STATISTICAL ENERGY ANALYSIS
COMPUTER PROGRAM
USER'S GUIDE

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PREFACE

The work reported herein was performed for the National Aeronautics and Space Administrations's Marshall Space Flight Center under contract NAS8-33191, Supplemental Agreements 2 and 3. This effort involved the development of a computer program to perform StatistICAL Energy Analysis. This volume constitutes the final deliverable item under the contract. A card deck of the computer program was forwarded previously by MDAC letter A3-130-GWJ-1283.

Programming was accomplished by S. J. Nygaard, McDonnell Douglas Automation Company - Huntington Beach.
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<td>4-5</td>
<td>Loadsheet 5</td>
<td>4-12</td>
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Section 1
INTRODUCTION

Significant high frequency random vibration environments are generated during the operation of aerospace vehicles within the atmosphere. To achieve optimum vehicle design, vibration and acoustic criteria are developed early in the vehicle development program and are updated periodically as the design matures.

High frequency random vibration response prediction does not lend itself well to classical structural dynamics and such predictions are usually made by extrapolation from existing data banks. This method gives excellent results when similar structures are involved. However, as similarity decreases and associated extrapolations become large, uncertainty over accuracy also increases.

The efforts of numerous investigators (Maidanik, Lyons, et al.) have examined a more general high frequency random vibration analysis approach - the so-called Statistical Energy Analysis method. The SEA method is able to accomplish high frequency prediction of arbitrary structural configurations and is therefore a significant improvement over extrapolation methods when little or no previous data exist. The SEA method also represents a great improvement over normal mode methods for high frequency random vibration prediction because of the greatly reduced computational complexity associated with the more general SEA model elements and the attendant improvement in analysis turnaround time.

SEA has been developed for complex structures by MDAC under contract to MSFC (Ref. 1 and 2) over the past three years. The past year's effort has created a general SEA computer program which is described in this manual. The manual contains (1) a summary of SEA theory, (2) example problems of SEA program application, (3) a description of the computer program, and (4) a complete program listing (Appendices).
Section 2
A SUMMARY OF STATISTICAL ENERGY ANALYSIS PRINCIPLES

Statistical Energy Analysis (SEA) is a powerful tool for estimating the high frequency vibration spectra of complex systems. The analysis method is based on the estimation of the power flow between idealized gross elements of a vibrating system. The method is statistical in that averaging assumptions are made with regard to distribution of energy within an element, distribution of resonant modes, and the coupling between elements. These assumptions greatly simplify the computational complexity associated with normal mode methods. These same assumptions impose the limitation that point response predictions cannot be made.

The assumptions on which the method rests and their implications can be quite rigorously stated as follows:

1. The total vibrating system can be partitioned into SEA elements (with suitable boundary conditions) whose modes approximate the modes of the original vibrating system.

2. The modes of the elements of a system contain all of the vibratory energy of the system.

3. The energy in one frequency band of a system element is equally distributed among the modes of that element occurring in the frequency band.

4. Only modes occurring within the same frequency band are coupled.

5. For two coupled elements, all of the modes occurring in one of the elements in one frequency band are equally coupled to each mode occurring in the same frequency band in the other element.
Assumption 1 contains the fundamental existence basis for SEA: the concept of partitionability. This concept implies that a coupled vibrating system with system modes can be approximated by two or more separately idealized vibrating elements, each with its own independent mode set. These sets are coupled only in the sense of having power flow to and from each set across the partition boundary (later referred to as the "joint"). The approximation to this model exists in most structures having reflective boundaries in the higher frequencies. For example, a skin/stringer structure has higher order skin panel modes that are nearly the same frequency and shape as an ideally supported panel because the stringer is a comparatively massive boundary causing reflection of flexural waves from the skin panel. An SEA plate element could logically be equal to the panel area bounded by stringers or frames. Such elements will then have to be coupled with joint elements in order to develop an SEA model which emulates the vibratory power flow of the real structure.

Assumption 3 is the most important simplifying assumption of SEA because it eliminates the necessity to calculate generalized modal forces and responses. The conditions implicit in this assumption are usually approximated by the higher order modes of a structure in a reasonable bandwidth, say 1/3 octave. One-third octave bands represent a reasonable compromise between the necessity to get a fairly large number of modes (>20) in the band for good statistics and the necessity to have some frequency response resolution in the vibration prediction. The number of modes in a unit bandwidth can be estimated for simple structural forms (such as beams, plates, etc.) using algebraic expressions for modal density such as those given in Section 4 of this report. Estimation of modal density in this way is a considerable simplification over normal mode methods.

Given SEA elements with the properties described above it is now necessary to join them to permit power flow between the modes of one element and the modes of another. This is done with a parameter called the coupling loss factor $\phi$ and leads to assumptions 4 and 5. Assumption 4 is directly linked to assumption 2 and the further assumption of a linear process. Assumption 5 follows directly from assumption 3 as part of the simplification associated with a statistical rather than explicit description of modes.
With these properties and assumptions we can now write the SEA equation systems as follows:

\[
\begin{bmatrix}
\alpha_{11} & \alpha_{12} & \alpha_{13} & \cdots & \alpha_{1j} \\
\alpha_{21} & \alpha_{22} & \alpha_{23} & \cdots & \alpha_{2j} \\
\alpha_{31} & \alpha_{32} & \alpha_{33} & \cdots & \alpha_{3j} \\
\end{bmatrix}
\begin{bmatrix}
E_1 \\
E_2 \\
E_3 \\
\end{bmatrix} =
\begin{bmatrix}
S_1 \\
S_2 \\
S_3 \\
\end{bmatrix}
\]  

(1)

where

\[
\alpha_{ij} = \begin{cases} 
-N_i \phi_{ij} & \text{if } i \neq j \\
\omega_n + \sum_{k=1}^{M} N_k \phi_{ik} & \text{if } i = j 
\end{cases}
\]

- \(M\) is the number of SEA elements
- \(N_i\) is the number of modes resonant in element \(i\)
- \(\eta_i\) is the element \(i\) loss factor
- \(\phi_{ij}\) is the power transfer coefficient for coupling between modes in elements \(i\) and \(j\)
- \(\omega\) is the center frequency of the bandwidth
- \(E_i = m_i \frac{\langle a_i^2 \rangle}{\omega^2}\) is the total energy of element \(i\), \(\langle a^2 \rangle\) being the mean square acceleration
- \(S_i\) is the external acoustic or mechanical excitation in the bandwidth of interest

Note that the matrix \(\alpha\) is square but not symmetric. The lack of symmetry arises from the nature of the term \(-N_i \phi_{ij}\). Using the first two rows as an example the power balance equations are

\[
(\omega n_1 + \sum_{k=1}^{M} N_k \phi_{1k}) E_1 - N_1 \phi_{12} E_2 - N_1 \sum_{k=2}^{M} \phi_{1k} E_k = S_1
\]

\[
-N_2 \phi_{12} + (\omega n_2 + \sum_{k=1}^{M} N_k \phi_{2k}) E_2 - N_2 \sum_{k=3}^{M} \phi_{1k} E_k = S_2
\]
Note that the "symmetric" positions $a_{21}$ and $a_{12}$ actually carry the number of modes belonging to the row number only. This unsymmetric form preserves the power flow both to and from each element.

Each equation in the matrix states the following relationship for each element. The net power flow into element $i$ ($S_i$) equals the difference between (1) the power flow dissipated within the element ($\omega_i E_i$) plus the power flow lost to other elements across the joints

$$E_i = \sum_{k=1}^{M} N_k \phi_{ik}$$

and (2) the power flow added to element $i$ from all other elements

$$N_i = \sum_{k=1}^{M} E_k \phi_{ik}, \ i \neq k$$

It must be remembered that the coupling term $\phi_{ik}$ has nothing to do with coupling modes; it only relates the fractional amount of energy resident in the modes of element $i$ that flows to the modes of element $k$.

For all but the simplest of systems even the SEA equations can be laborious to evaluate by hand. The computer program described in the following sections performs all of the computations necessary to evaluate terms and solves the above system of equations for element energies and prints the results as vibration PSD or RMS levels for all elements. This program relieves the analyst of the necessity to have an extensive knowledge of how to compute SEA parameters and permits the use of SEA model sizes that would otherwise be intractable. The program is described in detail in Section 2; some SEA modeling examples and corresponding program inputs are described in Section 3.
Section 3
EXAMPLES OF SEA PROGRAM APPLICATIONS

An SEA computer program has been developed that performs the organization of specific problem solutions for up to a 20-element system. A number of different element and joint types are available to describe a wide variety of structural forms in terms of an SEA model. Random acoustic or mechanical excitation can be applied in 1/3 octave bands to any arbitrary number of elements within a given model. The resulting equations are then solved giving the vibration response spectrum for each element. This section illustrates the use of SEA and the computer program with specific examples. The basic analysis procedure is divided into three steps:

1. Idealization
2. Parameter Generation
3. Problem Solution

The idealization step must be performed entirely by the user as it consists of modeling the physical structure in terms of available SEA program elements – a conceptual process. The second step is one of simply providing the proper data to the program which then carries out the third step. These steps will be illustrated below with specific examples, and the SEA program elements will be discussed in detail.

The idealization step is by far the most crucial step in the process. It is here that the art of engineering judgement must reach a well developed state, balancing the realities of the structural article to be analyzed with the capabilities and assumptions implicit in the SEA process to
obtain a useful engineering solution. Consider the model shown in Figure 3-1. This is the basic form of all SEA models. It consists of elements, denoted as boxes, which may be plates, beams, etc., and joints denoted by connecting lines which correspond to the physical interfaces at the selected partitions.

The model shows the articles included in each SEA element and the connection relationships between or among the elements. To gain a better understanding of what these elements and connections are it is helpful to now explain in detail the various types available in the computer program. Each of the elements is made up of one or more sub-elements, the first of which is the main sub-element. The sub-element system provides a convenient way to compute and include the modal density and mass properties of individual structural pieces that make up the element on a piece-by-piece basis. However, the sub-element with the most important property being modelled in that SEA element should always be the first or main sub-element. The joint properties must also be consistent with this sub-element as it is the only one that can be coupled to other SEA main elements. An example is given by element 1 of the model. This element has structure elements exposed to an acoustic field and those that are not. The most important property is the reception of acoustic excitation and transmission of vibration through its boundaries to other main elements. That portion must therefore be sub-element 1.

It is often the case that structures are made of different materials; this condition is taken into account when the program sets up the solution. The program automatically recomputes properties (thickness, density, etc.) to match the elastic modulus of element 1, sub-element 1. Furthermore, only sub-element 1 of each element can receive acoustic excitation; the others contribute only to the modal density and to the element mass. Sub-element 1 will always be used for the structure element that is the main piece of the given SEA element because all other properties except mass and modal density will be those of this sub-element.

The types of sub-elements available are beams, plates, cylinders, membrane, and reverberant room. In general, beams, plates and cylinders can
Figure 3-1. SEA Model Elements for Acoustic Test Configuration
be freely mixed in describing a structure. The membrane sub-element should only be used as an ancillary sub-element (i.e., sub-element number > 1). The room sub-element requires special treatment in that the loss factor must be developed from the reverberation time \( n = 2.2/fT_{60} \) and the answers must be converted from \( q^2 \) to pressure\(^2\) using energy density relationship. The room sub-element must always be the only sub-element in that particular element.

Given these SEA elements, joint properties must now be developed to describe the power flow from the modes of one element to another. The program gives the user a choice of four types: (1) plate to plate, (2) beam to plate, (3) riveted joint, and (4) plate to acoustic. Each joint has two ends for accounting purposes and the word order used describes the A and B ends respectively. For example, in joint (2) the beam is always at the A end and plate is always at the B end. The joint loss factors are from the literature (cited in References 1 and 2) except for the bolted joint. This joint is a plate-to-plate joint with an additional insertion loss to account for internal losses in the joint due to fastener effects. The insertion loss is a load sheet input which provides to the user a more general purpose alternative to joints (1) and (2). Values of the insertion loss parameter for various fastener arrangements are not well defined, however, and must be the topic of continuing research. In the case of the Materials Experiment Assembly (MEA) analyzed during the last phase of this study, the empirically determined insertion loss factor was approximately 10 for each bolted joint.

With the basics of the program now given, two examples will be shown as a guide for program use. The first example will be a segment of skin stringer structure exposed to an acoustic field with an equipment panel on the opposite side. The second example will be a simplified MEA analysis.

The first case can be idealized with two SEA elements as shown in Figure 3-2. The relevant parameters are shown in the following table:
Skin Thickness
Segment Dimensions
Stringer Spacing
Stringer Dimensions
Internal Frames
Panel

.040"
18" x 72"
10" O.C.
1-1/2" high x 1" wide with 3/4 flanges,.063 thick (full hat section)
400 in² of .063 thick aluminum
1" honeycomb with .020 face sheets
17 x 30 with 16 lb of small equipment items mounted on its surface.
Panel riveted to frames at four places (U-shaped channels) .063" thick x 1-1/2" high

The SEA element 1 shown in Figure 3-2 will consist of all structural elements in the table except the panel and its mounted equipment which is SEA element 2. From this information an elementary SEA analysis can be made. The load sheet entries are determined as follows and are shown in Figures 3-3 through 3-10 in the proper sequence.

![Two-Element SEA Model Example](image)

Figure 3-2. Two-Element SEA Model Example

Figure 3-3 shows the header card which basically describes the problem as consisting of two elements and eleven 1/3 octave bands from 250 to 2500 Hz and that the output will be a vibration PSD. Figure 3-4 describes element 1 as consisting of two sub-elements, the first of which is exposed to acoustic excitation, and describes the damping vs. frequency curve. Figure 3-5 shows the 1/3 octave sound pressure levels; Figures 3-6 and 3-7 describe the sub-element properties in detail.
LOADSHEET (1): HEADER CARD

- One required per case
- First card in sequence

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Total number of elements in model (2 ≤ E ≤ 20)</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Total number of analysis frequencies (1 ≤ F ≤ 40) (Analysis frequencies are spaced 1/3 octave apart)</td>
</tr>
<tr>
<td>5-14</td>
<td>Real</td>
<td>Lowest analysis frequency</td>
</tr>
<tr>
<td>15</td>
<td>Alpha</td>
<td>Units; M = metric (MKS), default = English (in, lb, sec)</td>
</tr>
<tr>
<td>16-18</td>
<td>Alpha</td>
<td>Output mode; RMS or PSD</td>
</tr>
</tbody>
</table>

Figure 3-3. Card 1, Example Case 1
LOADSHEET (2): SEA ELEMENT PROPERTIES CARD

- One required for each element (2 ≤ E ≤ 20)
- Must be in ascending numerical sequence

DATA ENTRY DESCRIPTION

<table>
<thead>
<tr>
<th>Card Column</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Element number</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Number of sub-elements (SE ≥ 1)</td>
</tr>
</tbody>
</table>
| 5           | Alpha  | Excitation type on this element (if any)  
              |        | A = acoustic, M = direct mechanical |
| 6-8         | Alpha  | If CC5 = A, leave blank; defaults to dB re 20 μbar  
              |        | If CC5 = M, RMS = 1/3 octave RMS g's  
              |        | PSD = g^2/l1z input at 1/3 octave centers |
| 9-18        | Real   | Element loss factor constant (η₀) |
| 19-28       | Real   | Loss factor high frequency slope (s)  
              |        | such that η(f) = η₀(f/f₀)^s |
| 29-38       | Real   | Loss factor crossover frequency (f₀) |

Figure 3-4. Card 2, Example Case 1
LOADSHEET (3): EXCITATION SPECTRUM CARD

- Must immediately follow element properties if LS #2, CC5 ≠ blank
- All entries are real numbers, and must be consistent with LS #2, CC6-8 (units) and LS #1, CC 3-4 (no. of frequencies - 40 max)
- Make entries across in order of increasing frequency

<table>
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<tr>
<th></th>
<th>147.0</th>
<th>147.5</th>
<th>148.0</th>
<th>149.0</th>
<th>149.5</th>
<th>150.0</th>
<th>150.0</th>
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<td>150.0</td>
<td>150.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-5. Card 3, Example Case 1
LOADSHEET (4): SUB-ELEMENT PROPERTIES, CARDS 1 AND 2

- Must be consistent with Loadsheet 2, CC 3-4 (SE ≥ 1)
- Two cards (records) per sub-element
- Must follow associated element card and excitation card (if any)

DATA ENTRY DESCRIPTION

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Sub-element number (Sub-element 1 is always the main sub-element)</td>
</tr>
<tr>
<td>3</td>
<td>Alpha</td>
<td>Sub-element type; B = beam, C = cylinder, M = membrane, P = plate R = room (acoustic element)</td>
</tr>
<tr>
<td>4-13</td>
<td>Real</td>
<td>Mass density (B, C, M, P, R)</td>
</tr>
<tr>
<td>14-23</td>
<td>Real</td>
<td>Elastic modulus (B, C, M, P)</td>
</tr>
<tr>
<td>24-33</td>
<td>Real</td>
<td>Thickness (B, C, M, P)</td>
</tr>
<tr>
<td>34-43</td>
<td>Real</td>
<td>Area (section if B; surface if M or P)</td>
</tr>
<tr>
<td>44-53</td>
<td>Real</td>
<td>Poisson's ratio (C, P)</td>
</tr>
<tr>
<td>54-63</td>
<td>Real</td>
<td>Length (B, C)</td>
</tr>
<tr>
<td>64-73</td>
<td>Real</td>
<td>Pressure (M only)</td>
</tr>
<tr>
<td>1</td>
<td>Logical</td>
<td>Replace F with T if stiffness increase is desired (B, C, P)</td>
</tr>
<tr>
<td>2-11</td>
<td>Real</td>
<td>Radius (C only)</td>
</tr>
<tr>
<td>Card 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-21</td>
<td>Real</td>
<td>Volume (R only)</td>
</tr>
<tr>
<td>22-31</td>
<td>Real</td>
<td>Speed of sound - Sub-element 1 only and if ( \frac{(P)}{(R)} ) unconditionally</td>
</tr>
<tr>
<td>32-41</td>
<td>Real</td>
<td>Added non-structural mass (B, C, M, P)</td>
</tr>
</tbody>
</table>

Figure 3-6. Card 4, Example Case 1
LOADSHEET (4): SUB-ELEMENT PROPERTIES, CARDS 1 AND 2

- Must be consistent with Loadsheet 2, CC 3-4 (SE ≥ 1)
- Two cards (records) per sub-element
- Must follow associated element card and excitation card (if any)

DATA ENTRY DESCRIPTION

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Sub-element number (Sub-element 1 is always the main sub-element)</td>
</tr>
</tbody>
</table>
| 3            | Alpha  | Sub-element type; B = beam, C = cylinder, M = membrane, P = plate  
|              |        | R = room (acoustic element) |
| 4-13         | Real   | Mass density (B, C, M, P, R) |
| 14-23        | Real   | Elastic modulus (B, C, M, P) |
| 24-33        | Real   | Thickness (B, C, M, P) |
| 34-43        | Real   | Area (section if B; surface if M or P) |
| 44-53        | Real   | Poisson's ratio (C, P) |
| 54-63        | Real   | Length (B, C) |
| 64-73        | Real   | Pressure (M only) |
| 1            | Logical | Replace F with T if stiffness increase is desired (B, C, P) |
| 2-11         | Real   | Radius (C only) |
| 12-21        | Real   | Volume (R only) |
| 22-31        | Real   | Speed of sound - Sub-element 1 only and if \( f(P) \) and CC5, LS2 = A, or \( f(R) \) unconditionally |
| 32-41        | Real   | Added non-structural mass (B, C, M, P) |

Figure 3-7. Card 5, Example Case 1
Sub-element 1 consists of the skin and stringer elements. The skin is used as the principal property because it is the major element being excited by the acoustic field. The stringers are added as a smeared mass because their internal resonant frequencies are very high and therefore would be expected only to load the skin in the frequency range of interest. Sub-element 2 (Figure 3-7) represents the properties of the internal frames and channels which mount the panel.

Figures 3-6 and 3-9 show the loadsheets for the inside equipment panel. Figure 3-8 defines the panel as Element 2, with one sub-element and constant damping vs. frequency. Figure 3-9 has the panel properties which have been equivalenced to an isotropic plate because the panel is a composite structure. Note that both the thickness and the density have been changed to be consistent. Any other equivalence could also be used, e.g. leave the thickness = 1.0 and the density and Young's modulus will be recalculated using

\[
\frac{1}{T} \sum \omega_i T_i = \rho_{\text{eff}}
\]

\[
E_{\text{eff}} = \frac{12E(1-\nu^2) \sum I_i}{bt^3}
\]

There is no requirement that sub-elements be of similar materials, but all plate, beam and cylinder sub-element properties must always be isotropic equivalents.

The weight of the components is treated as a non-structural mass. If half or more of the panel area were covered with these components, the F should be changed to a T as shown on the sheet to account for the reduction of modal density associated with stiffening of the panel by the components as reported in Reference 2.

Figure 3-10 describes the joint properties between the skin and the plate. Note that an added insertion loss factor of 2 is used to account for rivet effects.

3-11
LOADSHEET (2): SEA ELEMENT PROPERTIES CARD

- One required for each element (2 ≤ E ≤ 20)
- Must be in ascending numerical sequence

<table>
<thead>
<tr>
<th>Card Column</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Element number</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Number of sub-elements (SE ≥ 1)</td>
</tr>
<tr>
<td>5</td>
<td>Alpha</td>
<td>Excitation type on this element (if any)</td>
</tr>
</tbody>
</table>
|             |        | A = acoustic
|             |        | M = direct mechanical |
| 6-8         | Alpha  | If CC5 = A, leave blank; defaults to dB re 20 μbar |
|             |        | If CC5 = M, RMS = 1/3 octave RMS g's |
|             |        | PSD = g²/Hz input at 1/3 octave centers |
| 9-18        | Real   | Element loss factor constant(η₀) |
| 19-28       | Real   | Loss factor high frequency slope (s) |
| 29-38       | Real   | Loss factor crossover frequency (f₀) |

such that $\eta(f) = \eta_0 \left( \frac{f}{f_0} \right)^s$

Figure 3-8. Card 6, Example Case 1
LOADSHEET (4): SUB-ELEMENT PROPERTIES, CARDS 1 AND 2

- Must be consistent with Loadsheet 2, CC 3-4 (SE ≥ 1)
- Two cards (records) per sub-element
- Must follow associated element card and excitation card (if any)

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Sub-element number (Sub-element 1 is always the main sub-element)</td>
</tr>
<tr>
<td>3</td>
<td>Alpha</td>
<td>Sub-element type; B = beam, C = cylinder, M = membrane, P = plate, R = room (acoustic element)</td>
</tr>
<tr>
<td>4-13</td>
<td>Real</td>
<td>Mass density (B, C, M, P, R)</td>
</tr>
<tr>
<td>14-23</td>
<td>Real</td>
<td>Elastic modulus (B, C, M, P)</td>
</tr>
<tr>
<td>24-33</td>
<td>Real</td>
<td>Thickness (B, C, M, P)</td>
</tr>
<tr>
<td>34-43</td>
<td>Real</td>
<td>Area (section if B; surface if M or P)</td>
</tr>
<tr>
<td>44-53</td>
<td>Real</td>
<td>Poisson's ratio (C, P)</td>
</tr>
<tr>
<td>54-63</td>
<td>Real</td>
<td>Length (B, C)</td>
</tr>
<tr>
<td>64-73</td>
<td>Real</td>
<td>Pressure (M only)</td>
</tr>
<tr>
<td>1</td>
<td>Logical</td>
<td>Replace F with T if stiffness increase is desired (B, C, P)</td>
</tr>
<tr>
<td>2-11</td>
<td>Real</td>
<td>Radius (C only)</td>
</tr>
<tr>
<td>Card 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-21</td>
<td>Real</td>
<td>Volume (R only)</td>
</tr>
<tr>
<td>22-31</td>
<td>Real</td>
<td>Speed of sound - Sub-element 1 only and if ( \Gamma(P) ) and CC5, LS2 = A, or ( \Gamma(R) ) unconditionally</td>
</tr>
<tr>
<td>32-41</td>
<td>Real</td>
<td>Added non-structural mass (B, C, M, P)</td>
</tr>
</tbody>
</table>

Figure 3-9. Card 7, Example Case 1
LOADSHEET (5): JOINT PROPERTIES

- Must follow all element and sub-element cards at end of deck.
- Must be consistent with elements being joined.

DATA ENTRY DESCRIPTION

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Element number of A end of joint</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Element number of B end of joint</td>
</tr>
<tr>
<td>5-6</td>
<td>Alpha</td>
<td>Joint type: PP = plate-to-plate, BP = beam-to-plate, BJ = bolted joint, PA = plate to acoustic</td>
</tr>
<tr>
<td>7-8</td>
<td>Integer</td>
<td>No. of sides exposed to acoustic input (1 or 2 for PA only)</td>
</tr>
<tr>
<td>9-18</td>
<td>Real</td>
<td>Joint length</td>
</tr>
<tr>
<td>19-28</td>
<td>Real</td>
<td>Thickness of A end of joint</td>
</tr>
<tr>
<td>29-38</td>
<td>Real</td>
<td>Thickness of B end of joint</td>
</tr>
<tr>
<td>39-48</td>
<td>Real</td>
<td>Acoustic space mass density (P/RT)</td>
</tr>
<tr>
<td>49-58</td>
<td>Real</td>
<td>Beam length (BP only)</td>
</tr>
<tr>
<td>59-68</td>
<td>Real</td>
<td>Energy reduction factor (BJ only)</td>
</tr>
</tbody>
</table>

Figure 3-10. Card 8, Example Case 1
These data are then assembled as a file which the program reads as an input.

The corresponding program output is shown in Figure 3-11 and consists of a labeled list of the input data, a display of the element modal densities, and a table of vibration responses. The adequacy of the SEA model with regard to assumptions 4 and 5 can be checked using the modal density tables of the figure. For example, element 1 contains more than 20 modes per 1/3 octave over the entire analysis range, whereas element 2 has far fewer. Since frequency response will be smoother with more modes per band, it is expected that the panel prediction will be poorer than the skin predictions. Specifically, the actual panel response may have some peaks which exceed the SEA prediction.

The SEA response prediction is shown in Table 3-1. The levels for element 1 are high compared to the criteria published in Reference 3, but one must remember that this estimate includes a space average over the skin. The stringer and frame vibration levels which are inputs to the panel are a factor of \( \sim 100 \) less.

Simple changes can be made to improve the prediction. For example, an internal acoustic field can be put on the panel by also placing an A in card column 5 of Figure 3-8 and entering the appropriate table immediately after, as shown in Figure 3-12. The results of this modification are shown in Table 3-2. As can be seen, the panel vibration increases considerably and critical frequency behavior is evident around 625 Hz. It should be noted that SEA often overpredicts in the critical frequency region. This simple example illustrates some of the possibilities of SEA with the help of this computer program.

A more extensive example is that of the MEA done in the previous phase. The input for this six-element model (Fig. 3-1) is extensive and much too elaborate to be explained in detail here, but the breakdown of the sub-elements used is given in Table 3-3. The input listing is given in Appendix III and the output is shown in Table 3-4.

A mechanical vibration input may also be applied if the known vibration level is included as an additional element. Load sheet 2 card column 5

3-15
Figure 3-11. Two-Element SEA Program Output - External Acoustic Excitation
Figure 3-11 (Continued)
Table 3-1
TWO-ELEMENT SEA VIBRATION PREDICTION
EXTERNAL ACOUSTIC EXCITATION

<table>
<thead>
<tr>
<th>Center Frequency (Hz)</th>
<th>PSD Levels (G²/Hz)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Element 1</td>
<td>Element 2</td>
<td></td>
</tr>
<tr>
<td>250.0</td>
<td>4.90675E+01</td>
<td>3.38593E-01</td>
<td></td>
</tr>
<tr>
<td>312.5</td>
<td>3.59925E+01</td>
<td>2.37220E-01</td>
<td></td>
</tr>
<tr>
<td>400.0</td>
<td>2.53599E+01</td>
<td>1.58301E-01</td>
<td></td>
</tr>
<tr>
<td>500.0</td>
<td>2.11177E+01</td>
<td>1.25095E-01</td>
<td></td>
</tr>
<tr>
<td>625.0</td>
<td>1.53027E+01</td>
<td>8.85583E-02</td>
<td></td>
</tr>
<tr>
<td>787.5</td>
<td>1.17827E+01</td>
<td>6.21389E-02</td>
<td></td>
</tr>
<tr>
<td>1000.0</td>
<td>7.83661E+01</td>
<td>3.86783E-02</td>
<td></td>
</tr>
<tr>
<td>1250.0</td>
<td>5.44536E+00</td>
<td>2.51832E-02</td>
<td></td>
</tr>
<tr>
<td>1575.0</td>
<td>3.81675E+00</td>
<td>1.64492E-02</td>
<td></td>
</tr>
<tr>
<td>2000.0</td>
<td>2.72180E+00</td>
<td>1.08695E-02</td>
<td></td>
</tr>
<tr>
<td>2500.0</td>
<td>2.05294E+00</td>
<td>7.61286E-03</td>
<td></td>
</tr>
</tbody>
</table>
for that element would contain an M and the vibration spectrum description would follow. The only restriction is that this element may not also have an acoustic input as it will be eliminated in the solution because the energy level is already known.

The possible permutations and combinations of elements, sub-elements, and other factors which this computer program can create go far beyond the ability to document in this report. These few examples give some insight into the processes involved in the performance of SEA using this program. Although determination of some of the parameters such as damping and insertion loss is still a difficult and often obscure process which requires substantial future improvement, this computer program provides a significant step toward streamlining and simplifying SEA for the analyst.
LOADSHEET (3): EXCITATION SPECTRUM CARD

- Must immediately follow element properties if LS#2, CC5 ≠ blank
- All entries are real numbers, and must be consistent with LS #2, CC6-8 (units) and LS #1, CC 3-4 (no. of frequencies - 40 max)
- Make entries across in order of increasing frequency

<table>
<thead>
<tr>
<th>146.5</th>
<th>147.0</th>
<th>147.5</th>
<th>148.0</th>
<th>148.5</th>
<th>149.0</th>
<th>149.5</th>
<th>150.0</th>
<th>150.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>146.5</td>
<td>147.0</td>
<td>147.5</td>
<td>148.0</td>
<td>148.5</td>
<td>149.0</td>
<td>149.5</td>
<td>150.0</td>
<td>150.5</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-12. Internal Acoustic Input Table for Example 1
Table 3-2

TWO-ELEMENT SEA VIBRATION PREDICTION
EXTERNAL AND INTERNAL ACOUSTIC EXCITATION

<table>
<thead>
<tr>
<th>Center Frequency (Hz)</th>
<th>PSD Levels (G²/Hz)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Element 1</td>
<td>Element 2</td>
<td></td>
</tr>
<tr>
<td>250.0</td>
<td>4.9698E+01</td>
<td>9.6954E-01</td>
<td></td>
</tr>
<tr>
<td>312.5</td>
<td>3.6716E+01</td>
<td>1.0448E+00</td>
<td></td>
</tr>
<tr>
<td>400.0</td>
<td>2.6201E+01</td>
<td>1.2199E+00</td>
<td></td>
</tr>
<tr>
<td>500.0</td>
<td>2.2660E+01</td>
<td>2.2995E+00</td>
<td></td>
</tr>
<tr>
<td>625.0</td>
<td>2.0572E+01</td>
<td>7.5974E+00</td>
<td></td>
</tr>
<tr>
<td>787.5</td>
<td>1.4005E+01</td>
<td>3.9863E+00</td>
<td></td>
</tr>
<tr>
<td>1000.0</td>
<td>8.7544E+00</td>
<td>1.8639E+00</td>
<td></td>
</tr>
<tr>
<td>1250.0</td>
<td>5.7508E+00</td>
<td>7.0396E-01</td>
<td></td>
</tr>
<tr>
<td>1575.0</td>
<td>3.9438E+00</td>
<td>3.3090E-01</td>
<td></td>
</tr>
<tr>
<td>2000.0</td>
<td>2.7614E+00</td>
<td>1.2218E-01</td>
<td></td>
</tr>
<tr>
<td>2500.0</td>
<td>2.0654E+00</td>
<td>4.6929E-02</td>
<td></td>
</tr>
<tr>
<td>ELEMENT 1</td>
<td>ELEMENT 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-element</td>
<td>Sub-element</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1  Thermal Panels</td>
<td>1  Power Distribution Panel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2  Orbiter Interface Panels</td>
<td>2  Power Distribution Box</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3  Support Structure</td>
<td>3  Power Distribution Box</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4  Support Structure</td>
<td>4  Power Distribution Box</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5  Radiator</td>
<td>6  Interface Support Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7  Interface Support Structure</td>
<td>8  Interface Support Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9  Data Acquisition Cold Plate</td>
<td>10  Interface Support Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11  Interface Support Structure</td>
<td>12  Interface Support Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13  Signal Distributor Panel</td>
<td>13  Signal Distributor Panel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14  Signal Distribution Box</td>
<td>14  Signal Distribution Box</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15  Support Brace Assembly and Gusset</td>
<td>15  Support Brace Assembly and Gusset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16  Pressure Sensor and Voltage Regulator Panels</td>
<td>16  Pressure Sensor and Voltage Regulator Panels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3-22
### Table 3-4

**SEA COMPUTER PROGRAM OUTPUT**

**FOR MEA/AcouSTIC EXCITATION CASE**

<table>
<thead>
<tr>
<th>CENTER FREQ (Hz)</th>
<th>PSD LEVELS (G^2/Hz)</th>
<th>CENTER FREQ (Hz)</th>
<th>PSD LEVELS (G^2/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ELEMENT 1</td>
<td></td>
<td>ELEMENT 1</td>
</tr>
<tr>
<td>31.50</td>
<td>1.37117E+01</td>
<td>5.40344E-02</td>
<td>1.23604E-02</td>
</tr>
<tr>
<td>35.39</td>
<td>1.39434E+01</td>
<td>5.33723E-02</td>
<td>1.16254E-02</td>
</tr>
<tr>
<td>50.40</td>
<td>1.35352E+01</td>
<td>5.01950E-02</td>
<td>1.03534E-02</td>
</tr>
<tr>
<td>63.00</td>
<td>1.37834E+01</td>
<td>4.58003E-02</td>
<td>9.75593E-03</td>
</tr>
<tr>
<td>78.75</td>
<td>1.40475E+01</td>
<td>4.16226E-02</td>
<td>9.20447E-03</td>
</tr>
<tr>
<td>92.23</td>
<td>1.41144E+01</td>
<td>3.74861E-02</td>
<td>8.53694E-03</td>
</tr>
<tr>
<td>126.00</td>
<td>1.39473E+01</td>
<td>3.30110E-02</td>
<td>7.79522E-03</td>
</tr>
<tr>
<td>157.50</td>
<td>1.13790E+01</td>
<td>2.49716E-02</td>
<td>5.87560E-03</td>
</tr>
<tr>
<td>198.45</td>
<td>1.02517E+01</td>
<td>1.32038E-02</td>
<td>4.89234E-03</td>
</tr>
<tr>
<td>252.00</td>
<td>7.25089E+00</td>
<td>1.21935E-02</td>
<td>3.20436E-03</td>
</tr>
<tr>
<td>315.00</td>
<td>4.73043E+00</td>
<td>8.57629E-03</td>
<td>2.19256E-03</td>
</tr>
<tr>
<td>353.75</td>
<td>3.10031E+00</td>
<td>6.04840E-03</td>
<td>1.51212E-03</td>
</tr>
<tr>
<td>504.00</td>
<td>1.95717E+00</td>
<td>4.13889E-03</td>
<td>1.01070E-03</td>
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<td>1.36311E-03</td>
<td>4.46556E-04</td>
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<td>3.51231E-04</td>
<td>1.58790E-04</td>
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<td>2.44964E-04</td>
<td>5.69056E-05</td>
</tr>
<tr>
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<td>4.96000E-02</td>
<td>1.15065E-04</td>
<td>3.15427E-05</td>
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<tr>
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<td>2.77460E-02</td>
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<td>1.85765E-05</td>
</tr>
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<td>1.24863E-02</td>
<td>4.13075E-05</td>
<td>8.61054E-06</td>
</tr>
<tr>
<td>2520.00</td>
<td>7.48556E-03</td>
<td>2.03057E-05</td>
<td>4.28491E-06</td>
</tr>
<tr>
<td>3150.00</td>
<td>2.92043E-03</td>
<td>1.05428E-05</td>
<td>2.21322E-06</td>
</tr>
<tr>
<td>3937.50</td>
<td>1.48151E-03</td>
<td>6.12303E-06</td>
<td>1.22397E-06</td>
</tr>
<tr>
<td>5040.00</td>
<td>8.49335E-04</td>
<td>3.17799E-06</td>
<td>7.34066E-07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CENTER FREQ (Hz)</th>
<th>PSD LEVELS (G^2/Hz)</th>
<th>CENTER FREQ (Hz)</th>
<th>PSD LEVELS (G^2/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ELEMENT 5</td>
<td></td>
<td>ELEMENT 5</td>
</tr>
<tr>
<td>31.50</td>
<td>3.09585E-03</td>
<td>3.53944E-03</td>
<td></td>
</tr>
<tr>
<td>35.38</td>
<td>3.55341E-03</td>
<td>8.38172E-03</td>
<td></td>
</tr>
<tr>
<td>50.40</td>
<td>3.13632E-03</td>
<td>7.90207E-03</td>
<td></td>
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<tr>
<td>157.50</td>
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<td>4.02753E-03</td>
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<td>252.00</td>
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<td>6.93161E-04</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
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<td>1.40294E-04</td>
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</tr>
<tr>
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<td>1.62123E-05</td>
<td>4.00061E-05</td>
<td></td>
</tr>
<tr>
<td>1260.00</td>
<td>9.25557E-06</td>
<td>2.28779E-05</td>
<td></td>
</tr>
<tr>
<td>1575.00</td>
<td>5.50341E-06</td>
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</tr>
<tr>
<td>1984.50</td>
<td>2.63620E-06</td>
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</tr>
<tr>
<td>2520.00</td>
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<td>3.21405E-06</td>
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<tr>
<td>3150.00</td>
<td>6.72121E-07</td>
<td>1.67509E-06</td>
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<tr>
<td>3937.50</td>
<td>3.41252E-07</td>
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</tr>
<tr>
<td>5040.00</td>
<td>2.26942E-07</td>
<td>5.67554E-07</td>
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</tr>
</tbody>
</table>
Section 4
SEA COMPUTER PROGRAM DESCRIPTION AND USAGE

This section describes the computer code and the input requirements for problem solutions.

The program was written in ASCII Fortran V for the MS/C UNIVAC 1108 with the EXEC8 operating system resident in the computer. The program is designed to be run in the demand/interactive mode using the system editor to assemble and sequence the load sheet information.

The SEA computer code uses a main program whose function is essentially to call the various subroutines in the correct order. First called are two subroutines, EPROP and JINPUT, which read user-supplied data. Then for each analysis frequency, three other subroutines (JPROP, EXCITE, and ANSWER) are called to perform the various calculations. The subroutine ANSWER calls the UNIVAC library subroutine GASSEM from SYS $MATHSTAT$. Finally, subroutine RITER is called to print the solution. The complete program listing is given in Appendix I and the program flow charts are given in Appendix II.

4.1 SUBROUTINE DESCRIPTION
Subroutine EPROP reads user-supplied data giving element and sub-element properties and calls one of five subroutines (BEAM, MEMBR, PLATE, ROOM, or CYLIN) to calculate element modal densities. See Appendix I for the list of variables read by EPROP. EPROP first reads a record giving the number of elements, number of analysis frequencies, the first frequency, and the type of units (metric or English). EPROP checks that the number of elements and analysis frequencies is within the bounds allowed by the program, since memory is reserved with maximum values in mind. Then EPROP creates a table of analysis frequencies by multiplying each element of a
predefined 1/3 octave table by the first frequency. The predefined table consists of a series of frequencies, each of which is approximately one-third octave higher than the preceding one, and the first one of which is equal to 1. EPROP then reads element properties. If the type of excitation indicated on this read operation is acoustic, EPROP then reads a list of sound pressure levels for each analysis frequency for this element. Next, sub-element properties are read. Included in sub-element properties is the type of sub-element. Depending on whether this is a beam, membrane, plate, room or cylinder, EPROP calls the appropriate subroutine to calculate the modal density.

Subroutines BEAM, MEMBR, PLATE, ROOM and CYLIN calculate the modal density for a sub-element which is a beam, membrane, plate, room or cylinder, respectively. First, the part of the equation which is not frequency dependent is calculated. If stiffness reduction has been indicated, this partial value is multiplied by 1/2. Then for each analysis frequency, the rest of the modal density equation is computed and the result summed to element modal density. The sub-element mass is summed to the element mass. If this is the first sub-element for the given element, it is assumed to be the main sub-element and element properties other than mass are set equal to the properties of this sub-element. The following equations are used to calculate modal densities:

- **Beam:**
  \[ n(\omega) = \frac{L}{2\pi} \left( \omega \sqrt{\frac{Et^2}{12\rho}} \right)^{-\frac{1}{2}} \]

- **Membrane:**
  \[ n(\omega) = \frac{A_0 \omega^2 E}{2\pi} \]

- **Plate:**
  \[ n(\omega) = A \left( \frac{Et^2}{12\rho (1-\nu^2)} \right)^{-\frac{1}{2}} \]

- **Room:**
  \[ n(\omega) = \frac{V_0^2 \omega^2}{2\pi c} \]

- **Cylindrical shell:**
  \[ n(\omega) = A \left( \frac{Et^2}{12\rho (1-\nu^2)} \right)^{-\frac{1}{2}} \left( \omega \rho (\rho / E)^{\frac{1}{2}} \right)^{\frac{1}{2}} \]
  \[ \text{if } \omega \rho (\rho / E)^{\frac{1}{2}} > 1 \]
  \[ n(\omega) = A \left( \frac{Et^2}{12\rho (1-\nu^2)} \right)^{-\frac{1}{2}} \left( \omega \rho (\rho / E)^{\frac{1}{2}} \right)^{\frac{3}{2}} \]
  \[ \text{if } \omega \rho (\rho / E)^{\frac{1}{2}} < 1 \]
### Symbol | FORTRAN Name | Description
--- | --- | ---
$n$ | N | Modal Density
$L$ | L | Length
$\omega$ | OMEGA | 2$\pi$ Times the Frequency
$E$ | E | Modulus of Elasticity
$t$ | T | Thickness
$\rho$ | RHO | Density
$A$ | A | Area
$S$ | S | Pressure
$\gamma$ | GAMMA | Poisson's Ratio
$V$ | V | Volume
$c$ | C | Speed of Sound

Subroutine JINPUT reads joint properties supplied by the user. See Appendix I for a list of the variables read by JINPUT. JINPUT checks that element numbers are within range (i.e., less than or equal to the number of elements in the system) and that no pair of element numbers is input more than once. JINPUT keeps a running total of the number of pairs input and continues reading until the end of file is encountered. JINPUT checks to see that at least one pair of elements was read.

Subroutine JPROP calculates coupling coefficients based on the data read by JINPUT, using one of the following equations, depending on the type of joint as read by JINPUT:

**Plate to plate at right angles:**

\[
\phi_{12} = \frac{1.07L}{\pi AN_2} \left( \omega t_1 \left( \frac{E_1}{\rho_1(1-\gamma^2)} \right) \right)^{\frac{1}{2}} \left( \frac{V_2}{V_1} \right)^2 \tau
\]

\[
A = n_2 t_2 \left( \frac{E_2}{12 \rho_2(1-\gamma^2)} \right)
\]

\[
\tau = \begin{cases} 
\frac{8}{27} & \text{if } t_1 > \frac{t_2}{2} \\
\frac{t_1}{t_2} & \text{if } t_1 < \frac{t_2}{2}
\end{cases}
\]

**Beam to plate (cantilevered):**

\[
\phi_{12} = \frac{2\pi fb}{N_2^2 4L}
\]

**Plate to acoustic space:**

\[
\phi_{12} = \left( \frac{4.33\pi c^3}{\omega^2 V_2} \right) \left( \frac{\rho_1 c^2}{\rho_A} \right)
\]

4-3
Bolted or riveted joints:

1) Calculate \( \Phi \) as if for a plate-to-plate rigid joint.

2) Reduce \( \Phi \) by insertion loss factor.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>FORTRAN Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi )</td>
<td>PHI</td>
<td>Coupling Coefficient</td>
</tr>
<tr>
<td>L</td>
<td>JL</td>
<td>Joint Length</td>
</tr>
<tr>
<td>N</td>
<td>MODES</td>
<td>Number of Modes in Bandwidth</td>
</tr>
<tr>
<td>( \omega )</td>
<td>OMEGA</td>
<td>( 2\pi ) Times the Frequency</td>
</tr>
<tr>
<td>t</td>
<td>T</td>
<td>Thickness</td>
</tr>
<tr>
<td>E</td>
<td>EE</td>
<td>Modulus of Elasticity</td>
</tr>
<tr>
<td>( \rho )</td>
<td>DENSE</td>
<td>Density</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>EGAMMA</td>
<td>Poisson's Ratio</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>TAU</td>
<td>Thickness Ratio</td>
</tr>
<tr>
<td>n</td>
<td>N</td>
<td>Modal Density</td>
</tr>
<tr>
<td>f</td>
<td>FREQ</td>
<td>Frequency</td>
</tr>
<tr>
<td>b</td>
<td>BW</td>
<td>Beam Width</td>
</tr>
<tr>
<td>c</td>
<td>EC</td>
<td>Speed of Sound in Room Medium</td>
</tr>
<tr>
<td>V</td>
<td>VOL</td>
<td>Volume</td>
</tr>
<tr>
<td>a</td>
<td>NS</td>
<td>Number of Sides</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>SIGMA</td>
<td>Radiation Efficiency</td>
</tr>
<tr>
<td>( \rho_A )</td>
<td>ASD</td>
<td>Acoustic Space Density</td>
</tr>
</tbody>
</table>

Function SIGF returns a value for the radiation efficiency of a panel. A single argument, \( X \), is passed to SIGF. The value of \( X \) is the ratio of the analysis frequency to the critical frequency. An internal table of 16 values of the log of the radiation efficiency for \( 0 < X < 4 \) is maintained. The first value, \( 0 \), is the value of \( X \) for which SIGF is a minimum. When \( X = 0 \), SIGF = -1.8. Each subsequent value of the internal table is the value of \( X \) for which SIGF increases by 0.2 over the previous value. The 13th value in the table is 1. Since this is the 12th value after the 1st, SIGF = \( 12 \times 0.2 + (-1.8) = 0.6 \) when \( X = 1 \). This is the maximum value of SIGF. SIGF = 0 for \( X = 4 \), the final value of the table. The value of SIGF is calculated by finding the least value of the table that is greater than \( X \). This value and the preceding one give two values of SIGF that differ by 0.2. Linear interpolation is then used to find the actual value of SIGF.

Subroutine EXCITE calculates acoustic and mechanical energy inputs for the elements of the system. These values are initially set to 0. Then for each element, the acoustic or mechanical energy input is calculated.
according to the following equations, depending on the type of excitation as read by EPROP:

Acoustic: \[ S = \frac{0.66 \pi c^2 A^2 <p^2> \sigma N}{\omega^3 m} \]

\[ <p^2> = 10^{5 \text{SPL}} / 10(8.41 \times 10^{-14}) \]

Mechanical in grms: \[ E = \frac{m}{\omega^2} g_{\text{rms}}^2 \]

Mechanical in PSD Levels: \[ E = \frac{m}{\omega^2} \text{PSD} g^2 \frac{f}{4.33} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>FORTRAN Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>S</td>
<td>Acoustic Energy Input</td>
</tr>
<tr>
<td>c</td>
<td>EC</td>
<td>Speed of Sound in Room Medium</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>Surface Area Exposed to Sound Field</td>
</tr>
<tr>
<td>\sigma</td>
<td>SIGMA</td>
<td>Radiation Efficiency</td>
</tr>
<tr>
<td>N</td>
<td>MODES</td>
<td>Number of Modes in Bandwidth</td>
</tr>
<tr>
<td>\omega</td>
<td>OMEGA</td>
<td>(2\pi) Times the Frequency</td>
</tr>
<tr>
<td>m</td>
<td>MSUB</td>
<td>Mass</td>
</tr>
<tr>
<td>SPL</td>
<td>SPL</td>
<td>Sound Pressure Level</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>Element Energy Level</td>
</tr>
<tr>
<td>g_{\text{rms}}</td>
<td>MECH</td>
<td>Mechanical Input</td>
</tr>
<tr>
<td>g</td>
<td>G</td>
<td>Gravitational Constant</td>
</tr>
<tr>
<td>PSD</td>
<td>MECH</td>
<td>Mechanical Input</td>
</tr>
<tr>
<td>f</td>
<td>FREQ</td>
<td>Frequency</td>
</tr>
</tbody>
</table>

Subroutine ANSWER solves the SEA system of equations for element energy levels. First, element damping is determined. If the damping is constant, it is equal to the value read by EPROP. Otherwise the following equation is used:

\[ \eta_2 = \eta_f \left( \frac{f}{f_s} \right)^s \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>FORTRAN Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\eta_2</td>
<td>ETA2</td>
<td>Element Damping</td>
</tr>
<tr>
<td>\eta_f</td>
<td>ETA</td>
<td>Constant Level of Damping</td>
</tr>
<tr>
<td>f_s</td>
<td>SFREQ</td>
<td>Start Frequency</td>
</tr>
<tr>
<td>s</td>
<td>SLOPE</td>
<td>Slope</td>
</tr>
</tbody>
</table>

Next, the elements of the alpha matrix of equation 1, Section 1, are calculated.
If there are any elements for which the energy levels (the E matrix) are already known, these are eliminated from the equation as shown by the following example: Suppose the system has six elements and the second and fifth have known energy levels. Then the equation becomes:

\[
\begin{bmatrix}
\alpha_{11} & \alpha_{13} & \alpha_{14} & \alpha_{16} \\
\alpha_{31} & \alpha_{33} & \alpha_{34} & \alpha_{36} \\
\alpha_{41} & \alpha_{43} & \alpha_{44} & \alpha_{46} \\
\alpha_{61} & \alpha_{63} & \alpha_{64} & \alpha_{66}
\end{bmatrix}
\begin{bmatrix}
E_1 \\
E_3 \\
E_4 \\
E_6
\end{bmatrix}
= \begin{bmatrix}
S_1 - \alpha_{12}E_2 - \alpha_{15}E_5 \\
S_3 - \alpha_{32}E_2 - \alpha_{35}E_5 \\
S_4 - \alpha_{42}E_2 - \alpha_{45}E_5 \\
S_6 - \alpha_{62}E_2 - \alpha_{65}E_5
\end{bmatrix}
\]

Since (for example) \( S_1 = \alpha_{11}E_1 + \alpha_{12}E_2 + \alpha_{13}E_3 + \alpha_{14}E_4 + \alpha_{15}E_5 + \alpha_{16}E_6 \), it can be seen that this has the same solution as the original equation. ANSWER recalculate the values of the S matrix and calls SOLVE to eliminate the unnecessary rows and columns from the matrices and find the solution. The solution is then used to calculate the average acceleration with the formula

\[
\bar{a} = E \frac{\omega^2}{m}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>FORTRAN Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{a} )</td>
<td>ABAR</td>
<td>Average Acceleration</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>Element Energy Levels</td>
</tr>
<tr>
<td>( \omega )</td>
<td>OMEGA</td>
<td>2( \pi ) Times the Frequency</td>
</tr>
<tr>
<td>m</td>
<td>MASS</td>
<td>Mass</td>
</tr>
</tbody>
</table>

Subroutine SOLVE solves the SEA system of equations. It copies the alpha and S matrices to new matrices, leaving out those rows and columns which were to be eliminated. It then calls MATHSTAT library subroutine GASSEM to solve the equation. SOLVE then puts the solution in the element energy array E, and subroutine RITER prints the solution.

4.2 PROGRAM USAGE

4.2.1 Deck Setup and Sequence

At present, the source program resides on element C of file S1, so that it is necessary to compile and collect it before execution. The program
reads the SEA load sheet data on logical unit 3, which must be created by the user with the text editor or data processor, using the Q option so that file 3 is in ASCII code. The following sequence of control statements illustrates the creation of file 3 and the execution of the program:

```
@RUN ...
@ASG,C 3.
@ED,IQ 3.

Statements creating file 3
EXIT
@ASG,A S1
@FTN,N S1.C,REL
@MAP,IN SYM,ABS
LIB SYS$*MATHSTAT$.
LIB SYS$*MSFC$.
LIB SYS$*MSFC$.
END
@XQT ABS
@FIN
```

4.2.2 Input - Drum/Disk

The only input for the program is on logical unit 3, which contains the user's data. This file consists of the following five types of records:

1. Initial information used to process the other records.
2. Element properties.
3. Sound pressure levels or mechanical inputs.
4. Sub-element properties.
5. Joint properties.

The arrangement of these records and their data elements is shown on the following five loadsheet pages (Figures 4-1 through 4-5).
LOADSHEET (1): HEADER CARD

- One required per case
- First card in sequence

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Total number of elements in model (2 ≤ E ≤ 20)</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Total number of analysis frequencies (1 ≤ F ≤ 40) (Analysis frequencies are spaced 1/3 octave apart)</td>
</tr>
<tr>
<td>5-14</td>
<td>Real</td>
<td>Lowest analysis frequency</td>
</tr>
<tr>
<td>15</td>
<td>Alpha</td>
<td>Units; M = metric (MKS), default = English (in, lb, sec)</td>
</tr>
<tr>
<td>16-18</td>
<td>Alpha</td>
<td>Output mode; RMS or PSD</td>
</tr>
</tbody>
</table>

Figure 4-1. Loadsheet 1
LOADSHEET (2): SEA ELEMENT PROPERTIES CARD

- One required for each element (2 ≤ E ≤ 20)
- Must be in ascending numerical sequence

<table>
<thead>
<tr>
<th>Card Column</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Element number</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Number of sub-elements (SE ≥ 1)</td>
</tr>
</tbody>
</table>
| 5           | Alpha  | Excitation type on this element (if any)  
A = acoustic    M = direct mechanical |
| 6-8         | Alpha  | If CC5 = A, leave blank; defaults to dB re 20 μbar  
If CC5 = M, RMS = 1/3 octave RMS g's  
PSD = g^2/Hz input at 1/3 octave centers |
| 9-18        | Real   | If CC5 = A, input surface area exposed to acoustic excitation  
(consistent units) |
| 19-28       | Real   | Element loss factor constant(n₀) |
| 29-38       | Real   | Loss factor high frequency slope (s) } such that η(f) = η₀(f/f₀) S |
| 39-48       | Real   | Loss factor crossover frequency (f₀) |

Figure 4-2. Loadsheet 2
LOADSHEET (3): EXCITATION SPECTRUM CARD

- Must immediately follow element properties if LS#2, CC5 ≠ blank
- All entries are real numbers, and must be consistent with LS #2, CC 6-8 (units) and LS #1, CC 3-4 (no. of frequencies - 40 max)
- Make entries across in order of increasing frequency

Figure 4-3. Loadsheet 3
LOADSHEET (4): SUB-ELEMENT PROPERTIES, CARDS 1 AND 2

- Must be consistent with Loadsheets 2, CC 3-4 (SE ≠ 1)
- Two cards (records) per sub-element
- Must follow associated element card and excitation card (if any)

DATA ENTRY DESCRIPTION

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Sub-element number</td>
</tr>
<tr>
<td>3</td>
<td>Alpha</td>
<td>Sub-element type; B = beam, C = cylinder, M = membrane, P = plate, R = room (acoustic element)</td>
</tr>
<tr>
<td>4-13</td>
<td>Real</td>
<td>Mass density (B, C, M, P, R)</td>
</tr>
<tr>
<td>14-23</td>
<td>Real</td>
<td>Elastic modulus (B, C, M, P)</td>
</tr>
<tr>
<td>24-33</td>
<td>Real</td>
<td>Thickness (B, C, M, P)</td>
</tr>
<tr>
<td>34-43</td>
<td>Real</td>
<td>Area (section if B; surface if M or P)</td>
</tr>
<tr>
<td>44-53</td>
<td>Real</td>
<td>Poisson's ratio (C, P)</td>
</tr>
<tr>
<td>54-63</td>
<td>Real</td>
<td>Length (B, C)</td>
</tr>
<tr>
<td>64-73</td>
<td>Real</td>
<td>Pressure (M only)</td>
</tr>
<tr>
<td>1</td>
<td>Logical</td>
<td>Replace F with T if stiffness increase is desired (B, C, P)</td>
</tr>
<tr>
<td>2-11</td>
<td>Real</td>
<td>Radius (C only)</td>
</tr>
<tr>
<td>Card 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-21</td>
<td>Real</td>
<td>Volume (R only)</td>
</tr>
<tr>
<td>22-31</td>
<td>Real</td>
<td>Speed of sound (R, or if LS #2, CC5 = A)</td>
</tr>
<tr>
<td>32-41</td>
<td>Real</td>
<td>Added non-structural mass (B, C, M, P)</td>
</tr>
</tbody>
</table>

Figure 4-4. Loadsheet 4
LOADESHEET (5): JOINT PROPERTIES

- Must follow all element and sub-element cards at end of deck.
- Must be consistent with elements being joined.

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Integer</td>
<td>Element number of A end of joint</td>
</tr>
<tr>
<td>3-4</td>
<td>Integer</td>
<td>Element number of B end of joint</td>
</tr>
<tr>
<td>5-6</td>
<td>Alpha</td>
<td>Joint type: PP = plate-to-plate, BP = beam-to-plate, BJ = bolted joint, PA = plate to acoustic</td>
</tr>
<tr>
<td>7-8</td>
<td>Integer</td>
<td>No. of sides exposed to acoustic input (1 or 2)</td>
</tr>
<tr>
<td>9-18</td>
<td>Real</td>
<td>Joint length</td>
</tr>
<tr>
<td>19-28</td>
<td>Real</td>
<td>Thickness of A end of joint</td>
</tr>
<tr>
<td>29-38</td>
<td>Real</td>
<td>Thickness of B end of joint</td>
</tr>
<tr>
<td>39-48</td>
<td>Real</td>
<td>Acoustic space mass density (P/RT)</td>
</tr>
<tr>
<td>49-58</td>
<td>Real</td>
<td>Beam length (BP only)</td>
</tr>
<tr>
<td>59-68</td>
<td>Real</td>
<td>Bolt spacing (BJ only)</td>
</tr>
</tbody>
</table>

Figure 4-5. Loadsheet 5
4.2.3 Output - Printout
The output consists of a list of input parameters, calculated modal densities, and calculated PSD levels (or $G_{\text{rms}}$), if this was specified on input by the user) for each element for each analysis frequency, arranged in five columns below a heading. The first column is the frequencies, the other four columns list the PSD levels for elements 1 to 4. This is followed by five more columns below a new heading and containing the frequencies and PSD levels for elements 5 to 8. This is repeated until all the elements have been listed.

4.2.4 Program Diagnostic Messages
The program can produce the error messages listed below. Suggestions for their cause and correction are also given. Lower case x's indicate values (usually, but not always, integers) that depend on the particular error.

*** ERROR *** THE INPUT FILE IS EMPTY. THE END OF FILE WAS ENCOUNTERED WHILE TRYING TO READ THE FIRST INPUT RECORD. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** WHILE TRYING TO READ ELEMENT PROPERTIES, THE END OF FILE WAS ENCOUNTERED BEFORE INPUT RECORD xxxx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** WHILE TRYING TO READ SUB-ELEMENT PROPERTIES, THE END OF FILE WAS ENCOUNTERED BEFORE INPUT RECORD xxxx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** WHILE TRYING TO READ SOUND PRESSURE LEVELS, THE END OF FILE WAS ENCOUNTERED BEFORE INPUT RECORD xxxx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** WHILE TRYING TO READ MECHANICAL INPUTS, THE END OF FILE WAS ENCOUNTERED BEFORE INPUT RECORD xxxx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.
*** ERROR *** THE END OF FILE WAS REACHED BEFORE ANY INFORMATION
ABOUT JOINT PROPERTIES WAS READ. THIS ERROR WAS DISCOVERED BY
SUBROUTINE JINPUT.

These errors are the result of an incomplete data file. The data file
cannot end before joint properties for at least one pair of elements are
read. The message indicates what kind of data the program was looking
for when the end of file was encountered.

*** ERROR *** A FORTRAN ERROR OCCURRED WHILE TRYING TO READ
ELEMENT PROPERTIES ON INPUT RECORD xxx. THIS ERROR WAS DISCOVERED
BY SUBROUTINE EPROP.

*** ERROR *** A FORTRAN ERROR OCCURRED WHILE TRYING TO READ
SUB-ELEMENT PROPERTIES ON INPUT RECORDS xxx AND xxxx. THIS ERROR
WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** A FORTRAN ERROR OCCURRED WHILE TRYING TO READ THE
FIRST INPUT RECORD. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** A FORTRAN ERROR OCCURRED WHILE TRYING TO READ SOUND
PRESSURE LEVELS ON OR BEFORE INPUT RECORD xxx. THIS ERROR WAS
DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** A FORTRAN ERROR OCCURRED WHILE TRYING TO READ
MECHANICAL INPUTS ON OR BEFORE INPUT RECORD xxx. THIS ERROR WAS
DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** WHILE ATTEMPTING TO READ JOINT PROPERTIES, A FORTRAN
ERROR OCCURRED ON INPUT RECORD xxx. THIS ERROR WAS DISCOVERED BY
SUBROUTINE JINPUT.

A FORTRAN error is usually the result of invalid characters appearing in
a data field; for example, alphabetic characters appearing where the
program expects to read an integer. This is likely to occur if data
RECORDS are missing or out of order; for example, if an element proper-
ties record says there are four sub-elements for that element, but records
for only three sub-elements are present. A FORTRAN error on the first
record may indicate that the data file was not given the name 3. If the
external file name is not 3, the internal file name should be made 3 by a
USE statement.

*** ERROR *** THE NUMBER OF ELEMENTS WAS GIVEN AS xx. IT MUST BE
BETWEEN 2 AND 20 INCLUSIVE. THIS ERROR WAS DISCOVERED BY SUBROUTINE
EPROP.

*** ERROR *** THE NUMBER OF ANALYSIS FREQUENCIES WAS GIVEN AS xx.
IT MUST BE BETWEEN 1 AND 40 INCLUSIVE. THIS ERROR WAS DISCOVERED
BY SUBROUTINE EPROP.

*** ERROR *** THE TYPE OF MECHANICAL INPUT GIVEN FOR ELEMENT xx ON
INPUT RECORD xxxx IS xxx. THIS IS NOT A VALID TYPE. THE TYPE MUST
BE RMS OR PSD. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

*** ERROR *** TYPE ~ x ON INPUT RECORD xxxx IS AN INVALID TYPE.
TYPE MUST BE B, M, P, C, OR R. THIS ERROR WAS DISCOVERED BY
SUBROUTINE EPROP.

*** ERROR *** THE TYPE OF JOINT GIVEN FOR ELEMENT PAIR xx AND xx
ON INPUT RECORD xxxx IS xx. THIS IS NOT A VALID TYPE. THE TYPE
MUST BE PP, BP, BJ, OR PA. THIS ERROR WAS DISCOVERED BY SUBROUTINE
JPROP.

*** ERROR *** THE DETERMINANT OF THE SEA EQUATION MATRIX IS 0.
HENCE THERE IS NO SOLUTION. THIS ERROR WILL CAUSE THE PROGRAM TO
ABORT. THIS ERROR WAS DISCOVERED BY SUBROUTINE SOLVE.

These messages are self explanatory. If any of the errors listed thus
far occur, the subroutine in which they occur will continue processing.
Before control is transferred to another subroutine, however, the follow-
ing message is printed and the program is aborted through a CALL FERR
statement:

BECAUSE OF THE ERRORS LISTED ABOVE, THE SEA PROGRAM WILL ABORT.
The following errors will not cause the program to abort, but may put the results in error:

*** WARNING *** ON INPUT RECORD xxx THE ELEMENT NUMBER WAS GIVEN AS xx, WHICH IS OUT OF ORDER. IT HAS BEEN CHANGED TO xx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

Element properties are stored in arrays in the order in which they are read. If elements are referenced in the joint properties section in any other order, that is, when they are referenced as one element of a pair, the results are almost certainly erroneous.

*** WARNING *** ON INPUT RECORD xxxx THE SUB-ELEMENT NUMBER WAS GIVEN AS xx, WHICH IS OUT OF ORDER. IT SHOULD BE xx. THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP.

Sub-element properties are not stored in arrays so this is not likely to result in an error. If other errors occur, this message probably indicates that there are missing or extraneous records.

*** WARNING *** ON INPUT RECORD xxxx, ONE OR BOTH MEMBERS OF THE ELEMENT PAIR xx AND xx WAS EITHER LESS THAN 1 OR GREATER THAN xx, THE TOTAL NUMBER OF ELEMENTS. THIS PAIR WILL BE IGNORED. THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

*** WARNING *** THE ELEMENT PAIR xx AND xx ON INPUT RECORD xxxx WAS PREVIOUSLY READ ON INPUT RECORD xxxx. THE FIRST VALUES WILL BE USED. THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

*** WARNING *** ON INPUT RECORD xxxx, BOTH ELEMENT NUMBERS WERE GIVEN AS xx. THEY MUST BE DIFFERENT. THIS RECORD WILL BE IGNORED. THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

These errors result in the indicated record being ignored. Whether or not the results are erroneous depends on whether the indicated record is necessary to the results.

In addition, data which causes overflow, negative arguments to the square root functions, etc., will produce ASCII FORTRAN diagnostics.

4-16
Section 5
REFERENCES


C *************** SEA PROGRAM ***************

C STATISTICAL ENERGY ANALYSIS OF COMPLEX STRUCTURES

C INPUT IS READ FROM UNIT 3 IN ASCII CODE
C OUTPUT IS WRITTEN TO UNIT 6, THE PRINTER (OR TERMINAL IN DEMAND MODE)
C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM

C NAME TYPE DESCRIPTION

C ---- ---- ---------------

C AF INT ANALYSIS FREQUENCY ORDINAL (FROM 1 TO NUMAF)
C FREO REAL FREQUENCY
C TABLE(ME) REAL TABLE OF ANALYSIS FREQUENCIES
C NUMAF INT NUMBER OF ANALYSIS FREQUENCIES
C OMEGA REAL 2*PI*FREQUENCY

C THE FOLLOWING COMMON BLOCKS ARE USED:
C BLOCK OTHER PROGRAMS USING THIS COMMON BLOCK

C ------ ------------------------

C CB1 EPROPS,ENVAR,MVAR,PLATE,ROOM,CYLIN,RITER,BLOCK DATA
C CB2 EPROPS,INPUT,BLOCK DATA
C CB3 JPROPS,EXCITE,ANSWER

C INTEGER AR
C LOGICAL ERROR
C COMMON/C3/C3/,F1,NUMAF,FREQ
C COMMON/C2/,ERROR
C COMMON/C5/,FREQ,AF,OMEGA
C DATA PI,1.0
C FORMAT (1X,45X,10H1,1H)(BECUSE OF THE ERRORS LISTED ABOVE, THE SEA PROGRAM WILL ABORT)
C RETURN 3
C CALL EPROPS TO READ ELEMENT PROPERTIES INPUT
C CALL JINPUT TO READ JOINT PROPERTIES INPUT
C IF AN ERROR HAS OCCURRED ON INPUT, WRITE A MESSAGE AND TERMINATE THE PROGRAM
C IF (.NOT. ERROR GO TO 10
C WRITE (46,30)
C CALL FIND
C DO FOR EACH ANALYSIS FREQUENCY
C 10 DO 20 AF = 1,NUMAF
C DEFINE THE CURRENT ANALYSIS FREQUENCY
C FREQ = TABLE(AF)
C OMEGA = 2.0*PI*FREQ
C CALL JPROPS TO CALCULATE JOINT PROPERTIES
C CALL EXCITE TO DETERMINE ENERGY SOURCES FROM EXCITATION INPUT
C CALL EXCITE
C CALL ANSWER TO SOLVE THE SEA EQUATIONS FOR ELEMENT ENERGIES
C CALL ANSWER
C 20 CONTINUE
C CALL RITER TO WRITE GLT THE ANSWER

PAGE 1
SUBROUTINE EPROP

C THIS SUBROUTINE READS ELEMENT AND SLM-ELEMENT PROPERTIES FROM UNIT
C 3 AND CALLS THE APPROPRIATE SUBROUTINE, DEPENDING ON THE TYPE OF
C SUB-ELEMENT, TO CALCULATE ELEMENT MODAL DENSITIES. EPROP IS CALLED
C FROM THE MAIN PROGRAM.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

C NAME TYPE DESCRIPTION
C ---- ---- ---------------
C A REAL AREA
C C REAL SPEED OF SOUND IN ROOM MEDIUM
C E REAL MODULUS OF ELASTICITY
C ELNUM INT ELEMENT NUMBER
C ETA1(20) REAL DAMPINC
C ETYPE(20) CHAR TYPE OF EXCITATION
C FREQ1 REAL FIRST ANALYSIS FREQUENCY
C FTAP(40) REAL TABLE OF ANALYSIS FREQUENCIES
C G REAL GRAVITATIONAL CONSTANT
C GPA REAL POISSON'S RATIO
C G1 REAL GRAVITATIONAL CONSTANT IN METRIC UNITS
C INP INT NUMBER OF INPUT RECORDS READ
C L REAL LENGTH
C M REAL MASS
C NA TRUE IF SUB-ELEMENT IS MAIN SUB-ELEMENT
C MCH(20) REAL MECHANICAL INPUT
C MTYPE(20) CHAR TYPE OF MECHANICAL INPUT
C NNUMA INT NUMBER OF ANALYSIS FREQUENCIES
C NPEL INT NUMBER OF ELEMTS
C NRELMS INT NUMBER OF SUB-ELEMENTS
C NTYPE CHAR TYPE OF OUTPUT
C N REAL RADIUS
C Q REAL DENSITY
C S REAL REFERENCE FOR STARTING FREQUENCIES
C SLOPE(20) REAL SLOPE
C SOPL(20) REAL SOUND PRESSURE LEVEL
C STIFF LOG TRUE IF STIFFNESS REDUCTION REQUIRED
C SUBNUM INT SUB-ELEMENT NUMBER
C T REAL THICKNESS
C TYPE CHAR TYPE OF SUB-ELEMENT
C UNITS CHAR IF METRIC, OTHERWISE ENGLISH UNITS
C V REAL VOLUME

C THE FOLLOWING COMMON BLOCKS ARE USED:
C ------ ------
C AOO ONE PROGRAM UNIT USING THE COMMON BLOCK
C ------ ------
C C1 MAIN,PROP,PLATE,ROD,CYL,PIECE BLOCK DATA
C C2 JINPUT,PROP,ELEMENT DATA
C C4 ANS,JINPUT,PROP,ELEMENT DATA
C C5 ANS,JINPUT,PROP,ELEMENT DATA
C C6 JINPUT,PROP,ELEMENT DATA
C C7 JINPUT,PROP,ELEMENT DATA
C C8 JINPUT,PROP,ELEMENT DATA
C C9 JINPUT,PROP,ELEMENT DATA
C C10 JINPUT,PROP,ELEMENT DATA
C C11 JINPUT,PROP,ELEMENT DATA
C C12 JINPUT,PROP,ELEMENT DATA
C C13 JINPUT,PROP,ELEMENT DATA
C C14 JINPUT,PROP,ELEMENT DATA
C C15 JINPUT,PROP,ELEMENT DATA

END
172 1 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
173 2 TORDER. IT WAS CHANGED TO 1.12, T.
174 3 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
175 4 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OF 1.
176 5 TORDER. IT SHOULD BE 1.12, T.
177 6 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
178 7 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
179 8 TORDER. IT MUST BE BETWEEN 1 AND 20, T.
180 9 TINCISE, 1.
181 10 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
182 11 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
183 12 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
184 13 TINCISE, 1.
185 14 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
186 15 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
187 16 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
188 17 TINCISE, 1.
189 18 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
190 19 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
191 20 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
192 21 TINCISE, 1.
193 22 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
194 23 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
195 24 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
196 25 TINCISE, 1.
197 26 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
198 27 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
199 28 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
200 29 TINCISE, 1.
201 30 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
202 31 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
203 32 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
204 33 TINCISE, 1.
205 34 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
206 35 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
207 36 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
208 37 TINCISE, 1.
209 38 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
210 39 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
211 40 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
212 41 TINCISE, 1.
213 42 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
214 43 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
215 44 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
216 45 TINCISE, 1.
217 46 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
218 47 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
219 48 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
220 49 TINCISE, 1.
221 50 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
222 51 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
223 52 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
224 53 TINCISE, 1.
225 54 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
226 55 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
227 56 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
228 57 TINCISE, 1.
229 58 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
230 59 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
231 60 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
232 61 TINCISE, 1.
233 62 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
234 63 A ELEMENT NUMBER WAS GIVEN AT 1.12, WHICH IS OUT OF 1.
235 64 TORDER. IT MUST BE BETWEEN 1 AND 40, T.
236 65 TINCISE, 1.
237 66 THIS ERROR WAS DISCOVERED BY SUBROUTINE EPROP. T.
C WRITE THE HEADING FOR THE OUTPUT
C WRITE (6,520)
C READ HOW MANY ELEMENTS AND ANALYSIS FREQUENCIES THERE ARE, THE
C FIRST FREQUENCY, THE SYSTEM OF UNITS, AND THE TYPE OF OUTPUT
READ (13,380,ERR=210,END=220)NUMEL,NUMAF,FREQ1,UNITSYOTYPE
C WRITE THE FIRST RECORD TO OUTPUT
WRITE (6,530)NUMEL,NUMAF,FREQ1,UNITSYOTYPE
C CHECK TO SEE THAT THE NUMBER OF ELEMENTS AND ANALYSIS
C FREQUENCIES IS WITHIN RANGE
IF (NUMEL .LT. 2 OR. NUMEL .GT. 200) GO TO 260
IF (NUMAF .LT. 1 OR. NUMAF .GT. 4) GO TO 270
C IF THE SYSTEM OF UNITS IS METRIC, CONVERT THE GRAVITATIONAL
C CONSTANT TO METRIC UNITS
C IF UNITS .EQ. 41
C PUT THE VALUES OF THE ANALYSIS FREQUENCIES IN THE FREQUENCY TABLE
DO 10 I = 1,NUMAF
   FTAB(I) = FTAB(I) + FREQI
10 CONTINUE
C DO FOR EACH ELEMENT
   DO 20 I = 1,NUMEL
      C INCREMENT INPUT
      C INPUT = INPUT + 1
      C READ THE ELEMENT PROPERTIES
      READ (2,350,END=230)ELNUM,NUMSUP,ETYPE(I),MLYTYPE(I)
      * ETANI,SLOPE(I),SFREQ(I)
      C WRITE THE ELEMENT PROPERTIES TO OUTPUT
      WRITE (6,540)INPUT,ELNUM,NUMSUP,ETYPE(I),MYTYPE(I)
      * ETANI,SLOPE(I),SFREQ(I)
      C IF THE ELEMENT NUMBER IS OUT OF ORDER, WRITE A WARNING
      C MESSAGE
      IF (ELNUM .LE. EQ. I) GO TO 12
      WRITE (6,425)INPUT,ELNUM,I
20   ELMUL = I
C IF THE TYPE OF ELEMENT IS MECHANICAL BUT THE TYPE OF MECHANICAL
C INPUT IS NEITHER RMS NOR PSD, WRITE A MESSAGE AND SET THE
C ERRNO FLAG
   C IF (ETYPE(I) .NE. PM) OR. MYTYPE(I) .EQ. RMS OR.
   * MYTYPE(I) .EQ. PSD GO TO 12
   WRITE (6,490)ELNUM,INPUT,MYTYPE
   ERRNO = .TRUE.
C IF THE TYPE OF EXCITATION IS ACOUSTIC
12   IF (ETYPE(I) .NE. FAT) GO TO 18
C THEN TACCRPMT INPUT
   INPUT = INPUT + 1
   LINES = (NUMAF + 2) / 8
   WRITE INPUT + LINES
   C ARE READ THE SLCNG PRESSURE LEVEL FOR EACH FREQUENCY
   READ (12,360,ERR=240,END=250)SFREQ(I),NUMAF
   C WRITE THE SOUND PRESSURE LEVELS TO OUTPUT
   WRITE (6,550)INPUT,K, (SFREQ(I),K = 1,NUMAF)
   * J = 1,8, K = 1, LINES)
C ELSE IF THE TYPE OF EXCITATION IS MECHANICAL
18   IF (ETYPE(I) .NE. PM) GO TO 28
   C THEN INCREMENT INPUT
   INPUT = INPUT + 1
   LINES = (NUMAF + 2) / 8
C ANE READ THE MECHANICAL INPUTS FOR EACH FREQUENCY
READ (3,400,PRF=140,END=280) (MECH(J),J=1,NMECH)
C WRITE THE MECHANICAL INPUTS TO OUTPUT
WRITE (6,550) (INPUT(I)*K,(MECH(I,B)K(I)+J),
     2,4) J = 1 B, K = 1, NMECH
C END IF
C INITIALIZE MAIN TO SIGNIFY THAT THE FIRST SUB-ELEMENT IS THE
C MAIN SUB-ELEMENT
MAIN = .TRUE.
C GC FOR EACH SUB-ELEMENT
DO 100 I = 1,NMECH
C INCREMENT INPUT
INPUT = INPUT + 2
C READ THE SUB-ELEMENT PROPERTIES
READ (3,320,ERR=80,END=240)(SUBNUM,TYPE,RHO,E,
   3,3) T,AM,GM,M,F,E,STIFF,PS,CM
C WRITE THE SUB-ELEMENT PROPERTIES TO OUTPUT
WRITE (6,570) INPUT - 1 SUBNUM(TYPE,RHO,E,T,AM,
   3,3) GM,M,F,E,STIFF,PS,CM
C CHANGE ALL PLATE, BEAM, CYLINDER, AND MEMBRANE TYPE SUB-
C ELEMENTS TO THE SAME MODULUS OF ELASTICITY AS THE ELEMENT 1
C MAIN ELEMENT AND SET THEIR THICKNESS SO THAT:
C T = T + (E/E(1)) ** ((1/2)/3)
C IF IF CLEAR, WRITE A WARNING MESSAGE
C IF SUBNUM .EQ. J, GO TO 28
WRITE (6,440) INPUT-1, SUBNUM, J
C IF SUB-ELEMENT IS A BEAM, CALL BEAM
BEAM 25 IF TYPE .NE. PÉ, F.O. 20
C IF SUB-ELEMENT IS A MEMBRANE, CALL MEMBR
MEMBR 30 IF TYPE .NE. MP, F.O. 40
C IF SUB-ELEMENT IS A PLATE, CALL PLATE
PLATE 40 IF STIFF .NE. F.O. 40
C IF SUB-ELEMENT IS A CYLINDER, CALL CYLIN
CYLIN 60 IF TYPE .NE. FCY, F.O. 60
SUBROUTINE EPROP

GO TO 100

C ELSE IF THE TYPE OF SUB-ELEMENT IS ONE OF THE ABOVE, WRITE AM:
C ERROR MESSAGE AND SET THE ERROR FLAG TO TERMINATE THE PROGRAM
C WRITE (6,330) TYPE, INPUT-1
C ERROR = .TRUE.
GO TO 100

C END IF

C IF AN ERROR WAS ENCOUNTERED WHILE READING SUB-ELEMENT PROPERTIES:
C WRITE A MESSAGE AND SET THE ERROR FLAG
80  WRITE (6,340) INPUT-1, INPUT-2
C ERROR = .TRUE.
100 CONTINUE
GO TO 200

C IF AN ERROR WAS ENCOUNTERED WHILE READING ELEMENT PROPERTIES:
C WRITE A MESSAGE AND SET THE ERROR FLAG
120 WRITE (6,350) INPUT
C ERROR = .TRUE.
GO TO 200

C IF AN ERROR WAS ENCOUNTERED WHILE READING SOUND PRESSURE LEVELS:
C WRITE A MESSAGE AND SET THE ERROR FLAG
130 WRITE (6,340) INPUT
C ERROR = .TRUE.
GO TO 200

C IF AN ERROR WAS ENCOUNTERED WHILE READING MECHANICAL INPUTS:
C WRITE A MESSAGE AND SET THE ERROR FLAG
140 WRITE (6,370) INPUT
C ERROR = .TRUE.
GO TO 200

200 CONTINUE
DO 207 K = 1, NUMEL
   KPLUS1 = M1(K) - K + 3
   WRITE (6,4500) (1+K,KPLUS1)
   DO 207 J2 = 1, NUMAF
      WRITE(6,510) FITAF(J2), F(J,J2), J, K, KPLUS1
207 CONTINUE
IF (ERROR) RETURN 1

RETURN

C IF AN ERROR OCCURRED WHILE READING THE FIRST INPUT RECORD:
C WRITE A MESSAGE AND SET THE ERROR FLAG
110 WRITE (6,360)
GO TO 205

C IF AN END OF FILE WAS ENCOUNTERED WHILE TRYING TO READ THE FIRST INPUT RECORD:
C WRITE A MESSAGE AND SET THE ERROR FLAG
120 WRITE (6,370)
GO TO 205

C IF AN END OF FILE WAS ENCOUNTERED WHILE READING ELEMENT PROPERTIES:
C WRITE A MESSAGE AND SET THE ERROR FLAG
130 WRITE (6,380) INPUT
GO TO 205

C IF AN END OF FILE WAS ENCOUNTERED WHILE READING SUB-ELEMENT PROPERTIES:
C WRITE A MESSAGE AND SET THE ERROR FLAG
140 WRITE (6,350) INPUT
GO TO 205

C IF AN END OF FILE WAS ENCOUNTERED WHILE READING SOUND PRESSURE LEVELS:
C WRITE A MESSAGE AND SET THE ERROR FLAG
150 WRITE (6,420) INPUT
396       GO TO 285
397       C IF THE NUMBER OF ELEMENTS IS OUT OF RANGE, WRITE A
398       C MESSAGE AND SET THE ERROR FLAG
399       260 WRITE (6,490) NMEM
400       GO TO 285
401       C IF THE NUMBER OF ANALYSIS FREQUENCIES IS OUT OF RANGE, WRITE A
402       C MESSAGE AND SET THE ERROR FLAG
403       270 WRITE (6,460) NUMAF
404       GO TO 285
405       C IF AN END OF FILE WAS ENCOUNTERED WHILE READING MECHANICAL
406       C INFLS, WRITE A MESSAGE AND SET THE ERROR FLAG
407       280 WRITE (6,480) INPUT
408       285 ERROR = .TRUE.
409       RETURN 1
410       ENC
C THIS SUBROUTINE CALCULATES THE MODAL DENSITY FOR A SUB-ELEMENT
C WHICH IS A BEAM AND SUMS THIS VALUE TO THE ELEMENT MODAL
C DENSITY. BEAM IS CALLED FROM EPBEAM.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

C NAME TYPE DESCRIPTION

C A REAL SUB-ELEMENT AREA
C AREA(20) REAL ELEMENT AREA
C C REAL SPEED OF SOUND IN SUB-ELEMENT ROOM MEDIUM
C DENSE(20) REAL ELEMENT DENSITY
C F REAL SUB-ELEMENT MODULUS OF ELASTICITY
C FC(20) REAL SPEED OF SOUND IN ELEMENT ROOM MEDIUM
C FE(20) REAL ELEMENT MODULUS OF ELASTICITY
C EGAPPA(20) REAL POISSON'S RATIO FOR ELEMENT
C ELNUM INT ELEMENT NUMBER
C FTAB(40) REAL TABLE OF ANALYSIS FREQUENCIES
C GAMMA REAL POISSON'S RATIO FOR SUB-ELEMENT
C L REAL LENGTH
C M REAL SUB-ELEMENT ADDED MASS (NON-STRUCTURAL)
C MASS(20) REAL ELEMENT MASS
C SUB REAL SUB-ELEMENT TOTAL MASS
C W(20,40) REAL ELEMENT MODAL DENSITY
C NUPAF INT NUMBER OF ANALYSIS FREQUENCIES
C OMEGA REAL 2*PI*FREQUENCY
C PSUBPD REAL PARTIAl SUB-ELEMENT MODAL DENSITY
C P REAL RADIUS
C RHO REAL SUB-ELEMENT DENSITY
C S REAL PRESSURE
C SUBPD REAL SUB-ELEMENT MODAL DENSITY
C T REAL SUB-ELEMENT THICKNESS
C THICK(20) REAL ELEMENT THICKNESS
C V REAL SUB-ELEMENT VOLUME
C VOL(20) REAL ELEMENT VOLUME

C THE FOLLOWING COMMON BLOCKS ARE USED:

C BLOCK OTHER PROGRAM UNITS USING THIS COMMON BLOCK

C INTEGER ELNUM
C REAL MAIN, MASS, PSUR
C LOGICAL STIFF, MAIN
C COMMON /CB1/ FTAB(40), NUPAF, FREQ
C COMMON /CB/ AREA(20), DENSE(20), VOL(20), FE(20)
C COMMON /CB1/ ELNUM, YF, GAMPAPHA, MA5C(20)
C COMMON /CB1/ AREA(20), DENSE(20), VOL(20), FE(20)
467     DATA PI /3.1415927/
469     C CALCULATE THE PART OF THE SUB-ELEMENT MODAL DENSITY THAT IS
471     C NOT FREQUENCY DEPENDENT
473     FSLRM = L / (2. * PI) * SQR(SQR(12. * RHO / E)) / T
475     C IF STIFFNESS REDUCTION IS REQUIRED, MULTIPLY BY SQR(T.5)
477     IF (STIFF) PSUBMO = SQR(T.5) * PSUBMO
479     C DO FOR EACH ANALYSIS FREQUENCY
481     CO 20 I = 1,NURAF
483     OMEGA = 2. * PI * FIAB(I)
485     C CALCULATE THE SUB-ELEMENT MODAL DENSITY
487     SUBMO = PSUBMO / SQR(OMEGA)
489     C SUM THE SUB-ELEMENT MODAL DENSITY TO THE ELEMENT MODAL DENSITY
491     N(EELNUM,I) = N(EELNUM,I) + SUBMO
493     20 CONTINUE
495     C SUM THE SUB-ELEMENT MASS TO THE ELEMENT MASS
497     PSLA = RHO * A * L * M
499     PASEL(EELM) = PASEL(EELM) + PSLA
501     C IF THIS IS NOT THE MAIN SUB-ELEMENT, RETURN TO EPROP
503     IF (.NOT. PAIN) RETURN
505     C ELSE PLOT THE VALUES OF THE FOLLOWING SUB-ELEMENT VARIABLES INTO
507     C THE CORRESPONDING ELEMENT ARRAYS
510     EE(EELM) = E
512     THICK(EELM) = T
514     DEASE(EELM) = RHO
516     ARE(EELM) = A
518     WCE(EELM) = V
520     EGAMMA(EELM) = GAMMA
522     EG(EELM) = C
524     C SET PAIN TO INDICATE THAT ANY FOLLOWING SUB-ELEMENTS ARE NOT
526     C THE MAIN SUB-ELEMENT
528     PAIN = .FALSE.
530     RETURN
532     END
**SUBROUTINE MEMR**

C THIS SUBROUTINE CALCULATES THE MODAL DENSITY FOR A SUB-ELEMENT
C WHICH IS A MEMBRANE ANG SUMS THIS VALUE TO THE ELEMENT MODAL
C DENSITY. MEMR IS CALLED FROM EPROM.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

C NAME TYPEDESCRIPTION
C A REALSUB-ELEMENT AREA
C AREA(20) REAL ELEMENT AREA
C C REALSPEED OF SOUND IN SUB-ELEMENT ROOM MEDIUM
C DENSE(20) REAL ELEMENT DENSITY
C E REALSUB-ELEMENT MODULUS OF ELASTICITY
C FC(20) REALSEARCH IN ELEMENT ROOM MEDIUM
C FEE(20) REAL ELEMENT MODULUS OF ELASTICITY
C FGAMMA(20) REAL POUTSSIMTS RATIO FOR ELEMENT
C ELNP INT ELEMENT NUMBER
C FFTAB(40) REAL TABLE OF ANALYSIS FREQUENCIES
C GANPA REAL POUTSSIMTS RATIO FOR SUB-ELEMENT
C L RFAL LENGTH
C M REALSUB-ELEMENT ADDED MASS (NON-STRUCTURAL)
C MASS(20) REAL ELEMENT MASS
C MSUB REAL SUB-ELEMENT TOTAL MASS
C M(20,40) REAL ELEMENT MODAL DENSITY
C NUMAF INT NUMBER OF ANALYSIS FREQUENCIES
C OPEF# REAL 2*PI*FREQUENCY
C PSGAM# REAL PARTIAL SUB-ELEMENT MODAL DENSITY
C R REALRADIUS
C RHO REALSUB-ELEMENT DENSITY
C S REALPRESSURE
C SUBD REALSUB-ELEMENT MODAL DENSITY
C T REALSUB-ELEMENT THICKNESS
C THICK(20) REAL ELEMENT THICKNESS
C V RFALSELEMENT VOLUME
C VOL(20) REAL ELEMENT VOLUME

C THE FOLLOWING COMMON BLOCKS ARE USED:
C Other program units using this common block

C INTEGER ELMNUM
C REAL NL,M,M,MASS,MSUB
C LOGICAL STIFF,MAIN
C COMMON /CB1/ FFTAB(40),ALMAF,FREG
C COMMON /CB1/ ELMNUM,ELUM,EE,EGAMMA,EMO,STIFF,L,M,CG,RE,MAIN
C COMMON /CB1/ ELMNUM,EE,EGAMMA,EMO,STIFF,L,M,CG,RE,MAIN
C COMMON /CB1/ AREA(301),DENSE(301),VOL(201),EEE(201)
C COMMON /CB1/ FGAMMA(201),EC(120)
C COMMON /CB1/ NL,MS,MASS,MSUB
DATA PI /3.1415926/  
C CALCULATE THE PART OF THE SUB-ELEMENT MODAL DENSITY THAT IS  
ACT FREQUENCY DEPENDENT  
FSUMO = A * RHO / (2. * PI * S)  
C IF STIFFNESS REDUCTION IS REQUIRED, MULTIPLY BY SORT(5)  
IF (STIFF) FSUMO = SORT(5) * FSUMO  
C DO FOR EACH ANALYSIS FREQUENCY  
DO 20 I = 1,NURAF  
OMEGA = 2. * PI * FTAB(I)  
C CALCULATE THE SUB-ELEMENT MODAL DENSITY  
SUBRD = FSUMO * OMEGA  
C SUM THE SUB-ELEMENT MODAL DENSITY TO THE ELEMENT MODAL DENSITY  
NELNUM(I) = NELNUM(I) + SUBRD  
20 CONTINUE  
C SUM THE SUB-ELEMENT MASS TO THE ELEMENT MASS  
MSUR = RHO * A * T * M  
MASSE(LNUM) = MASSE(LNUM) + MSUB  
C IF THIS IS NOT THE MAIN SUB-ELEMENT, RETURN TO EPROP  
IF (.NOT. PAIN) RETURN  
C ELSE PUT THE VALUES OF THE FOLLOWING SUB-ELEMENT VARIABLES INTO  
C THE CORRESPONDING ELEMENT ARRAYS  
IF(ECEILNUM) = E  
THICK(LNUM) = T  
DENS(LNUM) = RHO  
AREALNUM = A  
VOL(LNUM) = V  
EIGA(LNUM) = GAMA  
ECELNUM = C  
C SET PAIN TO INDICATE THAT ANY FOLLOWING SUB-ELEMENTS ARE NOT  
C THIS SUB-ELEMENT  
PAIN = *FALSE*  
RETURN  
END
SUBROUTINE PLATE

C THIS SUBROUTINE CALCULATES THE MODAL DENSITY FOR A SUR-ELEMENT
C WHICH IS A PLATE AND SUMS THIS VALUE TO THE ELEMENT MODAL
C DENSITY. PLATE IS CALLED FROM EPREP.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C NAME TYPE DESCRIPTION PLATE 19
C --------- --------- --------
C A REAL SUB-ELEMENT AREA
C ANP(20) REAL AREA * MODES / MASS OF SURFACE EXCITED AT
C ACoustIC FIELD
C AREA(20) REAL ELEMENT AREA
C C REAL SPEED OF SOUND IN SUB-ELEMENT ROOM MEDIUM
C DEASE(20) REAL ELEMENT DENSITY
C C REAL SUB-ELEMENT MODULUS OF ELASTICITY
C EC(20) REAL SPEED OF SOUND IN ELEMENT ROOM MEDIUM
C EFGH(20) REAL ELEMENT MODULUS OF ELASTICITY
C ELM(20) REAL POISSON'S RATIO FOR ELEMENT
C FLM(20) REAL ELEMENT NUMBER
C FNAME(40) REAL TABLE OF ANALYSIS FREQUENCIES
C GAMMA REAL POISSON'S RATIO FOR SUR-ELEMENT
C G REAL ELEMENT LENGTH
C S REAL ELEMENT ADDDFD MASS (NON-STRUCTURAL)
C NA REAL ELEMENT MASSES
C NUMF INT NUMBER OF ANALYSIS FREQUENCIES
C OMEGA REAL 2*PI*FREQUENCY
C OMN(20) REAL PARTIAL SUB-ELEMENT MODAL DENSITY
C R REAL ELEMENT LENGTH
C S REAL ELEMENT MODULUS OF ELASTICITY
C T REAL ELEMENT THICKNESS
C V REAL ELEMENT VOLUME
C W REAL ELEMENT VOLUME

C THE FOLLOWING COMMON BLOCKS ARE USED:
C COMMON /CP1, FNAME, NUMF, FREC
C COMMON /CP4, FNAME, E, G, A, M, S, MAIN

INTEGER E, TYPE, D, R
REAL M, L, S, MA, SB, SB, EL, C, R, S, S
SUBROUTINE PLATE

COMMON /CHS/, THICK(20), AREA(20), ENGF(20), VOL(20), FE(20),
     & ELMMA(420), ECG(20)
COMMON /CHS/, SPL(20,40), MECH(20,50), MKH(20), ETYPE(20), STRIP(20)
COMMON /CHS/, N(20,40)
COMMON /CB/1I, MASS(20)
DATA PI /3.1415927/
C CALCULATE THE SUB-ELEMENT MODAL DENSITY
SUBENG = A / (E0 + PI) * SORT(12, * RHO * (1. - GAMMA ** 2)
     + / (E * T ** 2))
C IF STIFFNESS REDUCTION IS REQUIRED, MULTIPLY BY SORT(3,5)
IF (STIFF * SUBENG = SORT(3,5)) * SUPRD
C DO FOR EACH ANALYSIS FREQUENCY
DO 20 I = 1, NUMAF
C SUM THE SUB-ELEMENT MODAL DENSITY TO THE ELEMENT MODAL DENSITY
N(ELEMNUM) = N(ELEMNUM) + SUBENG
20 CONTINUE
C SUM THE SUB-ELEMENT MASS TO THE ELEMENT MASS
MSLNG = RHO * A * T + M
PASS(ELEMNUM) = MASS(ELEMNUM) + MSLNG
IF (ETYPE(ELEMNUM) = ECR, TAT (AND, MAIN) ANM(ELEMNUM) =
     / (A * SUBENG) / MSLNG = 2. + PI
C IF THIS IS NOT THE MAIN SUB-ELEMENT, RETURN TO EPROP
IF (.NOT. MAIN) RETURN
C ELSE PUT THE VALUES OF THE FOLLOWING SUB-ELEMENT VARIABLES INTO
C THE CORRESPONDING ELEMENT ARRAYS
E(ELEMNUM) = E
TMIC(ELEMNUM) = T
DENSS(ELEMNUM) = RHO
AREA(ELEMNUM) = A
VOL(ELEMNUM) = V
EPMAM(ELEMNUM) = GAMMA
C SET MAIN TO INDICATE THAT ANY FOLLOWING SUB-ELEMENTS ARE NOT
C THE MAIN SUB-ELEMENT
MAIN = .FALSE,
RETURN
END
C THIS SUBROUTINE CALCULATES THE MODAL DENSITY FOR A SUB-ELEMENT.
C WHICH IS A RAMP AND SIMILARIS THIS VALUE TO THE ELEMEET MODAL
C DENSITY. ROOM IS CALLED DDMODE.
C
C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C
C NAME TYPE DESCRIPTION
C ---- --- -----------
C A REAL SUB-ELEMENT AREA
C AREA(20) REAL ELEMENT AREA
C C REAL SPEED OF SOUND IN SUB-ELEMENT ROOM MEDIUM
C DENSE(20) REAL ELEMENT DENSITY
C E REAL SUB-ELEMENT MODULUS OF ELASTICITY
C FC(20) REAL SPEED OF SOUND IN ELEMENT ROOM MEDIUM
C EEE(20) REAL ELEMENT MODULUS OF ELASTICITY
C FGAPPA(20) REAL POISSON'S RATIO FOR ELEMENT
C ELNP INT ELEMENT NUMBER
C FTA(40) REAL TABLE OF ANALYSIS FREQUENCIES
C GAPPA REAL POISSON'S RATIO FOR SUB-ELEMENT
C L REAL LENGTH
C P REAL SUB-ELEMENT ADDED MASS (NON-STRUCTURAL)
C MASS(20) REAL ELEMENT MASS
C MSLD REAL SUB-ELEMENT TOTAL MASS
C N(20,40) REAL ELEMENT MODAL DENSITY
C NUMAF INT NUMBER OF ANALYSIS FREQUENCIES
C OMEGA REAL 2*PI*FREQUENCY
C PSCLPD REAL PARTIAL SUB-ELEMENT MODAL DENSITY
C R REAL RADIUS
C RMG REAL SUB-ELEMENT DENSITY
C S REAL PRESSURE
C SUBC REAL SUB-ELEMENT MODAL DENSITY
C T REAL SUB-ELEMENT THICKNESS
C THICK(20) REAL ELEMENT THICKNESS
C V REAL SUB-ELEMENT VOLUME
C VOL(20) REAL ELEMENT VOLUME

C THE FOLLOWING COMMON BLOCKS ARE USED:
C
C OTHER PROGRAM UNITS USING THIS COMMON BLOCK
C
C NAME OTHER PROGRAM UNITS
C ---- --
C CR1 MAIN,PROP,BEAM,PERBA,PLATE,CYLIN,SLSTM,ROCK DATA
C CR2 CR1,PROP,BEAM,PERBA,PLATE,CYLIN
C CR3 CR2,PROP,BEAM,PERBA,PLATE,CYLIN,PROP,EXCITE,RES,ROCK DATA
C CR4 CR3,PROP,BEAM,PERBA,PLATE,CYLIN,PROP,EXCITE,ROCK DATA
C CF11 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF12 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF13 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF14 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF15 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF16 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF17 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF18 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF19 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
C CF20 CR11,PROP,BEAM,PERBA,PLATE,CYLIN,RES,ROCK DATA
CATA PI /3.141592/  
C CALCULATE THE PART OF THE SUB-ELEMENT MODAL DENSITY THAT IS  
C NOT FREQUENCY DEPENDENT  
FS.HPO = U / (2. * PI ** 2 * C ** 4)  
C DC PER EACH ANALYSIS FREQUENCY  
DO 2C 1 = 1,NUMAF  
144  
Omega = 2. * PI * F1AF  
C CALCULATE THE SUB-ELEMENT MODAL DENSITY  
SUBD = C*OMEGA ** 2 * FS.HPO  
C SUM THE SUB-ELEMENT MODAL DENSITY TO THE ELEMENT MODAL DENSITY  
NEELNUMI = NEELNUMI + SUBD  
20 CONTINUE  
C SUM THE SUB-ELEMENT MASS TO THE ELEMENT PASS  
MSUM = MSUM + M  
MASEELEM = MASEELEM + MSUM  
C IF THIS IS NOT THE MAIN SUB-ELEMENT, RETURN  
IF (NOT, MAIN) RETURN  
C ELSE PUT THE VALUES OF THE FOLLOWING SUB-ELEMENT VARIABLES INTO  
C THE CORRESPONDING ELEMENT ARRAYS  
FF(ELEMENT) = F  
THICK(ELEMENT) = T  
DENS(ELEMENT) = MHO  
AAREA(ELEMENT) = A  
VCA(ELEMENT) = V  
FGAMAP(ELEMENT) = GAMMA  
EC(ELEMENT) = L  
C SET MAIN TO INDICATE THAT ANY FOLLOWING SUB-ELEMENTS ARE NOT  
C THE MAIN SUB-ELEMENT  
MAIN = FALSE  
RETURN  
END
SUBROUTINE CYLIN

C THIS SUBROUTINE CALCULATES THE MODAL DENSITY FOR A SUB-ELEMENT
C WHICH IS A CYLINDER AND SAVES THIS VALUE TO THE ELEMENT MODAL
C DENSITY. CYLIN IS CALLED FROM EPRO.
C
C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>REAL</td>
<td>SUB-ELEMENT AREA</td>
</tr>
<tr>
<td>AREA(20)</td>
<td>REAL</td>
<td>ELEMENT AREA</td>
</tr>
<tr>
<td>C</td>
<td>REAL</td>
<td>SPEED OF SOUND IN SUB-ELEMENT ROOM MEDIUM</td>
</tr>
<tr>
<td>DENS(20)</td>
<td>REAL</td>
<td>ELEMENT DENSITY</td>
</tr>
<tr>
<td>E</td>
<td>REAL</td>
<td>SUB-ELEMENT MODULUS OF ELASTICITY</td>
</tr>
<tr>
<td>EE(20)</td>
<td>REAL</td>
<td>ELEMENT MODULUS OF ELASTICITY</td>
</tr>
<tr>
<td>EGAMMA(20)</td>
<td>REAL</td>
<td>POISSON'S RATIO FOR ELEMENT</td>
</tr>
<tr>
<td>ELNUM</td>
<td>INT</td>
<td>ELEMENT NUMBER</td>
</tr>
<tr>
<td>FTA(40)</td>
<td>REAL</td>
<td>TABLE OF ANALYSIS FREQUENCIES</td>
</tr>
<tr>
<td>GAMMA</td>
<td>REAL</td>
<td>POISSON'S RATIO FOR SUB-ELEMENT</td>
</tr>
<tr>
<td>L</td>
<td>REAL</td>
<td>LENGTH</td>
</tr>
<tr>
<td>M</td>
<td>REAL</td>
<td>SUB-ELEMENT ADDED MASS (NON-STRUCTURAL)</td>
</tr>
<tr>
<td>MA5E(20)</td>
<td>REAL</td>
<td>ELEMENT MASS</td>
</tr>
<tr>
<td>PSUB</td>
<td>REAL</td>
<td>SUB-ELEMENT TOTALmass</td>
</tr>
<tr>
<td>WGE(20)</td>
<td>REAL</td>
<td>ELEMENT MODAL DENSITY</td>
</tr>
<tr>
<td>NUMAF</td>
<td>INT</td>
<td>NUMBER OF ANALYSIS FREQUENCIES</td>
</tr>
<tr>
<td>OMEGA</td>
<td>REAL</td>
<td>2<em>PI</em>FREQUENCY</td>
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<tr>
<td>PPSME</td>
<td>REAL</td>
<td>PARTIAL SUB-ELEMENT MODAL DENSITY</td>
</tr>
<tr>
<td>R</td>
<td>REAL</td>
<td>RADIUS</td>
</tr>
<tr>
<td>RHO</td>
<td>REAL</td>
<td>SUB-ELEMENT DENSITY</td>
</tr>
<tr>
<td>S</td>
<td>REAL</td>
<td>PRESSURE</td>
</tr>
<tr>
<td>SUBME</td>
<td>REAL</td>
<td>SUB-ELEMENT MODAL DENSITY</td>
</tr>
<tr>
<td>T</td>
<td>REAL</td>
<td>ELEMENT THICKNESS</td>
</tr>
<tr>
<td>THICK(20)</td>
<td>REAL</td>
<td>ELEMENT THICKNESS</td>
</tr>
<tr>
<td>U</td>
<td>REAL</td>
<td>SUB-ELEMENT VOLUME</td>
</tr>
<tr>
<td>WCL(20)</td>
<td>REAL</td>
<td>ELEMENT VOLUME</td>
</tr>
</tbody>
</table>

C C THE FOLLOWING COMMON BLOCKS ARE USED:

C C BLOCK  OTHER COMMON BLOCKS USING THIS COMMON BLOCK
C -------------- --------------------------------------------
C CB1 MAIN,EPROP,BEAM,MEMBR,PLATE,ROOM,ITER,BLOCK DATA
C CB4 EPROP,MAIN,EPROP,BEAM,MEMBR,PLATE,ROOM
C CB5 EPROP,MAIN,EPROP,BEAM,MEMBR,PLATE,ROOM,PROP,EXCITE,ANSWER
C CH1 EPROP,MAIN,EPROP,BEAM,MEMBR,PLATE,ROOM,ANSWER,BLOCK DATA

C INTEFR CLAM
C REAL WCL,MASS,MSUR
C
C COMMON /CH1/ T,FT,AREA(20),DENS(20),WCL(20),EE(20)
C COMMON /CB5/ AREA(20),DENS(20),WCL(20),EE(20)
C COMMON /CB4/ EPROP,MAIN,EPROP,BEAM,MEMBR,PLATE,ROOM
C COMMON /CB1/ T,FT,AREA(20),DENS(20),WCL(20),EE(20)
C
SUBROUTINE CYLIN

DATA PI/3.1415927/

C CALCULATE THE PART OF THE SUB-ELEMENT MODAL DENSITY THAT IS
C NOT FREQUENCY DEPENDENT

FSUBMO = R * L / Z * SQRT(I2) * R * C * 
* (13 - GAMMA ** 2) / (C * T ** 2)

C IF STIFFNESS REDUCTION IS REQUIRED, MULTIPLY BY SQRT(4)

IF (STIFF) PSUBMO = SQRT(4) * FSUBMO

C DO FOR EACH ANALYSIS FREQUENCY

DO 20 I = 1,NUMAF

SUBMO = FSUBMO

OPPA = 2 * PI * FPROP(I)

C CALCULATE THE CRITERION FOR THE FREQUENCY DEPENDENT PART

C OF THE SUB-ELEMENT MODAL DENSITY

CRIT = OMEGA * R * SQRT(PSUBMO / E)

C IF THE CRITERION IS GREATER THAN 1, ALTER THE MODAL DENSITY

C APPROPRIATELY

IF (CRIT LE 1.0) SUBMO = SUBMO * CRIT ** (2.0 / 3.0)

C SLIP THE SUB-ELEMENT MODAL DENSITY TO THE ELEMENT MODAL DENSITY

N(ELEMNUM,I) = N(ELEMNUM,I) * SUBMO

20 CONTINUE

C SUM THE SUB-ELEMENT MASS TO THE ELEMENT MASS

A = Z * PI * R ** 3

MSUM = A * T + RNW * M

C IF THIS IS NOT THE MAIN SUB-ELEMENT, RETURN TO EPROP

IF (I.NEG.1) RETURN

C ELSE PUT THE VALUES OF THE FOLLOWING SUB-ELEMENT VARIABLES INTO

C THE CORRESPONDING ELEMENT ARRAYS

EG(ELEMNUM) = E

THICK(ELEMNUM) = T

CENS(ELEMNUM) = RMO

AREA(ELEMNUM) = A

VOL(ELEMNUM) = V

ESAM(ELEMNUM) = GAMA

EC(ELEMNUM) = C

C SET MAIN TO INDICATE THAT ANY FOLLOWING SUB-ELEMENTS ARE NOT

C THE MAIN SUB-ELEMENT

MAIN = .FALSE.

RETURN

END
SUBROUTINE JINPUT

C THIS SUBROUTINE READS JOINT PROPERTIES FROM UNIT 3 AND CHECKS
C THAT ELEMENT PAIRS ARE NOT INPUT MORE THAN ONCE. JINPUT IS
C CALLED FROM THE MAIN PROGRAM.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

C NAME TYPE DESCRIPTION
C ---- ------ ------------
C ASD(150) REAL ACoustIC SPACE DENSITY
C BL(150) REAL REAL LENGTH
C INP(190) INT NUMBER OF INPUT RECORDS READ
C JL(190) REAL JOINT LENGTH
C JTYPE(190) CHAR TYPE OF JOINT
C NE1(150) INT FIRST ELEMENT
C NE2(190) INT SECOND ELEMENT
C KS(190) INT NUMBER OF SIDES
C NPEL INT NUMBER OF ELEMENTS
C SP(190) REAL PLOT SPACING
C TL(190) REAL THICKNESS OF FIRST ELEMENT OF PAIR
C T2(190) REAL THICKNESS OF SECOND ELEMENT OF PAIR
C TOTAL INT NUMBER OF ELEMENT PAIRS INPUT

C THE FOLLOWING COMMON BLOCKS ARE USED:

C BLOCK OTHER PROGRAM UNITS USING THIS COMMON BLOCK

C CB2 NAME=BPROP+BLOCK DATA
C CH7 BPROP+PROP+EXCITE+ANSWER+SOLVE+RITER+BLOCK DATA
C CB10 BPROP+BLOCK DATA
C CP12 JPROP

C

CHARACTER*2 JTYPE
INTEGER TOTAL
REAL DL
LOGICAL ERROR

COMMON /CB2/ ERROR
COMMON /CB7/ NPEL,G
COMMON /CB10/ INPUT
COMMON /CB12/ NE1(190),NE2(190),JL(190),BL(190)
T1(190),T2(190),ASD(190),KS(190),SP(190),JPUT(190),TOTAL

180 FORMAT (212,47,12,6F10.2)
110 FORMAT (10*** WARNING *** ON INPUT RECORD #, ONE OR MORE
1 1 BOTH MEMBERS OF THE JOINT ELEMENT PAIR #,12 AND #,12,
1 2 THERE ARE EITHER LESS THAN 1 OR GREATER THAN T12, T2,
1 3 TOTAL NUMBER OF ELEMENTS, THIS PAIR WILL BE IGNORED.
1 4 1 THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

120 FORMAT (10*** WARNING *** THE ELEMENT PAIR #,12,1 AND #,12,
1 12,1 ON INPUT RECORD #,14,1 WAS NOT PREVIOUSLY READ ON #,12,1,
1 2 THIS INPUT RECORD #,14,1, THE FIRST VALUES WILL BE USED.
1 3 1 THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

130 FORMAT (10*** ERROR *** WHILE ATTEMPTING TO READ JOINT #,
1 1 PROPERTIES, #,11,1 A FORTRAN ERROR OCCURRED ON INPUT RECORD #,
1 2 #,11,1.
1 3 1 THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

MAY 11 49
JINPUT 1
JINPUT 2
JINPUT 3
JINPUT 4
JINPUT 5
JINPUT 6
JINPUT 7
JINPUT 8
JINPUT 9
JINPUT 10
AUG 12 4
JINPUT 11
JINPUT 12
JINPUT 13
JINPUT 14
JINPUT 15
JINPUT 16
JINPUT 17
JINPUT 18
JINPUT 19
JINPUT 20
JINPUT 21
JINPUT 22
JINPUT 23
JINPUT 24
JINPUT 25
JINPUT 26
JINPUT 27
JINPUT 28
JINPUT 29
JINPUT 30
JINPUT 31
JINPUT 32
JINPUT 33
JINPUT 34
JINPUT 35
JINPUT 36
JINPUT 37
JINPUT 38
JINPUT 39
JINPUT 40
MAY 13 50
AUG 12 5
JINPUT 41
JINPUT 42
JINPUT 43
JINPUT 44
MAY 13 52
JINPUT 45
MAY 13 53
JINPUT 46
MAY 13 54
JINPUT 47
JINPUT 48
JINPUT 49
MAY 13 55
JINPUT 50
JINPUT 51
JINPUT 52
JINPUT 53
MAY 13 56
JINPUT 54
140 FORMAT (10*** ERROR *** THE END OF FILE WAS REACHED BEFORE 1.
1 TANS INFORMATION ABOUT JOINT PROPERTIES WAS READ.)
1 5 I THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

150 FORMAT (10*** WARNING *** ON INPUT RECORD 1, I4,
1 10TH ELEMENT NUMBERS WERE GIVEN AS 1,12, 2.
1 THEY MUST BE DIFFERENT. THIS RECORD WILL BE IGNORED.)
1 5 I THIS ERROR WAS DISCOVERED BY SUBROUTINE JINPUT.

170 FORMAT (10, 4X, 'FIRST ELEMENT = ', I2, 10X, 'SECOND TO
1 1 ELEMENT = ', I2, 10X, 'TYPE OF JOINT = ', I2, 10X, 'JOINT
1 LENGTH = ', I2, 10X, 'THICKNESS OF FIRST ELEMENT = ', I2,
1 10X, 'THICKNESS OF SECOND ELEMENT = ', I2, 10X, 'AQUEOUS
1 SPACE DENSITY = ', I2, 10X, 'IPE12.SZ2 / 10X, INSERTION
1 LENGTH = ', I2, 10X, 'TUMOR LENGTH = ', I2, 10X, 'INSERTION
1 FACTOR = ', I2, 10X, 'IPE12.SZ2)

180 FORMAT (10, 4X, 10, 6(IH-), 10X, 10, 6(IH-), 10X, 10, 6(IH-))

C WRITE A HEADING TO CONTINUE PRINTING INPUT DATA

WRITE (6,180)
C INITIALIZE TOTAL
TOTAL = 0
C INITIALIZE I
I = 0
C INCREMENT I
I = I + 1
C INCREMENT INPUT
INPUT = INPUT + 1
C READ THE JOINT PROPERTIES
READ (3,100, ERR=60, END=7) NE1(I), NE2(I), JTYPE(I), NS(I), JL(I)
C WRITE THE JOINT PROPERTY OUTPUT
WRITE (6,170) I, NE1(I), NE2(I), JTYPE(I), NS(I), JL(I)
C PUT THE INPUT RECORD NUMBER IN JPUT
JPUT(I) = INPUT
C IF ELEMENT NUMBER IS OUT OF RANGE.
IF NE1(I) .LT. 1 OR NE1(I) .GE. NE2(I) GO TO 15
C THEN WRITE A WARNING MESSAGE
WRITE (6,110) NE1(I), NE2(I), NUMEL
GO TO 10
C END IF
C IF PCT ELEMENTS IN THE PAIR ARE THE SAME.
1 IF NE1(I) = NE2(I) GO TO 20
C THEN WRITE A WARNING MESSAGE
WRITE (6,160) INPUT, NE1(I)
GO TO 10
C END IF
C IF THIS IS THE FIRST ELEMENT PAIR, SKIP THE FOLLOWING TEST
20 IF I .LT. 1 GO TO 0
C FOR EACH PAIR OF ELEMENTS PREVIOUSLY INPUT
GO TO 3C.4 = 1, TOTAL
C IF THE CURRENT PAIR OF ELEMENTS MATCHES A PREVIOUS PAIR.
C JINPUT57 JINPUT58 JINPUT59 JINPUT60 JINPUT61 JINPUT62 JINPUT63 JINPUT64 JINPUT65 JINPUT66 JINPUT67 JINPUT68 JINPUT69 JINPUT70 JINPUT71 JINPUT72 JINPUT73 JINPUT74 JINPUT75 JINPUT76 JINPUT77 JINPUT78 JINPUT79 JINPUT80 JINPUT81 JINPUT82 JINPUT83 JINPUT84 JINPUT85 JINPUT86 JINPUT87 JINPUT88 JINPUT89 JINPUT90 JINPUT91 JINPUT92 JINPUT93 JINPUT94 JINPUT95 JINPUT96 JINPUT97
SUBROUTINE JINPUT

917 IF (I .EQ. NE2(I) .AND. NF(I) .OR. NE2(I) .NEQ. NE1(I)) GO TO 90
919 C THEN WRITE A WARNING MESSAGE
922 WRITE (6,120) NE1(I),NE2(I),INPUT,JPUT(J)
924 GO TO 10
926 C END IF
927EMENT TOTAL
929 GO TO 5
931 C IF AN ERROR OCCURRED ON READING, WRITE AN ERROR MESSAGE
934 GO WRITE (6,130) INPUT
937 ERROR = "TRUE"
939 GO TO 10
940 C IF THE END OF FILE WAS ENCOUNTERED, PUT NO RECORDS
943 IF (TOTAL .GE. 1) GO TO 90
946 ERROR = "TRUE"
948 WRITE (6,140)
950 C IF THERE WERE NO ERRORS, RETURN
953 GO IF (.NOT. ERROR) RETURN
955 C ELSE WRITE A MESSAGE AND TERMINATE THE PROGRAM
958 WRITE (6,150)
960 CALL FEND
962 END
SUBROUTINE JPROP

C THIS SUBROUTINE CALCULATES THE ELEMENT-TO-ELEMENT STRUCTURAL
C COUPLING COEFFICIENT (PM). JPROP IS CALLED FROM THE MAIN
C PROGR.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C
C NAME     TYPE     DESCRIPTION
C -------    -----     --------
C A          R     PSEUDO AREA
C AF         I     ANALYSIS FREQUENCY ORIGNAL
C IAREA(20)   R     SURFACE AREA
C ACS(19)    R     ACOUSTIC SPACE DENSITY
C B(190)     R     BEAM LENGTH
C CFREQ      R     CRITICAL FREQUENCY
C DENS(20)   R     DENSITY
C E2(20)     R     SPEED OF SOUND IN PCCN MEDIUM
C E2E2003    R     MODULUS OF ELASTICITY
C EPAPA(20)  R     POISSON'S RATIO
C E1         I     FIRST ELEMENT
C E2         I     SECOND ELEMENT
C FREQ       R     FREQUENCY
C JL(190)    R     JOINT LENGTH
C JTYPE(190)  C     TYPE OF JOINT
C NODES      R     NUMBER OF NODES IN BANDWIDTH
C N(20,40)   R     MODAL DENSITY
C N(190)     I     FIRST ELEMENT
C N(2190)    I     SECOND ELEMENT
C N(150)     I     NUMBER OF SIDES
C OMEGA      R     2*PI*FREQUENCY
C PMT(20,20) R     COUPLING COEFFICIENT
C SIGMA(20)  R     RADIATION EFFICIENCY
C SP(150)    R     RADIATION REDUCTION
C TAU        R     THICKNESS RATIO
C THICK(20)  R     THICKNESS
C TOTAL      R     TOTAL NUMBER OF ELEMENT PAIRS (i.e., JOINTS)
C V(20)      R     VOLUME
C
C THE FOLLOWING COMMON BLOCKS ARE USED:
C
C NAME     OTHER PROGRAM UNITS USING THIS COMMON BLOCK
C -------            -------
C CR3        MAIN,EXCITE,ANSWER
C CP1        EPROP,BEAM,MEMB,PLATE,ROAM,CYLIN,EXCITE,ANSWER
C CE1        EPROP,INPUT,EXCITE,ANSWER,SOLVE,ITER,BLOCK DATA
C CB9        EPROP,BEAM,MEMB,PLATE,ROAM,CYLIN,EXCITE,BLOCK DATA
C CH12       INPUT
C CP14       EXCITE,ANSWER
C CD         
C CCA4
C C

C CHARACTER*2 JTYPE
C INTEGER AF,iel2 TOTAL
C REAL JL,IPNODES
C LOGICAL ERROR
C COMMON /CB3/ FREQ,AF,OMEA
C COMMON /CP1/ THICK(20),AREA(20),DENS(20),VOL(20),F(20)
C EXP(20)
SUBROUTINE JPROP

COMMON /CA7/, NUMFL, G
COMMON /CS6/, N(L2+40)
COMMON /CA8/, JTYPIF(190)
COMMON /CA12/, NE(J1) ME2(190), JL(J1), RL(J1),
* T1(190), T2(190), A(190), NS(T1), SP(T1), PUT(190), TOTAL
COMMON /CB1/ PH1(20,20), MODES(20)
COMMON /PI/, ERROR(5), MODEL(195), MODEL(195)
CATA Pl., ERROR /0, 15/ = FALSE
700 FORMAT (I20, ' THIS IS NOT A VALID TYPE, THE TYPE MUST BE'
2, I2, ' THEN RE-PROB. OR ABORT.')
710 IF THIS ERROR WAS DISCOVERED BY SUBROUTINE JPROP.
720 FORMAT (I20, ' (BECAUSE OF THE ERRORS LISTED ABOVE, THE EA PROGRAM WILL ABORT.)')

C INITIALIZE THE COUPLING COEFFICIENTS TO C AND CALCULATE MODES
10 CO 2C d = 1, 20
105 MODES(2) = N(2,AF) + OMEGA / 2.33
20 DO 10 i = 1, 20
105 PH1(i,1) = 0.
10 CONTINUE
20 CONTINUE

C DO FOR EACH PAIR OF ELEMENTS FOR WHICH JOINT PROPERTIES
C WERE INPUT
C
DO 100 I = 1, TOTAL
C PUT THE ELEMENT NUMBERS IN SIMPLE VARIABLES TO AVOID
C OOFLE SUBSCRIPTS
E1 = NE(1)
E2 = NE(2)

105 C IF THE TYPE OF JOINT IS PLATE TO PLATE,
106 IF JTJFAIL(1) .NE. TYPF1) GO TO 30
107 C IF THE JOINT IS TYPF1 OR TYPF2.
108 C TYPF1, TYPF2 TO A22.
109 C UNLESS THE RATIO OF THICKNESS IS LESS THAN .5, IN WHICH CASE
1010 C SET TAU TO THE RATIO
1011 IF T1(I) / T2(I) .LT. .5
1012 TAU = T1(I) / T2(I)
1013 C CALCULATE THE PSEUDO AREA
1014 A = 2. + PI * MEI(AF) * T1(I) * SORT(E(E1)) / 
1015 (1. + EPS(E(E1)) * (1. - 3*EPS(E(E1)) * 2)))
1016 C CALCULATE THE COUPLING COEFFICIENT FOR PLATE TO PLATE COUPLING
1017 PH1(E1,E2) = 1.07 * JL(1) / (PI * A / MODES(2))
1018 E = SORT(OMEGA + THICK(E1)) * SORT(OMEGA + THICK(E1)) / (OMEGA + THICK(E1)) * 
1019 A = EPS(E(E1)) * 2))) * TAU
1020 GO TO 40
1021 C ELSE IF TYPE OF JOINT IS REAM TO PLATE,
1022 30 IF (JTJFAIL(1) .NE. TYPF1) GO TO 40
1023 C CALCULATE THE COUPLING COEFFICIENT FOR THAT TYPE
1024 PH1(E1,E2) = 2. * PI * FREG * JL(1) / (MODES(2)) * 
1025 A = RL(I) * 
1026 GO TO 40
1027 C ELSE IF THE TYPE OF JOINT IS BOLTED OR REARFJOINT,
1028 40 IF (JTJFAIL(1) .NE. TYPF1) GO TO 50
1029 C THEN SET TAU TO A/27.
1030 TAU = A / 27.
1031 C UNLESS THE RATIO OF THICKNESS IS LESS THAN .5, IN WHICH CASE
1032 C SET TAU TO THE
1113:            IF (T1(I) / T2(I) .LT. .5)  
1114:                TAU = T1(I) / T2(I)  
1115:            C CALCULATE THE PSEUDO AREA  
1116:                A = .5 * PI * AK(E1,AF1) * 2 * T(I) * SQRT(EE(I)) /  
1117:                (A12 * DENS(E1) + (1. - EGMMA(E1) ** 2))  
1118:            C CALCULATE THE COUPLING COEFFICIENT FOR THAT TYPE  
1119:                PHI(E1,E2) = 1./7 * JL(I) / (PI * A * MOES(E2)) *  
1120:                SQRT(OMEGA * THICK(E1)) / SQRT(EE(E1)) / (DENS(E1) *  
1121:                (1. - EGMMA(E1) ** 2)))) * TAU / SP(E1)  
1122:             GO TO 50  
1123:            C IF THE TYPE OF JOINT IS PLATE TO ACOUSTIC SPACE,  
1124:             50 IF (JTYPE(I) .NE. 125) GO TO 60  
1125:            C CALCULATE THE CRITICAL FREQUENCY  
1126:                CFREQ = FC(E2) ** 2 / (1.4 * THICK(E1))  
1127:                * SQRT(DENS(E1) / EFF(E1))  
1128:            C CALCULATE THE RADIATION EFFICIENCY USING THE SIGF FUNCTION  
1129:                SIGMA = 10. ** SIGF(CFREQ / CFREQ)  
1130:            C CALCULATE THE COUPLING COEFFICIENT FOR THAT TYPE  
1131:                PHI(E1,E2) = 4.33 * PI * FC(E2) ** 4 / (FREQ * OMEGA ** 2)  
1132:                * VOL(E2) * W5(I) * QENSE(E1) * THICK(E1)  
1133:                * SIGMA / ASO(I)  
1134:             GO TO 60  
1135:            C ELSE IF THE TYPE OF JOINT IS NONE OF THE ABOVE, SET THE ERROR  
1136:             60   ERROR = *TRUE*  
1137:            C CALL AND WRITE AN ERROR MESSAGE  
1138:                60    WRITE (200) E1,E2,JPUT(I),JTYPE(I)  
1139:                C ENC IF  
1140:                    90   PHI(E2,E1) = PHI(E1,E2)  
1141:                160 CONTINUE  
1142:            C IF NO ERRORS IN JOINT TYPE WERE ENCOUNTERED, RETURN  
1143:                IF (.NOT. ERROR) RETURN  
1144:            C ELSE WRITE A MESSAGE AND TERMINATE THE PROGRAM  
1145:                WRITE (*,220)  
1146:                CALL FERR  
1147:                ENC
FUNCTION SIGF(x)
C THIS FUNCTION SUBPROGRAM RETURNS A VALUE FOR THE RADIATION
C EFFICIENCY OF A PANEL BASED ON THE FOLLOWING TABLE:
C
X  SIGF // X  SIGF // X  SIGF // X  SIGF
--- ---- // --- ---- // --- ---- // --- ----
.10 -1.2 // .41 -1.0 // .67 -0.2 // 1.0 .0 //
.22 -1.5 // .50 -0.8 // .82 0.0 // 1.5 .4 //
.26 -1.9 // .60 -0.6 // .92 0.2 // 1.9 0.2 //
.28 -1.9 // .68 -0.4 // .92 0.4 // 0.0 //
C
C THE ENTRY IN THE X COLUMN IS THE MAXIMUM VALUE OF X FOR WHICH
C SIGF WAS THE INDICATED VALUE. SIGF IS CALLED FROM JPROP AND
C EXCITE.
C
C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C NAME TYPE DESCRIPTION
C --- ---- -------------------
C D(16) REAL A TABLE OF VALUES TO COMPARE WITH X
C I INT THE ORDINAL OF THE LEAST VALUE OF D GREATER THAN X
C X REAL THE RATIO OF THE ANALYSIS FREQUENCY TO THE
C CRITICAL FREQUENCY
C
D(16)
C
DIMENSION D(16)
DATA D /0.40, .11, .22, .32, .41, .50, .60, .6975496928, .92, 1.0, 1.5, 1.9, 2.0/
C DETERMINE WHERE X LIES IN THE TABLE
DO 20 I = 2, 15
IF (X .LE. D(I)) 60 TO 30
20 CONTINUE
C SIGF REACHES A MAXIMUM AT I = 15. A DIFFERENT ALGORITHM
C FOR COMPUTING SIGF IS REQUIRED DEPENDING ON WHETHER I IS
C GREATER OR LESS THAN 15.
C
I = 15
IF (I .LE. 14) GC TO 50
SIGF = -2.0 + 2.0 * FLOAT(I)
I = I - 1
C INTERPOLATE
SIGF = -2 / (D(I) - D(I - 1)) + SIGF
RETURN
C SIGF .LT. 0.0
SIGF = .5 - .2 * FLOAT(I - 1)
C INTERPOLATE IF X IS LESS THAN 4
IF (X .LT. D(I)) RETURN
SIGF = -2 / (D(I) - D(I - 1)) + (D(I) - X) * SIGF
RETURN
END
SUBROUTINE EXCITE

C THIS SUBROUTINE DETERMINES ELEMENT ENERGY LEVELS OR ACOUSTIC

C ENERGY INPUTS DEPENDING ON THE TYPE OF EXCITATION. EXCITE IS

C CALLED FROM THE MAIN PROGRAM.

C

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:

C NAME TYPE DESCRIPTION

C AF -------- ANALYSIS FREQUENCY OPCODE

C ANM(20) REAL AREA X MODES X MASS OF SURFACE EXCITED BY

C ACOUSTIC FIELD

C AREA(20) REAL AREA

C E(20) REAL ELEMENT ENERGY LEVELS

C FCM(20) REAL SPEED OF SOUND IN MEDIUM

C ETYPE(20) CHAR TYPE OF EXCITATION

C N(20) REAL NUMBER OF MODES IN BANDWIDTH

C FREG REAL FREQUENCY

C G REAL GRAVITATIONAL CONSTANT

C PASS(20) REAL MASS

C MECH(20) REAL MECHANICAL INPUT

C NTYPE(20) REAL TYPE OF MECHANICAL INPUT

C N20,40 REAL MODAL DENSITY

C NUMPE INT NUMBER OF ELEMENTS

C OMEGA REAL 2*PI*FREQUENCY

C SIGMA(20) REAL ACOUSTIC ENERGY INPUT

C SPL(20) REAL RADIATION EFFICIENCY

C SPL(20) REAL SOUND PRESSURE LEVELS

C

C THE FOLLOWING COMMON BLOCKS ARE USED:

C OTHER PROGRAM UNITS USING THIS COMMON BLOCK

C

C CB3 MAIN/PROP,ANSWER

C CB5 EPROP/REAP,MEMBR,PLATE,ROCK,CYLIN,PROP,ANSWER

C CB6 EPROP,PLATE

C CB7 EPROP,INPUT,PROP,ANSWER,SOLVE,ITER,BLOCK DATA

C CB9 EPROP/REAP,MEMBR,PLATE,ROCK,CYLIN,PROP,ANSWER,BLOCK DATA

C CB10 REAP,MEMBR,PLATE,ROCK,CYLIN,ANSWER/BLOCK DATA

C CB11 JPROP,ANSWER

C CB15 ANSWER,INPUT

C CB16 CHARACTER ETYPE,NTYPE,3

C INTEGER AF

C READ N, PASS, MODES, MECH

C COMMON /CB3/ AF,OMEGA

C COMMON /CB5/ THICK,AREA,DENSE,VOL,E(20)

C ETYPE(20),E(20)

C COMMON /CB7/ MECH,SPL,ANM,ETYPE,NTYPE

C COMMON /CB9/ N20,40

C COMMON /CH11/ MASS,ROCK

C COMMON /CH14/ PHI,OMEGA,MODES,70

C COMMON /CB15/ SIGMA,FI,FR

C DATA PI=3.14159,7

C DO FOR EACH ELEMENT

C NUMPE = 1, NUMPL
C INITIALIZE THE ACOUSTIC ENERGY INPUT AND ELEMENT ENERGY LEVELS

1250  S(I) = 0.
1251  E(I) = 0.
1252  C IF(I) THE TYPE OF EXCITATION IS ACOUSTIC,
1253      IF GETYPE(I) .NE. 10) GO TO 20
1254      C CALCULATE THE CRITICAL FREQUENCY
1255      CRFREQ = ECS(I) ** 2 / (1.0 - THICK(I)) * 
1256      * SIGDENSE(I) / EE(I))
1258      C CALCULATE THE RADIATION EFFICIENCY USING THE SIGF FUNCTION
1259      SIGMA = 10. ** SIGF(FREQ / CRFREQ)
1260      C THEN CALCULATE THE ACOUSTIC ENERGY INPUT
1261      S(I) = 4.33 * PI * ECS(I) ** 2 * 8.91 * 10. **
1262      * (SFL(I,AF) / 10. - THICK(I)) * SIGMA * ANN(1) /
1264      * (OMEGA ** 2)
1264      GO TO 100
1265      C ELSE IF(I) THE TYPE OF EXCITATION IS MECHANICAL,
1266      20 IF GETYPE(I) .NE. 10) GO TO 100
1267      C THEN IF(I) THE TYPE OF MECHANICAL INPUT IS RMS,
1268      IF OPTYPE(I) .NE. 103) GO TO 30
1269      C THEN CALCULATE THE ELEMENT ENERGY LEVEL
1270      EPS(I) = PASS(I) / OMEGA ** 2 * (MECH(I,AF) * G) ** 2
1271      IF (EPS(I) .LE. 100) GO TO 100
1272      C ELSE IF(2) THE TYPE OF MECHANICAL INPUT IS PSO,
1273      C THEN CALCULATE THE ELEMENT ENERGY LEVEL
1274      30 EPS = PASS(I) / (OMEGA**2)
1275      EPS(I) = FTEMP * MECH(I,AF) * (G**2) * (FREQ/4.33)
1276      C ENC IF(2)
1277      ENC IF(1)
1278      100 CONTINUE
1279      RETURN
1280      ENC
SUBROUTINE ANSWER

C THIS SUBROUTINE SOLVES THE SEA SYSTEM OF EQUATIONS FOR
C ELEMENT ENERGY LEVELS AND STORES THE SOLUTION IN ARRAY
C ARRIVAL TO BE PRINTED OUT BY RITER. ANSWER IS CALLED FROM
C THE MAIN PROGRAM.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C NAME TYPE DESCRIPTION
C ------ ------ -------------------
C ARBK REAL AVERAGE ACCELERATION
C ALPHAREAL MATRIX OF COEFFICIENTS
C E(20) REAL ELEMENT ENERGY LEVELS
C ETA(20) REAL DAMPING
C FREC REAL FREQUENCY
C HAST(20) REAL HASS
C MODES(20) REAL NUMBER OF MODES IN BANDWIDTH
C NUMEL INT MEMBER OF ELEMENTS
C OMEGA REAL 2*PI*FREQUENCY
C TYPE CHAR TYPE OF OUTPUT
C PHI(20) REAL COUPLING COEFFICIENT
C S201 REAL ACUSTIC ENERGY INPUT
C SFRG(20) REAL STARTING FREQUENCY
C SIZE INT SIZE OF REDUCED ALPH ARRAYS
C SLOPE(20) REAL SLOPE

C THE FOLLOWING COMMON BLOCKS ARE USED:
C COMMON OTHER PROGRAM UNITS USING THIS COMMON BLOCK
C ------------------
C CP2 MAIN,JPROP,EXCITE
C CP5 EPROP,REAL,MEMBER,PLATE,ROOM,ALPHA,ETC,JPROP,EXCITE
C CP7 EPROP,JINPUT,JPROP,EXCITE,SOLVE,RITE,BLOCK DATA
C CP8 EPROP,RITE,BLOCK DATA
C CP11 REAL,MEMBER,PLATE,ROOM,ALPHA,ETC,BLOCK DATA
C CP14 JPROP,EXCITE
C CP15 EXCITE,SOLVE
C CP16 SOLVE
C CP17 JPROP

C CHARACTER OTYPE
C INTEGER AF,SIZE
C REAL HASS,MODES
C DIMENSION AF(120),SMAT(20)
C CMND,CM/B,FREQ,OMEG
C CMON/CM/B/THICK/AREA(20),DENST(20),VOL(20),EC(20)
C CP/CM/B/ECC(20)
C CP/CUR/NUMEL,S
C CMN/CM/B/SLOPE(20),SFRG(20),ETA(20),OTYPE
C CP/M/CM/B/MASS(20)
C CMN/CM/B/PHI(20),ROOMS,REDMS(20)
C CMN/CM/B/S(20),F(20)
C CMN/CM/B/ALPHA(20,20)
C CMN/CM/B/ALPHA(20,40)

C END FOR EACH ELEMENT

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DO 150 I = 1, NULEM
C SET THE CANNING FACTOR EQUAL TO THE INPUT VALUET
C +1.2 = ETA(I)
C +SLOPE2(I) = SLOPE2(I)
1340 C IF DAMPING IS FREQUENCY DEPENDENT AND THE ANALYSIS FREQUENCY C +IS GREATER THAN THE STARTING FREQUENCY OF THE DEPENDENCY
1342 C CALCULATE THE CANNING FACTOR
1343 IF (SLOPE2(I) .LE. 0.5 AND FREQUENCY .GT. SPECTRAL) THEN
1344 ETA(I) = ETA(I) * (FREQUENCY / SPECTRAL)**SLOPE2(I)
1346 C IF THIS IS NOT THE LAST ELEMENT
1347 IF (I .EQ. NUMEL) GO TO 50
1348 C THEN FOR EACH SUCCESSING ELEMENT
1349 IPLUS = I + 1
1350 DC 40 J = IPLUS + NUMEL
1351 C CALCULATE THE I-TH ROW OF ALPHA TO THE RIGHT OF THE MAIN
1352 C DIAGONAL
1353 ALPHA(I,J) = -MODES(J) * PHI(J,I)
1354 C CALCULATE THE I-TH COLUMN OF ALPHA BELOW THE MAIN DIAGONAL
1355 ALPHA(I,J) = -MODES(J) * PHI(J,I)
1356 40 CONTINUE
1357 C END IF
1358 C CALCULATE ALPHA ON THE MAIN DIAGONAL
1359 30 ALPHA(I,I) = OMEGA + ETA(I)
1360 DC 80 J = 1, NUMEL
1361 C IF THE ENERGY LEVEL IS ALREADY KNOWN,
1362 IF (I .EQ. 0) GO TO 150
1363 C THEN BE FOR EACH ELEMENT
1364 DC 150 J = 1, NUMEL
1365 C IF THE ENERGY LEVEL IS ALREADY KNOWN,
1366 IF (I .EQ. 0) GO TO 150
1367 C THEN BE FOR EACH ELEMENT
1368 DC 150 J = 1, NUMEL
1369 C SUBTRACT FROM THE ACOSCLIC ENERGY ARRAY S THAT PORTION OF
1370 C THE VALUE WHICH CAME FROM THE PRODUCT OF THE ALPHA ARRAY
1371 C AND THE KNOWN ENERGY LEVEL
1372 C +SI(J) = SI(J) - ALPHA(J,I) * E(I)
1373 C +130 CONTINUE
1374 C DECREMENT SIZE TO SHOW THAT THE I-TH ROW AND COLUMN WILL BE
1375 C ELIMINATED FROM THE ALPHA ARRAY WHEN IT Becomes AMAT AND THE
1376 C I-TH ELEMENT FROM THE S ARRAY WHEN IT Becomes SMAT
1378 C SIZE = SIZE - 1
1380 C END IF
1382 C CALL Solve TO CREATE THE REDUCED ARRAYS AND SOLVE THE MATRIX
1384 C FILLING
1385 CALL SOLVE (AMAT,SMAT SIZE)
1386 C GO FOR EACH ELEMENT
1387 DC 200 I = 1, NUMEL
1388 C PUT THE SOLUTION IN
1389 C +AMAT(IF,AF) = E(I) + OMEGA ** 2 / MASS(I)
1390 C IF THE DEFAULT OUTPUT TYPE PSD IS SELECTED, PUT ARAR IN THAT FORM
1392 IF (DYTF .EQ. .TRUE.) GO TO 140
1394 AMAT(IF,AF) = AMAT(IF,AF) / (G ** 2 * FREQUENCY ** .5)
1293  GO TO 200
1294  C ELSE IF THE OUTPUT TYPE IS AWE, PUT AAAAA IN THAT FORM
1294  INC AAR(1:AF) = SQRT(AAB(1:AF)) / G
1296  C END IF
1297  200 CONTINUE
1298  RETURN
1299  END
SUBROUTINE SOLVE

C THIS SUBROUTINE CREATES MATRIX A + T F. ON ALPHA BY ELIMINATING
C THOSE ROWS AND COLUMNS REPRESENTING ELEMENTS FOR WHICH THE
C ENERGY LEVELS ARE ALREADY KNOWN. IN THE SAME WAY, WIDTH IS
C CREATED FROM S. SUBROUTINE GASSEM F. THE TRINARY SYSTEMS-MATRICES
C IS THEN CALLED TO SOLVE THE MATRIX E. ON MATRICX = MATICR FOR X.
C GASSEM PUTS THE SOLUTION IN MATICR, SO THIS SUBROUTINE PUTS
C THE RESULTS IN E., LEAVING INTACT THOSE ELEMENTS OF E
C WHICH WERE ALREADY KNOWN. SOLVE IS CALLED BY ANSWER.

C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:
C NAME TYPE DESCRIPTION
C ALPH(20*20) REAL MATRIX OF COEFFICIENTS
C AMAT(SIZE*SIZE) REAL REDUCED ALPHA ARRAY
C DET REAL DETERMINANT OF AMAT
C FE(20) REAL ELEMENT ENERGY LEVELS
C NPEL INT NUMBER OF ELEMENTS
C S(20) REAL ACOUSTIC ENERGY INPUT
C SIZE INT SIZE OF AMAT AND MATICR
C SMAT(SIZE) REAL REDUCED S ARRAY

C THE FOLLOWING COMMON BLOCKS ARE USED:
C BLOCK OTHER PROGRAM UNITS USING THIS COMMON BLOCK
C ------ ----------------------------------
C C87 EPARP, INPUT, JPROP, EXCITE, ANSWER, RATEP, BLOCK DATA
C C815 EXCITE, ANSWER
C C816 ANSWER

INTEGER SIZE
DIMENSION AMAT(SIZE,SIZE), SMAT(SIZE)
COP/1 C877 NPEL, C878 COP/1 C815 /S(20), E(20)
COP/1 C816 /ALPHA(20*20)
350 FORMAT (19*** ERROR *** THE DETERMINANT OF THE SEA T
1 THE EVALUATION MATRIX IS 0, IF IT HENCE THERE IS NO SOLUTION.1
2 THE ERROR WILL CAUSE THE PROGRAM TO ABORT.1
$ THIS ERROR WAS DISCOVERED BY SUBROUTINE SOLVE.1)

C INITIALIZE II
II = 0
C DO FOR EACH ELEMENT FOR WHICH ENERGY LEVELS ARE UNKNOWN
DO 10 II = 1, SIZE
10 IC INCREN II
C IF THE ENERGY LEVEL FOR ELEMENT II IS KNOWN, GO TO NEXT ELEMENT
IF (E(II) .LT. 0.0) GO TO 10
C ELSE INITIALIZE J1
J1 = 0
C DO FOR EACH ELEMENT FOR WHICH ENERGY LEVELS ARE UNKNOWN
DO 40 J1 = 1, SIZE
40 IC INCREN J1
C IF ENERGY LEVEL FOR ELEMENT J1 IS KNOWN, GO TO NEXT ELEMENT

SUBROUTINE SOLVE

1456 IF (E(JJ) .NE. 0.) GO TO 30
1457 C ELSE PUT THE VALUE OF ALPHA FOR ELEMENT PAIR I1,J1 IN AMAT
1458 AMAT(I1,J1) = ALPHA(I1,J1)
1459 C END IF
1460 80 CONTINUE
1461 C PUT THE VALUE OF S FOR ELEMENT I1 IN SMAT
1462 SMAT(I1) = S(I1)
1463 C 180 CONTINUE
1464 C SOLVE THE MATRIX EQUATION
1465 CALL GSSBP (AMAT,SIZE,1,DET,SMAT)
1466 C IF THE DETERMINANT OF AMAT IS 0:
1467 IF (DET .NE. 0.) GO TO 150
1468 C THEN WRITE AN ERROR MESSAGE AND TERMINATE THE PROGRAM
1469 WRITE (6,380)
1470 CALL FERR
1471 C ELSE INITIALIZE I1 TO 1, REPRESENTING THE FIRST VALUE
1472 C RETURNED BY GASSEM TO ARRAY SMAT
1473 150 I1 = 1
1474 C CC FOR EACH ELEMENT
1475 200 I = 1, MUEIL
1476 C IF THE ELEMENT ENERGY LEVEL WAS UNKNOWN:
1477 IF (E(I) .NE. 0.) GO TO 200
1478 C THEN PLACE ITS VALUE IN THE ARRAY E
1479 E(I) = SMAT(I1)
1480 C INCREMENT I1
1481 I1 = I1 + 1
1482 C END IF
1483 200 CONTINUE
1484 RETURN
1485 END
SUBROUTINE RITER  
C THIS SUBROUTINE WRITES OUT THE RESULTS THAT ARE STORED IN 
C ARRAY RITER. RITER IS CALLED FROM THE MAIN PROGRAM.  
C 
C THE FOLLOWING VARIABLES ARE USED IN THIS PROGRAM UNIT:  
C NAME TYPE DESCRIPTION                             
C ------ ---- (-- --)                                
C ABAR(20,20) REAL AVERAGE ACCELERATION              
C FTAB(40,40) REAL TABLE OF ANALYSIS FREQUENCIES     
C NUMAF INT number of analysis frequencies           
C SUPEL INT number of elements                       
C OTYPE CHAR type of output                          
C 
C THE FOLLOWING COMMON BLOCKS ARE USED:              
C BLOCK OTHER PROGRAM UNITS USING THIS COMMON BLOCK  
C ------ ---------------------------------------     
C CBL1 MAIN,EPROP,BEAR,MEMBR,PLATE,ROOP,CYLIN,BLOCK DATA 
C CP7 EPROP,INPUT,PROP,EXCITE,ANALYSIS,SOLVE,BLOCK DATA 
C CH8 EPROP,ANSWER,BLOCK DATA                        
C CBL17 ANSWER                                        
C 
C CHARACTER#20 TITLE / 1 PSD LEVELS (G=2/HZ) /       
C * RNS / 7 OTYPE=5                                   
C COMMON /CB1/ FTAB(40,40),NUMAF,FREQ1               
C COMMON /CB7/ NUMEL=6                                
C COMMON /CB8/ SLOPE(20),SFREQ(20),ETA(20),OTYPE     
C COMMON /CB17/ ABAR(20,40)                          
C 100 FORMAT (/4/5X,T10F9.2,2X,A20/,                
C 1 4X,FREQ(HZ),4X,ELEMENT,4X,I2:2))               
C 110 FORMAT (F12.2,4(1PE15.5E2))                    
C IF THE TYPE OF OUTPUT IS RNS, CHANGE THE HEADING ACCORDINGLY 
C IF OTYPE = C : TITLE = RNS                          
C DO FOR EACH ELEMENT IN GROUPS OF 4                 
C DO 20 I = 1, NUMEL, 4                             
C IPLU35 WILL BE THE TERMINAL VARIABLE FOR IMPLIED DD LOOPS TO 
C PREDUCE 4 COLUMNS UNLESS THERE ARE FEWER THAN 4 ELEMENTS 
C REPAIRING TO BE LISTED                             
C 1P26 = MIN(NUMEL, I = 3)                          
C WRITE THE HEADING FOR THESE 4 ELEMENTS             
C WRITE (6,100) TITLE(,J,J=1,IPLU35)                 
C DC FOR EACH ANALYSIS FREQUENCY                     
C DO 10 J = 1, NUMAF                                 
C WRITE THE RESULTS                                   
C WRITE (6,110) FTAB(4),CHAREX,J,4X,K,IPLU35)       
1C CONTINUE                                           
20 CONTINUE                                           
RETURN                                              
END
The following variables are used in this program unit:

- **NAME**: Description
- **ERROR**: Log: True if a fatal error has occurred
- **FREQ(40)**: Real table of analysis frequencies
- **G**: Real gravitational constant
- **INPUT**: Integer number of input records read
- **MASS(20)**: Real Mass
- **N(20,40)**: Real modal density
- **SLOPE**: Real slope

The following common blocks are used:

- **BLOCK**: Other program units using this common block
- **CB1**: MAIN, EPROP, BEAM, KER, PLATE, RCPP, CYLIN, RITER
- **CB2**: EPROP, INPUT
- **CB5**: EPROP, INPUT, JPROP, EXCITE, ANSWER
- **CB9**: EPROP, BEAM, KER, PLATE, RCPP, CYLIN, JPROP, EXCITE, ANSWER
- **CB10**: EPROP, INPUT

Real variables:

- **N, MASS**: Logical error
- **COMMON (CB1, FTAB(40), NUMAF, FREG)**
- **COMMON (CB2, ERROR)**
- **COMMON (CB7, NUMEL6)**
- **COMMON (CB8, SLOPE(20), FREQ(40), ETA(20), TYPE)**
- **COMMON (CB9, N(20, 40))**
- **COMMON (CB10, INPUT)**
- **COMMON (CB11, MASS(20))**

Data:

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<tr>
<th>DATA</th>
<th>FREQ</th>
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<th>ERROR</th>
</tr>
</thead>
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<td>0.0</td>
<td>1.0</td>
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Initial conditions:

1. **N**: 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
2. **N**: 1.0, 2.0, 1.0, 2.0, 1.0, 2.0, 1.0, 2.0, 1.0, 2.0
3. **N**: 3.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
4. **N**: 4.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0

Final conditions:

1. **N**: 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
2. **N**: 1.0, 2.0, 1.0, 2.0, 1.0, 2.0, 1.0, 2.0, 1.0, 2.0
3. **N**: 3.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
4. **N**: 4.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
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<th>YY</th>
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<th>MM</th>
<th>MM</th>
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<td>GG</td>
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<td>FF</td>
<td>IIIIII</td>
<td>LLLLLLLLL</td>
<td>EEEEEEEE</td>
</tr>
</tbody>
</table>
Appendix II

SEA PROGRAM LOGIC AND FLOW
1. EPROP

READ INITIAL INFORMATION

NUMBER OF ELEMENTS IN RANGE?

YES

NUMBER OF ANALYSIS FREQUENCIES IN RANGE?

YES

METRIC UNIT INPUT?

YES

CHANGE GRAVITATIONAL CONSTANT TO METRIC UNITS

NO

LOOP FOR EACH ANALYSIS FREQUENCY

EXIT

3

EPROPZ

RETURN

WRITE ERROR MESSAGE

WRITE ERROR MESSAGE

WRITE ERROR MESSAGE

SET ERROR FLAG

WRITE ERROR MESSAGE

MULTIPLY FREQUENCY BY FIRST FREQUENCY

GENERAL PAGE IS IN LOW QUALITY
4

BEAM

CALCULATE THE PARTIAL SUB-ELEMENT MODAL DENSITY

IS STIFFNESS REDUCTION REQUIRED?

YES

REDUCE BY

\frac{1}{\sqrt{2}}

NO

LOOP FOR EACH ANALYSIS FREQUENCY

SUM MASS TO THE ELEMENT MASS

RETURN

CALCULATE ANGULAR VELOCITY

CALCULATE SUB-ELEMENT MODAL DENSITY

SUM TO THE ELEMENT MODAL DENSITY

RETURN

SET ELEMENT VALUES TO SUB-ELEMENT VALUES

IS THE MAIN SUB-ELEMENT?

YES

RETURN

NO
MEMBR

CALCULATE THE PARTIAL SUB-ELEMENT MODAL DENSITY

YES

REDUCE BY \( \frac{1}{2} \)

NO

LOOP FOR EACH ANALYSIS FREQUENCY

SUM MASS TO THE ELEMENT MASS

IS THE MAIN SUB-ELEMENT

YES

RETURN

NO

SET ELEMENT VALUES TO SUB-ELEMENT VALUES

SET FLAG TO INDICATE THAT FOLLOWING SUB-ELEMENTS ARE NOT MAIN

RETURN

CALCULATE ANGULAR VELOCITY

CALCULATE SUB-ELEMENT MODAL DENSITY

SUM TO THE ELEMENT MODAL DENSITY
PLATE

CALCULATE THE SUB-ELEMENT MODAL DENSITY

IS STIFFNESS REDUCTION REQUIRED?

YES

REDUCE BY $\frac{1}{12}$

NO

LOOP FOR EACH ANALYSIS FREQUENCY

SUM MASS TO THE ELEMENT MASS

IS THIS THE MAIN ELEMENT?

NO

RETURN

YES

SET ELEMENT VALUES TO SUB-ELEMENT VALUES

SET FLAG TO INDICATE THAT FOLLOWING SUB ELEMENTS ARE NOT MAIN

RETURN
ROOM

CALCULATE THE PARTIAL SUB-ELEMENT MODED DENSITY

IS STIFFNESS REDUCTION REQUIRED?

REDUCE BY \( \frac{1}{\sqrt{2}} \)

LOOP FOR EACH ANALYSIS FREQUENCY

SUM MASS TO THE ELEMENT MASS

CALCULATE ANGULAR VELOCITY

IS THIS THE SUPER-ELEMENT?

RETURN

CALCULATE SUB-ELEMENT MODAL DENSITY

SET ELEMENT VALUES TO SUB-ELEMENT VALUES

SET FLAG TO INDICATE THAT FOLLOWING SUB-ELEMENTS ARE NOT MAIN

SUM TO THE ELEMENT MODAL DENSITY

RETURN
CALCULATE THE SUB-ELEMENT MODAL DENSITY

IS STIFFNESS REDUCED BY REQUIREMENT?

REPLACE Y

LOOP FOR EACH ANALYSIS FREQUENCY

CALCULATE ANGULAR VELOCITY

CALCULATE THE FREQUENCY CRITERION

IS CRITERION > 1?

RECALCULATE SUB-ELEMENT MODAL DENSITY

SUM TO THE ELEMENT MODAL DENSITY

SET ELEMENT VALUES TO SUB-ELEMENT VALUES

SET FLAG TO INDICATE THAT FOLLOWING SUB-ELEMENTS ARE NOT MAIN

RETURN
SIGF

LOOP FOR EACH ELEMENT OF THE TABLE EXCEPT FIRST AND LAST

X ≤ THIS ELEMENT OF THE TABLE?

NO

EXIT

YES

SET INDEX TO 16 (= NUMBER OF ELEMENTS IN THE TABLE)

LOOP NEXT ELEMENT OF THE TABLE?

NO

CALCULATE SIGF AS INCREASING FUNCTION

INTERPOLATE

RETURN

YES

CALCULATE SIGF AS DECREASING FUNCTION

INTERPOLATE

RETURN

THE TABLE CONSISTS OF 16 VALUES; THE FIRST AND LAST ARE USED FOR INTERPOLATION
EXCITL

LOOP FOR EACH ELEMENT

RETURN

TYPE OF EXCITATION = ACOUSTIC?

YLS

CALCULATE CRITICAL FREQUENCY

12

SIGF

CALCULATE RADIATION EFFICIENCY

CALCULATE ACOUSTIC ENERGY INPUT

TYPE OF EXCITATION = MECHANICAL?

YES

CALCULATE ELEMENT ENERGY LEVEL AS PSD

TYPE OF MECHANICAL INPUT = RMS?

NO

NO

YES

CALCULATE ELEMENT ENERGY LEVEL AS RMS
Appendix III

SEA PROGRAM INPUT LIST

MATERIALS EXPERIMENT ASSEMBLY - EXAMPLE 2
### STATISTICAL ENERGY ANALYSIS OF COMPLEX STRUCTURES

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<td>TYPE OF OUTPUT = PSD</td>
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<td>TYPE OF MECHANICAL INPUT =</td>
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<td>SLOPE = 0.</td>
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<td>SOUND PRESSURE LEVELS</td>
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<td>VOLUME = 0.</td>
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MODULUS OF ELASTICITY = 1.00000E+07
THICKNESS = 2.50000E-01
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POISSONS RATIO = 3.30000E-01
LENGTH = 0.
PRESSURE = 0.

STIFFNESS REDUCTION REQUIRED = F
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = C.
ADDED MASS = 0.

SUB-ELEMENT NUMBER = 19
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MODULUS OF ELASTICITY = 1.00000E+07
THICKNESS = 2.00000E-01
AREA = 1.55250E+01
POISSONS RATIO = 3.30000E-01
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STIFFNESS REDUCTION REQUIRED = F
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = C.
ADDED MASS = 0.

SUB-ELEMENT NUMBER = 20
TYPE OF SUB-ELEMENT = P
DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
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SLOPE = -0.30000E-01
STARTING FREQUENCY = 2.50000E+02

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DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
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POISSONS RATIO = 3.30000E-01
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RADIUS = 0.
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SUB-ELEMENT NUMBER = 2
TYPE OF SUB-ELEMENT = P
DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
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AREA = 7.36000E-02
POISSONS RATIO = 3.30000E-01
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STIFFNESS REDUCTION REQUIRED = F
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = c.
ADDED MASS = 0.
SUB-ELEMENT NUMBER = 3
TYPE OF SUB-ELEMENT = P
DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
THICKNESS = 2.00000E-01
AREA = 1.98000E-02
POISSONS RATIO = 3.30000E-01
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PRESSURE = 0.
STIFFNESS REDUCTION REQUIRED = F
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = c.
ADDED MASS = 0.
SUB-ELEMENT NUMBER = 4
TYPE OF SUB-ELEMENT = P
DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
THICKNESS = 2.50000E-01
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POISSONS RATIO = 3.30000E-01
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STIFFNESS REDUCTION REQUIRED = F
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = c.
ADDED MASS = 0.
SUB-ELEMENT NUMBER = 3
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TYPE OF EXCITATION =
TYPE OF MECHANICAL INPUT =
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SLOPE = -0.30480E-01
STARTING FREQUENCY = 2.50000E+02
SUB-ELEMENT NUMBER = 1
TYPE OF SUB-ELEMENT = P
DENSITY = 2.61700E-04
MODULUS OF ELASTICITY = 1.00000E+07
THICKNESS = 6.50000E-01
AREA = 9.76300E-01
POISSONS RATIO = 3.30000E-01
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STIFFNESS REDUCTION REQUIRED = T
RADIUS = 0.
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SPEED OF SOUND IN ROOM MEDIUM = c.
ADDED MASS = 1.44800E-01
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RADIUS = 0.
VOLUME = 0.
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ADDED MASS = 0.

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THICKNESS = 3.50000E-01
AREA = 6.71110E+02
POISSON'S RATIO = 3.30000E-01
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MODULUS OF ELASTICITY = 1.00000E+07
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POISSON'S RATIO = 3.30000E-01
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PRESSURE = 0.
STIFFNESS REDUCTION REQUIRED = T
RADIUS = 0.
VOLUME = 0.
SPEED OF SOUND IN ROOM MEDIUM = 0.
ADDED MASS = 0.
<table>
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<tr>
<th>CENTER FREQ (Hz)</th>
<th>MODAL DENSITY - MODES / (RAD/SEC)</th>
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**Record Number**

**Data Read From Unit 3**

1. **First Element = 1**
2. **Second Element = 2**
3. **Type of Joint = BJ**
4. **Number of Stays = 0**
JOINT LENGTH = 7.06700E+01
THICKNESS OF FIRST ELEMENT = 2.50000E+01
THICKNESS OF SECOND ELEMENT = 1.90000E-06
ACOUSTIC SPACE DENSITY = 0.
BEAM LENGTH = 0.
INSERTION LOSS FACTOR = 1.00000E+02
FIRST ELEMENT = 1
SECOND ELEMENT = 3
TYPE OF JOINT = BJ
NUMBER OF SIDES = 0
JOINT LENGTH = 1.23340E+02
THICKNESS OF FIRST ELEMENT = 2.50000E+01
THICKNESS OF SECOND ELEMENT = 7.00000E-01
ACOUSTIC SPACE DENSITY = 0.
BEAM LENGTH = 0.
INSERTION LOSS FACTOR = 1.00000E+02
FIRST ELEMENT = 1
SECOND ELEMENT = 4
TYPE OF JOINT = BJ
NUMBER OF SIDES = 0
JOINT LENGTH = 4.00000E+00
THICKNESS OF FIRST ELEMENT = 2.50000E+01
THICKNESS OF SECOND ELEMENT = 2.50000E-01
ACOUSTIC SPACE DENSITY = 0.
BEAM LENGTH = 0.
INSERTION LOSS FACTOR = 1.00000E+02
FIRST ELEMENT = 1
SECOND ELEMENT = 5
TYPE OF JOINT = BJ
NUMBER OF SIDES = 0
JOINT LENGTH = 1.00000E+01
THICKNESS OF FIRST ELEMENT = 7.00000E-01
THICKNESS OF SECOND ELEMENT = 2.50000E-01
ACOUSTIC SPACE DENSITY = 0.
BEAM LENGTH = 0.
INSERTION LOSS FACTOR = 1.00000E+02
FIRST ELEMENT = 1
SECOND ELEMENT = 6
TYPE OF JOINT = BJ
NUMBER OF SIDES = 0
JOINT LENGTH = 2.67500E+02
THICKNESS OF FIRST ELEMENT = 2.50000E-01
THICKNESS OF SECOND ELEMENT = 3.45000E-01
ACOUSTIC SPACE DENSITY = 0.
BEAM LENGTH = 0.
INSERTION LOSS FACTOR = 1.00000E+02