>0.15785E+00</th>
<th>0.33269E+00</th>
<th>0.18805E+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33638E+00</td>
<td>0.16173E+00</td>
<td>0.16970E+00</td>
<td>0.97014E-01</td>
<td>0.28483E+00</td>
<td>0.40556E-01</td>
<td>0.25956E+00</td>
<td>0.34819E+00</td>
</tr>
</tbody>
</table>

**Frequency**: 0.51252E+03 Hz.

**Mode Shape**

<table>
<thead>
<tr>
<th>0.24741E+00</th>
<th>0.15803E+00</th>
<th>0.22079E+00</th>
<th>0.23026E+00</th>
<th>0.90784E-01</th>
<th>0.38635E+00</th>
<th>0.36510E-01</th>
<th>0.40397E+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.81548E-01</td>
<td>0.36428E+00</td>
<td>0.37254E-01</td>
<td>0.38097E+00</td>
<td>0.22660E+00</td>
<td>0.23710E+00</td>
<td>0.25326E+00</td>
<td>0.16195E+00</td>
</tr>
<tr>
<td>FREQUENCY</td>
<td>MODE SHAPE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.40419E+03 Hz</td>
<td>-0.19669E+00 -0.47799E-03 0.99424E-01 0.32641E+00 0.22240E-01 -0.44718E+00 -0.20419E+00 0.24689E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.28569E+03 Hz</td>
<td>-0.27949E+00 -0.16821E+00 -0.36683E-01 0.52010E+00 0.23223E+00 -0.19090E+00 -0.15459E+00 -0.34219E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.22294E+03 Hz</td>
<td>-0.19303E+00 -0.16827E+00 -0.10257E+00 0.33362E+00 0.24598E+00 0.23351E+00 0.30065E+00 -0.27188E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.15081E+03 Hz</td>
<td>-0.70434E-02 0.87246E-02 0.10034E-01 -0.38561E-02 0.33860E+02 0.46581E-02 0.97569E-02 0.19778E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.13356E+03 Hz</td>
<td>0.37344E+00 0.48855E+00 0.59755E+00 -0.11907E+00 0.26399E+00 -0.34988E+00 0.14336E+00 0.18782E-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10932E+03 Hz</td>
<td>-0.11838E+00 -0.15800E+00 -0.18767E+00 0.59874E-01 0.21177E-01 0.34200E+00 0.43930E+00 0.33925E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50686E+00 -0.22071E+00 0.13715E+00 -0.37636E+00 -0.92173E-01 -0.89548E-01 -0.74344E-01 0.92762E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D

FREQUENCY = $0.10932E+03$ HZ.

### BAY 1

<table>
<thead>
<tr>
<th>$X$</th>
<th>$W$</th>
<th>$\frac{DW}{DX}$</th>
<th>$V$</th>
<th>$M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.00000E+00</td>
<td>0.00000E+00</td>
<td>0.44278E+00</td>
<td>0.66679E+00</td>
</tr>
<tr>
<td>0.500</td>
<td>-0.20415E-01</td>
<td>-0.16172E+00</td>
<td>0.44106E+00</td>
<td>0.46165E+00</td>
</tr>
<tr>
<td>1.000</td>
<td>-0.72597E-01</td>
<td>-0.20699E+00</td>
<td>0.43014E+00</td>
<td>0.25914E+00</td>
</tr>
<tr>
<td>1.500</td>
<td>-0.14296E+00</td>
<td>-0.2524AE+00</td>
<td>0.40388E+00</td>
<td>0.65074E+01</td>
</tr>
<tr>
<td>2.000</td>
<td>-0.21790E+00</td>
<td>-0.41492E+00</td>
<td>0.35947E+00</td>
<td>0.11265E+00</td>
</tr>
<tr>
<td>2.500</td>
<td>-0.28390E+00</td>
<td>-0.35376E+00</td>
<td>0.29749E+00</td>
<td>0.26561E+00</td>
</tr>
<tr>
<td>3.000</td>
<td>-0.33181E+00</td>
<td>-0.26750E+00</td>
<td>0.22136E+00</td>
<td>0.38638E+00</td>
</tr>
<tr>
<td>3.500</td>
<td>-0.38983E-01</td>
<td>-0.11190E+00</td>
<td>0.13639E+00</td>
<td>0.46955E+00</td>
</tr>
<tr>
<td>4.000</td>
<td>-0.44545E+00</td>
<td>-0.15724E+00</td>
<td>0.49602E+00</td>
<td>0.51259E+00</td>
</tr>
<tr>
<td>4.500</td>
<td>-0.49940E+00</td>
<td>0.23952E+00</td>
<td>0.30415E+00</td>
<td>0.51660E+00</td>
</tr>
<tr>
<td>5.000</td>
<td>-0.21815E+00</td>
<td>0.22203E+00</td>
<td>0.94728E+00</td>
<td>0.48681E+00</td>
</tr>
<tr>
<td>5.500</td>
<td>-0.14455E+00</td>
<td>0.35737E+00</td>
<td>0.13520E+00</td>
<td>0.43246E+00</td>
</tr>
<tr>
<td>6.000</td>
<td>0.38983E-01</td>
<td>0.89815E+00</td>
<td>0.14356E+00</td>
<td>0.36648E+00</td>
</tr>
</tbody>
</table>

### BAY 2

<table>
<thead>
<tr>
<th>$X$</th>
<th>$W$</th>
<th>$\frac{DW}{DX}$</th>
<th>$V$</th>
<th>$M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.36983E-01</td>
<td>0.89815E+00</td>
<td>0.96445E+00</td>
<td>0.82748E+00</td>
</tr>
<tr>
<td>0.500</td>
<td>0.21850E+00</td>
<td>0.10000E+01</td>
<td>-0.93361E+00</td>
<td>0.38565E+00</td>
</tr>
<tr>
<td>1.000</td>
<td>0.42245E+00</td>
<td>0.86579E+00</td>
<td>-0.85454E+00</td>
<td>0.31022E+00</td>
</tr>
<tr>
<td>1.500</td>
<td>0.63008E+00</td>
<td>0.74554E+00</td>
<td>-0.72494E+00</td>
<td>0.39930E+00</td>
</tr>
<tr>
<td>2.000</td>
<td>0.80865E+00</td>
<td>0.89093E+00</td>
<td>-0.54725E+00</td>
<td>0.69600E+00</td>
</tr>
<tr>
<td>2.500</td>
<td>0.93495E+00</td>
<td>0.62932E+00</td>
<td>-0.33169E+00</td>
<td>0.90101E+00</td>
</tr>
<tr>
<td>3.000</td>
<td>0.99969E+00</td>
<td>0.40570E+00</td>
<td>-0.92580E+00</td>
<td>0.10000E+01</td>
</tr>
<tr>
<td>3.500</td>
<td>0.10000E+01</td>
<td>0.57060E+01</td>
<td>0.15458E+00</td>
<td>0.98563E+00</td>
</tr>
<tr>
<td>4.000</td>
<td>0.93303E+00</td>
<td>-0.57963E+00</td>
<td>0.39361E+00</td>
<td>0.85786E+00</td>
</tr>
<tr>
<td>4.500</td>
<td>0.93303E+00</td>
<td>-0.57963E+00</td>
<td>0.39361E+00</td>
<td>0.85786E+00</td>
</tr>
<tr>
<td>5.000</td>
<td>0.80203E+00</td>
<td>0.75310E+00</td>
<td>0.60801E+00</td>
<td>0.62437E+00</td>
</tr>
<tr>
<td>5.500</td>
<td>0.62856E+00</td>
<td>-0.69373E+00</td>
<td>0.78494E+00</td>
<td>0.29932E+00</td>
</tr>
<tr>
<td>6.000</td>
<td>0.43719E+00</td>
<td>0.99839E+00</td>
<td>0.10000E+01</td>
<td>0.54217E+00</td>
</tr>
</tbody>
</table>

### BAY 3

<table>
<thead>
<tr>
<th>$X$</th>
<th>$W$</th>
<th>$\frac{DW}{DX}$</th>
<th>$V$</th>
<th>$M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.25247E+00</td>
<td>-0.98389E+00</td>
<td>-0.79187E+00</td>
<td>0.52150E+00</td>
</tr>
<tr>
<td>0.500</td>
<td>0.96812E-01</td>
<td>-0.75629E+00</td>
<td>-0.36966E+00</td>
<td>0.49605E+00</td>
</tr>
<tr>
<td>1.000</td>
<td>-0.24596E-01</td>
<td>-0.50929E+00</td>
<td>-0.28777E+00</td>
<td>0.48196E+00</td>
</tr>
<tr>
<td>1.500</td>
<td>-0.11301E+00</td>
<td>-0.31354E+00</td>
<td>-0.46355E+00</td>
<td>0.46537E+00</td>
</tr>
<tr>
<td>2.000</td>
<td>-0.16967E+00</td>
<td>-0.23517E+00</td>
<td>-0.81741E+00</td>
<td>0.43621E+00</td>
</tr>
<tr>
<td>2.500</td>
<td>-0.19573E+00</td>
<td>-0.10180E+00</td>
<td>-0.17276E+00</td>
<td>0.38799E+00</td>
</tr>
<tr>
<td>3.000</td>
<td>-0.19521E+00</td>
<td>-0.23323E+00</td>
<td>-0.17590E+00</td>
<td>0.31717E+00</td>
</tr>
<tr>
<td>3.500</td>
<td>-0.17372E+00</td>
<td>0.69069E+00</td>
<td>0.22153E+00</td>
<td>0.22537E+00</td>
</tr>
<tr>
<td>4.000</td>
<td>-0.13685E+00</td>
<td>0.24361E+00</td>
<td>0.25996E+00</td>
<td>0.11338E+00</td>
</tr>
<tr>
<td>4.500</td>
<td>-0.13685E+00</td>
<td>0.24361E+00</td>
<td>0.25996E+00</td>
<td>0.11338E+00</td>
</tr>
<tr>
<td>5.000</td>
<td>-0.14155E-01</td>
<td>0.26532E+00</td>
<td>0.28810E+00</td>
<td>0.13141E+01</td>
</tr>
<tr>
<td>5.500</td>
<td>-0.47081E-01</td>
<td>0.23196E+00</td>
<td>0.30501E+00</td>
<td>0.15210E+00</td>
</tr>
<tr>
<td>6.000</td>
<td>-0.13379E-01</td>
<td>0.14352E+00</td>
<td>0.31213E+00</td>
<td>0.29552E+00</td>
</tr>
</tbody>
</table>

**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
\Gamma_e = 0.0024445, in^6

*Pole taken at shear center

FIGURE D-8. STIFFENER CROSS-SECTION SHAPE: EXAMPLE PROBLEM
NINE-BAY TWO-DIMENSIONAL PANEL
FIGURE D-9. INPUT DATA FORMAT: EXAMPLE PROBLEM

<table>
<thead>
<tr>
<th>Rib 1</th>
<th>Rib 2</th>
<th>Rib 3</th>
<th>Rib 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>80525</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.29985</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.44450</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.29985</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.44450</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.29985</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NOTE: NDATA = 1 FOR THIS EXAMPLE
Appendix D

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 = 0.16389E-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 = 0.16389E-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 = 0.16389E-01  IXZ = 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. 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 = 0.16389E-01  IXZ = 0.00000E+00  IZZ = 0.22298E-01
J = 0.40800E-04  REY = 0.00000E+00  REZ = 0.00000E+00  GAMMA = 0.24445E-02

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

DATA CASE 1000

Nondimensionalizing Constants

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.32763 \times 10^1$</td>
<td></td>
<td>$0.2582 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$-0.60316 \times 10^{-2}$</td>
<td>$-0.47696 \times 10^0$</td>
<td>$-0.10599 \times 10^0$</td>
</tr>
<tr>
<td>$0.10599 \times 10^0$</td>
<td>$0.60316 \times 10^{-2}$</td>
<td>$0.10599 \times 10^0$</td>
</tr>
<tr>
<td>$-0.47696 \times 10^{-2}$</td>
<td>$0.24869 \times 10^{-2}$</td>
<td>$0.12935 \times 10^0$</td>
</tr>
<tr>
<td>$0.37093 \times 10^{-3}$</td>
<td>$0.24869 \times 10^{-2}$</td>
<td>$-0.3804 \times 10^{-2}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.2483 \times 10^0$</td>
<td></td>
<td>$0.2116 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$0.40668 \times 10^{-2}$</td>
<td>$0.12674 \times 10^0$</td>
<td>$0.85587 \times 10^0$</td>
</tr>
<tr>
<td>$0.27892 \times 10^0$</td>
<td>$0.12674 \times 10^0$</td>
<td>$0.40668 \times 10^0$</td>
</tr>
<tr>
<td>$0.29630 \times 10^0$</td>
<td>$0.12674 \times 10^0$</td>
<td>$0.77907 \times 10^0$</td>
</tr>
<tr>
<td>$0.23973 \times 10^0$</td>
<td>$0.50452 \times 10^{-2}$</td>
<td>$0.29630 \times 10^0$</td>
</tr>
<tr>
<td>$-0.41871 \times 10^{-2}$</td>
<td>$0.74823 \times 10^{-2}$</td>
<td>$0.34553 \times 10^0$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.2403 \times 10^0$</td>
<td></td>
<td>$0.2116 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$0.85587 \times 10^{-2}$</td>
<td>$0.27892 \times 10^0$</td>
<td>$0.50452 \times 10^0$</td>
</tr>
<tr>
<td>$-0.12674 \times 10^0$</td>
<td>$-0.40668 \times 10^0$</td>
<td>$-0.12674 \times 10^0$</td>
</tr>
<tr>
<td>$0.29630 \times 10^0$</td>
<td>$0.50452 \times 10^{-2}$</td>
<td>$0.27892 \times 10^0$</td>
</tr>
<tr>
<td>$0.23973 \times 10^0$</td>
<td>$0.27892 \times 10^0$</td>
<td>$0.77907 \times 10^0$</td>
</tr>
<tr>
<td>$-0.90451 \times 10^{-2}$</td>
<td>$0.74823 \times 10^{-2}$</td>
<td>$0.34553 \times 10^0$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.2318 \times 10^0$</td>
<td></td>
<td>$0.2116 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$0.53408 \times 10^{-3}$</td>
<td>$0.35356 \times 10^0$</td>
<td>$0.48897 \times 10^0$</td>
</tr>
<tr>
<td>$0.35355 \times 10^0$</td>
<td>$0.35356 \times 10^0$</td>
<td>$0.27049 \times 10^{-2}$</td>
</tr>
<tr>
<td>$-0.59723 \times 10^{-3}$</td>
<td>$-0.34873 \times 10^{-2}$</td>
<td>$0.35553 \times 10^0$</td>
</tr>
<tr>
<td>$0.41365 \times 10^{-3}$</td>
<td>$0.98020 \times 10^{-2}$</td>
<td>$0.34873 \times 10^0$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.89302 \times 10^0$</td>
<td></td>
<td>$0.1348 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$-0.1776 \times 10^0$</td>
<td>$-0.35152 \times 10^2$</td>
<td>$0.38818 \times 10^0$</td>
</tr>
<tr>
<td>$0.35152 \times 10^0$</td>
<td>$0.35152 \times 10^2$</td>
<td>$-0.38818 \times 10^0$</td>
</tr>
<tr>
<td>$-0.35152 \times 10^0$</td>
<td>$0.35152 \times 10^2$</td>
<td>$-0.1776 \times 10^0$</td>
</tr>
<tr>
<td>$0.38818 \times 10^0$</td>
<td>$0.19067 \times 10^0$</td>
<td>$0.68695 \times 10^0$</td>
</tr>
<tr>
<td>$-0.50232 \times 10^0$</td>
<td>$0.68695 \times 10^0$</td>
<td>$0.19067 \times 10^0$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Eigenvector</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.81502 \times 10^0$</td>
<td></td>
<td>$0.1288 \times 10^4$ Hz</td>
</tr>
<tr>
<td>$0.21390 \times 10^0$</td>
<td>$0.47758 \times 10^0$</td>
<td>$-0.1158 \times 10^0$</td>
</tr>
<tr>
<td>$0.11434 \times 10^0$</td>
<td>$-0.44260 \times 10^0$</td>
<td>$0.10171 \times 10^0$</td>
</tr>
<tr>
<td>$-0.44260 \times 10^0$</td>
<td>$0.5508 \times 10^0$</td>
<td>$0.10171 \times 10^0$</td>
</tr>
<tr>
<td>$0.11434 \times 10^0$</td>
<td>$0.47758 \times 10^0$</td>
<td>$0.10171 \times 10^0$</td>
</tr>
<tr>
<td>$-0.1158 \times 10^0$</td>
<td>$-0.19860 \times 10^0$</td>
<td>$0.12966 \times 10^0$</td>
</tr>
<tr>
<td>$-0.10139 \times 10^0$</td>
<td>$-0.46047 \times 10^0$</td>
<td>$-0.12966 \times 10^0$</td>
</tr>
</tbody>
</table>

Figure D-10. Output data format: Eigenvalues and eigenvectors, example problem.
<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>EIGENVALUE</th>
<th>EIGENVECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.47758E+00</td>
<td>-0.55078E-01</td>
<td>0.12966E-01</td>
</tr>
<tr>
<td>-0.11586E+00</td>
<td>-0.21390E-01</td>
<td>0.46088E-02</td>
</tr>
<tr>
<td>-0.42620E+00</td>
<td>-0.94347E-02</td>
<td>0.0</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.97947E-01</td>
<td></td>
<td>0.44657E+03, Hz</td>
</tr>
<tr>
<td>0.12541E-01</td>
<td>0.42314E+00</td>
<td>0.41250E+00</td>
</tr>
<tr>
<td>-0.14430E+00</td>
<td>-0.10926E+00</td>
<td>0.10186E+00</td>
</tr>
<tr>
<td>-0.10926E+00</td>
<td>-0.10926E+00</td>
<td>0.12541E-01</td>
</tr>
<tr>
<td>-0.42720E-02</td>
<td>-0.24159E-02</td>
<td>0.82194E+01</td>
</tr>
<tr>
<td>-0.34003E-07</td>
<td>-0.89391E-01</td>
<td>0.57600E-01</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.97947E-01</td>
<td></td>
<td>0.44657E+03, Hz</td>
</tr>
<tr>
<td>0.29902E+00</td>
<td>-0.10926E+00</td>
<td>0.14430E+00</td>
</tr>
<tr>
<td>0.41250E+00</td>
<td>-0.42314E+00</td>
<td>0.42724E+00</td>
</tr>
<tr>
<td>-0.42314E+00</td>
<td>-0.42720E-02</td>
<td>0.29902E+00</td>
</tr>
<tr>
<td>0.10186E+00</td>
<td>0.57600E-01</td>
<td>0.89391E+01</td>
</tr>
<tr>
<td>0.30050E-07</td>
<td>-0.82194E-02</td>
<td>0.24158E-02</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.29039E-01</td>
<td></td>
<td>0.24316E+03, Hz</td>
</tr>
<tr>
<td>0.19097E+00</td>
<td>0.28427E+00</td>
<td>0.10907E+00</td>
</tr>
<tr>
<td>0.2427E+00</td>
<td>0.28427E+00</td>
<td>0.2427E+00</td>
</tr>
<tr>
<td>-0.2427E+00</td>
<td>-0.10907E+00</td>
<td>0.19097E+00</td>
</tr>
<tr>
<td>-0.10907E+00</td>
<td>-0.35377E-01</td>
<td>0.11373E+00</td>
</tr>
<tr>
<td>0.32140E+00</td>
<td>-0.11373E+00</td>
<td>0.35378E-01</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.60586E-02</td>
<td></td>
<td>0.11107E+03, Hz</td>
</tr>
<tr>
<td>-0.63666E-03</td>
<td>0.46583E-02</td>
<td>0.46580E-02</td>
</tr>
<tr>
<td>0.46582E+02</td>
<td>-0.46582E+02</td>
<td>-0.21134E-01</td>
</tr>
<tr>
<td>-0.46580E-02</td>
<td>-0.21134E+00</td>
<td>0.63666E-03</td>
</tr>
<tr>
<td>-0.21134E+00</td>
<td>-0.63666E-03</td>
<td>0.46582E-02</td>
</tr>
<tr>
<td>0.27245E+00</td>
<td>0.81047E+00</td>
<td>0.47379E+00</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.60484E-02</td>
<td></td>
<td>0.11097E+03, Hz</td>
</tr>
<tr>
<td>0.16332E-07</td>
<td>0.74795E+02</td>
<td>0.74795E+02</td>
</tr>
<tr>
<td>0.74795E-02</td>
<td>-0.74795E-02</td>
<td>0.65948E+05</td>
</tr>
<tr>
<td>0.74795E-02</td>
<td>-0.28875E+05</td>
<td>0.39173E+07</td>
</tr>
<tr>
<td>-0.20951E-05</td>
<td>0.92276E+05</td>
<td>0.49988E+00</td>
</tr>
<tr>
<td>0.48667E-05</td>
<td>0.49988E+00</td>
<td>0.27818E+05</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.60384E-02</td>
<td></td>
<td>0.11088E+03, Hz</td>
</tr>
<tr>
<td>-0.87996E-03</td>
<td>0.56074E-02</td>
<td>0.45847E-02</td>
</tr>
<tr>
<td>0.34193E+02</td>
<td>-0.11253E+00</td>
<td>0.17870E+00</td>
</tr>
<tr>
<td>0.11253E+02</td>
<td>0.17870E+00</td>
<td>0.39097E-02</td>
</tr>
<tr>
<td>0.11253E-01</td>
<td>0.14271E+00</td>
<td>0.63406E+00</td>
</tr>
<tr>
<td>-0.53555E-05</td>
<td>-0.11211E+00</td>
<td>0.17724E+00</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>Eigenvector</td>
<td>Frequency</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>0.60384E-02</td>
<td></td>
<td>0.11088E+03, Hz</td>
</tr>
<tr>
<td>-0.39097E+00</td>
<td>0.11253E+00</td>
<td>0.34192E+02</td>
</tr>
<tr>
<td>0.45847E-02</td>
<td>-0.56076E-02</td>
<td>0.40271E-01</td>
</tr>
<tr>
<td>0.56076E-02</td>
<td>0.40271E-01</td>
<td>0.39097E-02</td>
</tr>
<tr>
<td>0.17869E+00</td>
<td>0.63406E+00</td>
<td>0.14271E+00</td>
</tr>
<tr>
<td>0.46017E-05</td>
<td>0.17724E+00</td>
<td>0.34192E+02</td>
</tr>
</tbody>
</table>

**Figure D-10. Output Data Format: Eigenvalues and Eigenvectors, Example Problem**
<table>
<thead>
<tr>
<th>EIGENVALUE</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1358E-02</td>
<td>0.11086E+03</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.20068E+00</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.20068E+00</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EIGENVALUE</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5958E-02</td>
<td>0.11105E+03</td>
</tr>
<tr>
<td>0.1358E-02</td>
<td>0.11105E+03</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.20068E+00</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EIGENVALUE</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5958E-02</td>
<td>0.10862E+03</td>
</tr>
<tr>
<td>0.1358E-02</td>
<td>0.10862E+03</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.20068E+00</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EIGENVALUE</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5539E-02</td>
<td>0.10620E+03</td>
</tr>
<tr>
<td>0.1358E-02</td>
<td>0.10620E+03</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.20068E+00</td>
</tr>
<tr>
<td>0.3301E-02</td>
<td>0.13580E-02</td>
</tr>
<tr>
<td>0.20068E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
<tr>
<td>0.4579E+00</td>
<td>0.3301E-02</td>
</tr>
</tbody>
</table>

FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM
\[ \{ d_i \} = \begin{pmatrix} \frac{W_i}{TL} \\ \theta_x \\ \theta_y \\ \theta_{xy}^* TL \end{pmatrix} \]

\[ TL = \text{Nondimensionalizing length} \]

Eigenvalues listed in the sequence:

\[ \{ \{ d_1 \} , \{ d_2 \} , \{ d_3 \} , \{ d_4 \} , \{ W_{01}/TL, W_{02}/TL, \ldots, W_{09}/TL \} \} \]

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

Mode: $f = 106.2$ Hz.

Mode: $f = 108.62$ Hz.

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM
Appendix D

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM

Mode: $f = 110.15$ Hz. (repeated root)
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:

\[ f = \frac{N}{M} : R : Q \]

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.
Appendix E

CHLADNI PATTERNS SPECIMEN  SPI-2-1D
CHLADNI PATTERNS SPECIMEN SPI-2-1D
Appendix E

CHLADNI PATTERNS SPECIMEN  SPI-2-2
CHLADNI PATTERNS SPECIMEN  SPI-2-2D
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
CHLADNI PATTERNS SPECIMEN SPI-3-2D
CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMEN


CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMEN

189
Appendix E

CHLADNI PATTERNS FOR 9 BAY SPECIMEN SPII-2

f = 90/89:A
f = 97/112:A
f = 101/114:C
f = 107/115:D
f = 112/133:B
f = 134/-:B
f = 144/161:B
f = 168/211:B
REFERENCES


