DEVELOPMENT OF OPTIMIZATION PROCEDURE FOR DESIGN OF PACKAGE CUSHIONING

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Prepared for:
Army Natick Laboratories
January 1975
The objective of this project was to develop a computer-aided design procedure which will utilize an optimization technique that will select available materials and define the material or combinations of materials that will provide the protection to a packaged item from the expected shipping environment, at the least cost.

(Continued on reverse side)
20. Abstract (Contd.)

The basic cushioning problem is assumed to be one-dimensional and must therefore be solved independently for each of the three orthogonal directions. It is recognized that such a formulation is a considerable simplification from reality; however, in order to develop an optimization scheme that can utilize the bulk of presently available data, it is necessary to start from this point.

The most recent design developments for vibration isolation recognize the great utility of the complex modulus of a material for characterizing its vibration isolation properties. Therefore, the complex modulus method is the basis for our mathematical formulation.

A direct mathematical method for shock isolation is being used. It is a relatively simple design approach which can be formulated for mathematical computations by use of the typical cushioning materials design data, which is peak acceleration versus static stress for given drop heights.

Based on the data available, the temperature influence on materials will be utilized in this program. Ambient temperature variations over wide ranges have a significant influence on cushioning material properties. Unfortunately data for such variations are extremely scanty.
FOREWORD

This report prepared by the Southwest Research Institute under contract DAAG17-73-C-0239 describes a computer program for the least cost design of package cushioning systems. The effort was part of a program for the optimum design of packaging systems sponsored through the AMC CAD-E program under project no. 1E662703A090, Design, Analysis and Optimization of Structures. Requests for the program resulting from this work can be directed to Earl C. Steeves or Frank D. Barca at the U. S. Army Natick Laboratories.
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ACKNOWLEDGEMENTS

The authors thank Dr. E. A. Ripperger, Director of Engineering Mechanics Research Laboratory, The University of Texas at Austin, for his assistance as consultant on this project.
1. INTRODUCTION

The objective of this project was to develop the computer software for a cushion property and cost optimization procedure for the design selection from available package cushioning materials. The design problem relates to the use of existing cushioning materials to protect large quantity supply items from shock and vibration damage. Current state-of-the-art design procedures and criteria were used.

The General Equipment and Packaging Laboratory (GEPL), Natick Laboratories, has the responsibility to design and specify shipping packages for a large number of supply items which are shipped in large quantities. Current design procedures do not use computer-aided design (CAD) techniques; therefore, in the interest of time and economy, it was desirable to incorporate into computer-aided design the procedures and criteria that constitute the current state-of-the-art. Thus, development of new design procedures was not within the scope of work of this project.

The approach used in this project was to implement a computer-aided design (CAD) procedure which can be used to select from the available materials data files the material or materials that will protect the item to be shipped for the least cost. The shipping environments were accounted for in terms of shock vibration. The temperature effects on the package cushioning material properties were allowed for in the stored data. Thus, the CAD program optimizes least cost for the materials that will provide the necessary protection.
Literature Review

As with any effective research and development program, it was imperative to do a comprehensive literature study prior to and throughout the entire effort. SwRI has conducted a comprehensive literature survey related to the problem of the development of optimization procedure for design of package cushioning. See Bibliography.

As listed in the Bibliography, SwRI reviewed over 114 publications for package cushioning design procedures and materials design data. Some of the publications reviewed were completely unrelated; they were omitted from the Bibliography.

The Theory and Practice of Cushion Design - SVM 2, by J. S. Moda (1) is probably the best single reference book which provides the most recent package cushioning design data, materials data, and references. The theory of package cushioning design has been advanced more rapidly than the materials data that can be used in a practical manner with the theory.

SwRI project team personnel spent many hours of telephone contact with people associated with package cushioning materials trying to ascertain the availability and to obtain materials data related to both shock and vibration.

Table I illustrates the organizations contacted and the data supplied.

The Engineering Design Handbook Package and Pack Engineering (2) provides information about both shock and vibration environments.

The MIL-STD-810E, Military Standard, Environmental Test Methods (3), provides information about how packages are tested to specific shock and vibration conditions. Although the test conditions do not exactly duplicate what a package would be subjected to in actual shipment, the test conditions are intended to approximate actual shipping conditions.

Since the acceleration levels for shock for package cushioning materials are in the form of parametric curves, consideration was given.

*Superscript numbers in parentheses denote References which are listed on page 182 of this report.*

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<thead>
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<th>Organization</th>
<th>Material Data Sought</th>
<th>Data Supplied</th>
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</thead>
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<tr>
<td>Sinclair Koppers Company</td>
<td>Expanded polystyrene (Molded DYLITE®)</td>
<td>Room temp. $G_m$, $c_{st}$, some transmissibility.</td>
</tr>
<tr>
<td>Nopco Chemical Div. of Diamond-Shamrock Company</td>
<td>Polyurethane</td>
<td>None</td>
</tr>
<tr>
<td>U. S. Forest Products Lab</td>
<td>Anything available</td>
<td>None</td>
</tr>
<tr>
<td>Du Pont Company</td>
<td>Polyurethane</td>
<td>Nothing outside of that in 304</td>
</tr>
<tr>
<td>Package Evaluation Lab, Wright-Patterson AFB</td>
<td>Anything available</td>
<td>Only what is in 304. Some data on Air Cap, SD-240. Transmissibility data being developed under current contract.</td>
</tr>
<tr>
<td>Dow Chemicals</td>
<td>Expanded Polyethylene</td>
<td>Some additional data to 304</td>
</tr>
<tr>
<td>Michigan State Univ., School of Packaging</td>
<td>Anything available</td>
<td>None</td>
</tr>
<tr>
<td>Goodyear Tire Co. Foam Prods. Div.</td>
<td>Urethane Cushions</td>
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</tr>
<tr>
<td>Owens-Corning fiberglass Corp.</td>
<td>fiberglass</td>
<td>None</td>
</tr>
<tr>
<td>Armour &amp; Co.</td>
<td>Polyurethane Rubberized Hair</td>
<td>None</td>
</tr>
<tr>
<td>Flextron Industries</td>
<td>Curled Hair</td>
<td>None</td>
</tr>
<tr>
<td>3M Company</td>
<td>Polyester</td>
<td>None</td>
</tr>
<tr>
<td>Kimberly-Clark Corp.</td>
<td>Cellulose Wadding</td>
<td>None</td>
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TABLE I (Cont’d.)
MATERIALS DATA CONTACTS

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<th>Material Data Sought</th>
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<tr>
<td>The Williamson Company</td>
<td>Polyvinyl Chloride</td>
<td>None</td>
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<tr>
<td>Union Carbide Corp.</td>
<td>Polyester, Polyether</td>
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<tr>
<td>B. F. Goodrich Chemical Co.</td>
<td>Polyurethane</td>
<td>None</td>
</tr>
<tr>
<td>Continental Felt Co.</td>
<td>Felt</td>
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<tr>
<td>Armstrong Cork Company</td>
<td>Cork</td>
<td>None</td>
</tr>
<tr>
<td>Chicago Curled Hair Co.</td>
<td>Curled Hair</td>
<td>None</td>
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<tr>
<td>Stearns and Foster Co.</td>
<td>Cellulose Wadding</td>
<td>None</td>
</tr>
<tr>
<td>Boeing Aerospace Co.</td>
<td>Polyurethane Foam</td>
<td>None (Classified)</td>
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<td>Sheller-Globe Corp.</td>
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<td>GAF Corp.</td>
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<tr>
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<td>Anything available</td>
<td>Numerous Reports</td>
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<tr>
<td>Janesville Cotton Mills</td>
<td>Curled Hair (Hairkore)</td>
<td>None</td>
</tr>
<tr>
<td>Blockson &amp; Co.</td>
<td>Rubberized Curled Hair</td>
<td>Very little data</td>
</tr>
<tr>
<td>Goodyear Aerospace Corp.</td>
<td>Fiberglass</td>
<td>None</td>
</tr>
<tr>
<td>Tezzeo Chemicals, Inc. (Houston)</td>
<td>Polyurethane</td>
<td>None</td>
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4
to determine the best way to tabulate the voluminous shock data. An inter-
polation procedure was developed based upon "Digital Computer Program
EMI 494 Aerodynamic Interpolation"(4).

Since there has been much concern about using package cushioning
materials to protect against shock damage, most of the available materials
performance data for protection against shock are found in MIL-HDBK-304,
Package Cushioning Design(5).

The report "Vibration Testing of Resilient Package Cushioning
Materials"(6) provided the most useable vibration data. There is very
little vibration data available. The lack of good frequency response and
phase angle data for package cushioning materials according to the varying
parameters, i.e.,

- Density (lb/ft³)
- Static Stress (lb/in.²)
- Thickness (in.)
- Temperature (°F),

is hindering the effective use of the CAD program that was developed.

Some vibration data were obtained from the report "Resilient
Cushioning Materials"(7). The vibration data for package cushioning
needed some standard form of presentation. In this CAD Program, the
vibration-related parameters for each material that were standardized
are:

- Storage modulus, $E_r$, as a function of temperature and
  frequency
- Loss tangent, $\tan \delta$, as a function of temperature and
  frequency.

Shock data were obtained from the report "Test Results on Air-
Cap SD-240 Cushioning Material"(8). Frequency response vibration data
were not available.

For those materials included in the initial ten materials cataloged
that did not have available actual data related to the performance of the
material under shock and vibration environments, an estimate of the phys-
ical parameters was made and so indicated in the materials information
tabulation (Section C).
It is recommended that shock data (i.e., peak acceleration, g) generated for use with the CAD Program be in the parametric curve form used in MIL-HDBK-304; that is, with the parameters:

- Drop height (in.)
- Static Stress (lb/in.²)
- Material thickness (in.)
- Environmental Temperature (°F)
- Material Density (lb/ft³)

It is recommended that vibration data (i.e., storage modulus, \(E_r\), and loss tangent, \(\tan \delta\)) for use with this CAD Program be obtained from frequency response curves with phase angle plots for the parameters:

- Material Density (lb/ft³)
- Static Stress (lb/in.²)
- Material Thickness (in.)
- Environmental Temperature (°F)

It is our understanding that additional materials performance data under vibration conditions are being generated under contract for Wright-Patterson AFB, titled "Package Cushioning Materials Testing." Data from that work are not available.

B. Mathematical Modeling of Cushioning Material

1. Description of Problem

The basic cushioning problem is illustrated in Figure 1. The outer container as well as the inner item is assumed to be rigid, and the time-dependent input force \(P(t)\) is uniformly distributed across the outer container base, and its resultant acts through the center of gravity of the isolated item of weight \(W\). We also assume that the problem is one-dimensional, and must therefore be solved independently for each of the three orthogonal directions. It is recognized that such a formulation is a considerable simplification from reality; however, in order to develop an optimization scheme that can utilize the bulk of presently available data, it is necessary to start from this point.

At the outset we assume that we have the following statement of the problem. The weight \(W\) and its dimensions are given. Therefore, the supported area \(A\) is also given. The loading from \(P(t)\) is given in terms of a power spectral density, or RMS level and discrete spectrum for
vibration excitation, and is given in terms of an initial drop height $h$ for shock excitation. Finally, we are given the damage criteria for the item. For shock it will be damage fragility rating $G_F$ transmitted to it at the interface, and for vibration it will be maximum RMS vibration level $Y_F$ and possibly an associated power spectrum $S_F$ of acceleration transmitted at the interface. With this information given, we seek a suitable material of thickness $T_c$ that can satisfy the above criteria.

It is recognized that some of the literature considers various forms for the shock excitation including acceleration pulses, velocity pulses, etc. However, most of the design information appears to be presented in terms of equivalent drop height, and since a transformation to this parameter can be accomplished in any case, we use it as the most feasible design parameter.

2. Vibration Isolation at Room Temperature

The most recent design developments\(^{(1)}\) recognize the great utility of the complex modulus of a material for characterizing its vibration isolation properties. A complex modulus can be thought of as existing for any material exhibiting creep or relaxation behavior. Also, by
using the complex modulus for materials, both amplitude and phase angle are considered in the mathematical treatment for vibration analysis. Therefore, we used it in our mathematical formulation. However, it is recognized that complete data on this parameter are not available for all materials to be considered. Therefore, it has been necessary to estimate it from other parameters, such as static elastic modulus, material damping, etc. that are available. Therefore, consistent with notation in Reference 1, the complex modulus is

\[ E^* = E_r + iE_i = E_r (1 + i \tan \delta) \]  \hspace{1cm} (1)

where \( E_r \) is the storage modulus, \( E_i \) is the loss modulus, and \( \tan \delta \) is the loss tangent.

In view of the above formulation of the problem, the natural frequency of the supported item in the cushioning material is

\[ \omega_n^2 = A_c E_r \omega_n / T_c W \]  \hspace{1cm} (2)

where \( A_c \) is the supported area, \( T_c \) is the cushioning material thickness, \( W \) is the weight, \( E_r \) is the storage modulus at frequency, \( \omega_n \), and \( g \) is standard gravity (note that in this formulation the compliance contribution from the cushioning material outside the isolated object is ignored). With this, the squared magnitude of the transfer function for the material is

\[ |H(\omega)|^2 = \left\{ \left[ 1 - \frac{\omega^2}{\omega_n^2} \frac{E_r}{E_r} \right]^2 + \tan^2 \delta \right\}^{-1} \]  \hspace{1cm} (3)

where \( \omega \) is steady-state excitation frequency.

If \( P(t) \) is a steady-state sinusoidal input, then the complex transmitted acceleration is

\[ Y(\omega) = H(\omega) x(\omega) \]

where \( x(\omega) \) is the complex excitation. If \( P(t) \) is a combination excitation which may include random and multiple sine components (which is usually the case), then it will be characterized in terms of its stationary acceleration power spectrum \( S_x(\omega) \). In this case, the power spectrum of the transmitted acceleration response \( S_y(\omega) \) is

\[ S_y(\omega) = |H(\omega)|^2 S_x(\omega) \]  \hspace{1cm} (4)
Equation (4) is directly from Equation (3.137), page 99, Bendat and Piersol. Chapter 3 of this reference, "Mathematical Theory for Analyzing Random Data" provides the basis and derivation for Equation (4).

In general Equation (4) [i.e., Equation (3.137)\(^{(1c)}\)] is obtained from the transformation of [i.e., Equation (3.134)\(^{(1c)}\)]

\[
R_y(\tau) = \int_0^\infty h(\xi) h(\eta) R_x(\tau + \xi - \eta) \, d\xi \, d\eta
\]

(5)

where \(R_x(\tau)\) and \(R_y(\tau)\) are autocorrelation functions of the time displacement, \(\tau\), to a complex-valued frequency domain by taking Fourier transforms.

The latter approach was used in most cases, since the power spectral density formulation can always be used even for sinusoidal input, providing that the measured excitation data has been analyzed with a finite bandwidth resolution (which will always be the practical case), and this bandwidth is specified with the data.

The design problem is now clear. Upon selection of a trial material having a given modulus \(E_T\) and \(E_{TN}\), we must solve for the thickness \(T_C\) from Equations (2), (3), and (4), with all other information given. The effect of temperature on the problem is discussed later.

The CAD Program allows three options to the users regarding the vibration environment specification. These options are:

1. MIL-STD-810B Excitation (i.e., sinusoidal)
2. Multiple Sine Excitation
3. Random Excitation

**Vibration Optimization for MIL-STD-810B Type Excitation**

This excitation assumes a single sine wave is applied at the natural frequency for amplitudes given in the MIL-STD. The excitation at each i-octave band is calculated from Equation (2) for

\[
\omega_j = \omega_{ni}
\]

(6)

and

\[
x_{oi} = |T_{oij}| x_j
\]

(7)
also

\[ T_{ci} = \frac{A_c E \eta_{ni} g}{w_j^2 W} \] (8)

The smallest \( T_{ci} \) of all frequency bands that satisfies \( x_{oi} \leq x_{allow} \) is the optimum thickness value we seek.

The 1-octave band center frequencies, \( w_j \), are stored in a DATA statement in the subroutine VIBRTN as an array \( OB(I) \). The stored frequencies are:

1., 2., 4., 8., 16., 31.5, 63., 125., 250., 500., and 1000. Hz. These frequencies, Hz, are subsequently changed by multiplying by \( 2\pi \) to obtain the frequencies in rad/sec. These frequencies were chosen based upon the International Standardization Organization (I.S.O.) Recommendation R.266, Preferred Frequencies for Acoustical Measurements.

**Vibration Optimization for Multiple Sine Excitation**

Single or multiple sine components each at a fixed amplitude and frequency are the excitation. Octave band transfer functions and thicknesses are again computed from Equations (2) and (3). For each octave band, the total response becomes (conservative)

\[ x_{oi} = \sum_j |T_{oij}| x_j \] (9)

Again the smallest \( T_{ci} \) of all frequency bands that satisfies \( x_{oi} \leq x_{allow} \) is the optimum thickness value that we seek.

**Vibration Optimization from Random Excitation**

Excitation power spectral density \( S(w_j) \) must be specified in 1-octave frequency bands. Transfer functions and thicknesses are again calculated from Equations (2) and (3) for each \( i \)-th frequency band. For the material frequency in the \( i \)-th octave band, the total mean square response becomes

\[ \sigma_i^2 = \sum_j S(w_j) |T_{oij}(w_j)|^2 \] (10)

and the RMS response is

\[ \sigma_i = \sqrt{\sigma_i^2} \] (11)
Assume for a Gaussian process that

\[ x_{oi} = 2.5 \sigma_i \] (1.1)

Again, the smallest \( T_{ci} \) of all frequency bands that satisfies \( x_{oi} \leq x_{allow} \) is the optimum thickness that we seek. Note that \( 2.5 \sigma_i \) as maximum will be exceeded only 0.62% of the time.

These three options provide the user the ability to utilize whatever vibration environmental data he has available or to use typical vibration environments as provided in the sample problems.

The random excitation option provides for the utilization of the most comprehensive data that can be obtained and should be used wherever possible. The multiple sine excitation and single frequency MIL-STD-810B excitation provide for less comprehensive types of environmental vibrations.

3. **Shock Isolation at Room Temperature**

The rigorous mathematical design of cushioning for shock isolation is in a considerably less developed state than that for vibration. This results from more complexities involved with time, strain rate, and temperature dependence of the materials at large deflections normally considered part of the shock isolation problem. Therefore, we used the Direct Method. Again, temperature dependence will be discussed later.

The Direct Method is a relatively simple design approach which can be formulated for mathematical computations by use of the typical design data shown in Figure 2. Many such curves for various materials are given in Reference 1. The curves for a given material present the maximum transmitted acceleration as the function

\[ G_m = \mathcal{F}(W/A) \]

for selected trial thicknesses \( T_c \). One simply needs to verify that

\[ G_m < G_F \]

for the given conditions. However, in order to incorporate this procedure into a digital computer program, it was necessary to store the data for these curves for the candidate materials. This was done by an appropriate interpolation scheme. Here \( G_F \) is the fragility acceleration.

*Discussed in Subsection F, Computer Software.
FIGURE 2. A TYPICAL SET OF PEAK ACCELERATION-STATIC STRESS \((G_{m}-W/A)\) CURVES FOR FIXED DROP HEIGHT \(h\).
Since different materials have different ranges of optimum static stress, the static stress, $\sigma_s$, that would be created by a particular shipped item (i.e., of weight, $W$, and area, $A$) has to be calculated by the equation

$$\sigma_s = \frac{W}{A} \quad (13)$$

and then checked to determine that the materials are within their static stress optimum range.

4. Temperature Influence on Material Properties

Ambient temperature variations over wide ranges have a significant influence on cushioning material properties. Unfortunately, data for such variations are extremely scanty for all of the materials of interest for this CAD Program.

Basically, the temperature effects on the complex modulus of a cushion material are typical of that shown in Figure 3. The effects are relatively insignificant until the so-called rubber-to-glass transition occurs. In any event, provisions were made for the storage and retrieval of vibration data (i.e., complex modulus, $E^*$) and shock data (i.e., maximum acceleration, $G_m$).

The complex modulus form is

$$E^* = E_r \mathcal{F}_1(T) \left(1 + i \tan \delta \mathcal{F}_2(T) \right) \quad (14)$$

where $T$ is varying temperature and $\mathcal{F}_1(T)$ and $\mathcal{F}_2(T)$ are the functions which describe the temperature effects.

The maximum acceleration shock isolation form is

$$G_{mT} = G_m \mathcal{F}_3(T) \quad (15)$$

where $\mathcal{F}_3(T)$ is the function which describes the temperature effects. We generated the temperature effects on the complex modulus using the functional curves for $\mathcal{F}_1(T)$, $\mathcal{F}_2(T)$, and $\mathcal{F}_3(T)$ shown in Figures 4 and 5. These temperature effect curves (i.e., $\mathcal{F}_1(T)$, $\mathcal{F}_2(T)$, and $\mathcal{F}_3(T)$) are only estimates; therefore, any use of data from this CAD Program should be used with caution until actual temperature effect data have been cataloged.

Points on each of the Scale Factor Function Curves were used in the computer program TDATAF to generate the temperature effects on
FIGURE 3a. FREQUENCY AND TEMPERATURE EFFECTS ON COMPLEX MODULI

FIGURE 3b. APPROXIMATE BEHAVIOR OF $E_r$ AND LOSS TANGENT OVER A WIDE RANGE OF FREQUENCY AND TEMPERATURE; SKETCHES ARE BASED ON EXPERIMENTAL DATA FOR A CARBON-FILLED BUNA-N. [Mustin, G. S. \(^{(1)}\)]
Figure 4. Storage modulus scale factor as a function of temperature.

Scale factor function, \( F_1(T) \), for storage modulus, \( E_r \).
**FIGURE 5.** LOSS TANGENT AND SHOCK PEAK ACCELERATION SCALE FACTORS AS FUNCTIONS OF TEMPERATURE
the shock (i.e., peak acceleration, $G_m$) and the vibration (i.e., storage modulus, $E_r$, and loss tangent, $\tan \delta$) data. The shock and vibration data are then stored in the computer file.

C. Treatment of Fragility and Damage Susceptibility Criteria

The subject of fragility or damage criteria is complicated because of the way in which different items fail when they are subjected to different environments. Various individuals, depending upon their background and resources, advocate different concepts, equipment and testing procedures for obtaining fragility ratings for items.

The determination of fragility or damage susceptibility criteria for a specific item must be done by the program user prior to utilization of the computer program developed during this project.

Fragility rating, normally in terms of the peak acceleration of the pulse which causes damage or malfunction of the item, should represent the peak of the main pulse (as distinguished from peaks of superimposed high frequency components), expressed in multiples of gravitational acceleration, $g$. Fragility ratings for individual items of a group should be averaged to obtain a mean value for the group.

The fragility input data will have two forms:

(1) Those items that are not repairable and discarded when damaged

(2) Items that are made of components. These items can have a range of damage to the components.

For example, the fragility input data might be in the following form:

<table>
<thead>
<tr>
<th>Fragility Rating, $g$</th>
<th>Probable Percent Damaged, %</th>
<th>Repair Cost per Damaged Item, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>5.00</td>
</tr>
<tr>
<td>65</td>
<td>20</td>
<td>25.00</td>
</tr>
<tr>
<td>70</td>
<td>80</td>
<td>475.00</td>
</tr>
</tbody>
</table>
D. **Statistical Form of Environment**

It is recognized that many possibilities of shock and vibration environments exist for transportation of packaged items. The modes of shipment include (1) Plane, (2) Truck, (3) Train, and (4) Ship. In each case, the length of exposure time can vary, depending on the details of the package and its destination. Therefore, herein we suggest a procedure for application of average and maximum environments for each case.

1. **Shock Environment**

Statistical information about the typical number of shocks which occur in a given transportation environment are available to varying degrees of detail from several sources. Figure 6 shows a profile of shock excitation measured during a typical airline flight. Data of this type must be further reduced to an even more concise form as shown in Figure 6b. That is, by accumulation of such data from multiple flights of varying durations, in the future a probability density for shock levels must be developed by fitting a Gaussian distribution to the data. Then, the entire set of data is described mathematically by

\[
p(g_x) = \frac{\sigma_s}{2\pi} e^{-[(g_x - \mu_s)^2/2\sigma_s^2]} \tag{16}
\]

where \(\mu_s\) is the mean shock level, \(g_x\) is the deviation from the mean level, and \(\sigma_s\) is the standard deviation. This form is particularly useful for computational purposes. The maximum shock expected in a given environment can be taken as

\[
S_{\text{max}} = 3\sigma_s \tag{17}
\]

Thus, the above formulation can be utilized for design to withstand repeated shocks (assuming superposition) or maximum as well.

Since all of the available shock isolation data for package cushioning materials are presented in the form shown in Figure 2, and since probability density shock levels for the different modes of transportation are not available, the shock conditions specified in MIL-STD-810B, Method 516.1, Shock, were coded into the computer program, OPPACK. The shock conditions from Method 516.1 are the drop heights based upon weight and dimensions. The weight and dimensions which determine specific drop heights are in Table II. The 48-inch drop height was omitted from the computer procedure because materials data for a 48-inch drop height were not available.

Thus, it is not necessary for the OPPACK Program user to specify any shock environment.
FIGURE 6a. MAXIMUM SHOCKS RECORDED DURING AIRLINE TEST SHIPMENT

FIGURE 6b. SHOCK AMPLITUDE (g<sub>a</sub>)
TABLE II
TRANSIT DROP TEST HEIGHTS FROM MIL-STD-810E, METHOD 516.1

<table>
<thead>
<tr>
<th>Weight of test item and case</th>
<th>Largest dimensions (inches)</th>
<th>Notes</th>
<th>Height of drop (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 100 pounds, man-packed and man-portable</td>
<td>Under 36</td>
<td>A</td>
<td>48*</td>
</tr>
<tr>
<td></td>
<td>36 and over</td>
<td>A</td>
<td>30</td>
</tr>
<tr>
<td>100 to 200 pounds, inclusive</td>
<td>Under 36</td>
<td>A</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>36 and over</td>
<td>A</td>
<td>24</td>
</tr>
<tr>
<td>Over 200 to 1,000 Pounds, inclusive</td>
<td>Under 36</td>
<td>A</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>36 to 60</td>
<td>B</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Over 60</td>
<td>B</td>
<td>24</td>
</tr>
<tr>
<td>Over 1,000 pounds</td>
<td>No limit</td>
<td>C</td>
<td>18</td>
</tr>
</tbody>
</table>

*48-inch drop height was omitted from OPPACK Program because of the lack of materials data.

2. Vibration Environment

Vibration excitation can be expressed either as a discrete spectrum(2) as shown by the example for truck transportation in Figure 7, or by a power spectrum(3) as shown by Figure 8. In the latter case, the data have been accumulated for equipment mounted in air-launched missiles. In the past, the tendency has been to express transportation environments in terms of discrete spectra (Figure 7). However, in recent years, with the advent of more compact laboratory analysis and excitation equipment, presentations of data on such environments have been shifting more to the power spectral form (Figure 8).

For the present program, available data were reviewed, so that enveloping power spectra could be established for each type of environment. Considerable judgement was exercised in this process, to account for varying power spectra at different speeds in transportation environments. Again, the assumption of a Gaussian distribution about some mean levels allowed reduction of the data to two parameters,
**Figure 7.** Truck Transportation Vibration Data (Ref. 2)

**Random Vibration Curves**

**Random Vibration Envelope**

<table>
<thead>
<tr>
<th>Test Curve</th>
<th>Acceleration Power Composite Spectral Density $V_{10}$ (CPS)</th>
<th>G-RMS Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.07</td>
<td>5.4</td>
</tr>
<tr>
<td>A2</td>
<td>0.04</td>
<td>1.6</td>
</tr>
<tr>
<td>A2</td>
<td>0.10</td>
<td>9.3</td>
</tr>
<tr>
<td>A3</td>
<td>0.10</td>
<td>12.0</td>
</tr>
<tr>
<td>A4</td>
<td>0.20</td>
<td>18.9</td>
</tr>
<tr>
<td>A5</td>
<td>0.30</td>
<td>20.7</td>
</tr>
</tbody>
</table>

*Note: Composite $G_{-RMS} = \left[ \int_{f_1}^{f_2} P(f) \, df \right]^{1/2}$*

Where $f_1$ and $f_2$ are the lower and upper test frequency limits, respectively. $P(f)$ is the acceleration power spectral density in g$^2$/CPS units.

**Figure 8.** Vibration test curves for equipment installed in air launched missiles — equipment category (d)

**Method S14.1**

20 October 1969
mean and standard deviation. These power spectra of excitation then formed the inputs to the equations presented in the previous sections.

Since most of the package cushioning design procedures used in previous publications on the subject do not deal extensively with the protection of the packaged item from vibration, a widely accepted method of describing the materials data relative to vibration does not exist. Also, a widely accepted method of describing the environmental vibration does not exist. Therefore, because the vibration environment can be described in relatively simple conventional terms (i.e., single frequency sinusoidal excitation, such as MIL-STD-810B excitation) or in more complex terms (i.e., multiple sine excitation) or in the most complex terms (i.e., random excitation), the computer program OPPACK was written to allow three options for the optimization regarding the vibration environment. Those three options are:

- Single frequency sinusoidal excitation, i.e., MIL-STD-810B excitation (IC = 1)
- Multiple sine excitation (IC = 2)
- Random excitation (IC = 3)

The input environmental vibration data for the MIL-STD-810B excitation (IC = 1) are to be in the form of acceleration, g, at specific frequencies, rad/sec. If the user of OPPACK has specific environmental vibration data and wishes to optimize the package design for single frequency excitation, he may input these data on Data Card Number Two (i.e., frequencies, rad/sec) and on Data Card Number Four (i.e., acceleration levels, g, for the specified frequencies).

If the user does not know what the environmental vibration data are, he may use the following frequencies, rad/sec:

6.283, 62.83, 125.6, 314.159, 628.300, 1884.96, 3141.59, 4398.23, 5654.87, 5969.03, 6283.19,

and the following accelerations, g, which correspond to the previously given frequencies:

0.5, 0.5, 1., 2., 3., 3., 3., 3., 3., 3., 3.

*Note that the input vibration frequencies are to be in radians per sec (rad sec).
The input environmental vibration data for the multiple sine excitation (IC = 2) are also to be in the form of acceleration, \( g \), at specific frequencies, rad/sec.

Also, if the user does not know what the environmental vibration data are, he may use the previously listed accelerations and frequencies.

The input environmental vibration data for random excitation (IC = 3) are to be in the form of Power Spectral Density (PSD), \( g^2/Hz \) at specific frequencies, rad/sec. If the user has PSD data they are to be put on Data Card Number Three (i.e., PSD, \( g^2/Hz \), for the specified frequencies on Data Card Number Two). If the user does not know what the PSD, \( g^2/Hz \) data are, he may use the following PSD levels:

\[
3.66 \times 10^{-4}, \quad 5.17 \times 10^{-4}, \quad 1.91 \times 10^{-4}, \quad 1.19 \times 10^{-4}, \\
1.13 \times 10^{-4}, \quad 5.09 \times 10^{-7}, \quad 5.83 \times 10^{-6}, \quad 5.09 \times 10^{-7}, \\
5.09 \times 10^{-7}, \quad 5.09 \times 10^{-7}, \quad 5.09 \times 10^{-7},
\]

which correspond to the previously given frequencies.

These vertical excitation data are from a truck transporting a LANCE missile at 19 to 45 MPH over a gravel road from the accelerometer mounted on the missile skid. The data are from Contract DA-31-124-ARO-D-226.

E. Cost Function Considerations

To formulate a function that expresses the total cost of cushioning, packaging and shipping of a given item while allowing for the possibility of some damage, to be covered by overshipment, requires a functional knowledge of all the cost variables in packaging design. Many of these cost variables are tangible, such as cushioning material costs and shipping costs; however, some are intangible such as costs of storage of the cushioning and packaging materials and some phases of loading and handling during shipment. Since we are mainly concerned with optimizing the cost function for a given variety of candidate materials and modes of shipment, many of the intangible variables play very minor roles in determining the optimum package, since these costs are shared nearly equally for all possible designs. The primary cost variables that were considered in the cost function are:

\[
C_m \sim \text{cost per unit volume of cushioning material}, \\
C_c \sim \text{cost of the exterior container},
\]
C_f \sim \text{cost of fabrication of the cushioning material to the specified dimensions},

C_p \sim \text{cost of packaging of the item for shipment},

C_s \sim \text{cost of shipment},

C_I \sim \text{cost of the packaged item}.

These cost variables can be grouped into four main categories: cost of materials, cost of labor, cost of shipping, and cost of allowable damage replacement.

1. **Cost of Materials**

   The cost per unit volume of the cushioning material enters the cost function in a direct manner when the required volume of cushioning material is known. It is often the case that material prices are based on a given thickness and width of sheet; in these cases, the waste material must be accounted for in the overall cushion cost.

   The exterior container for the purpose of cushion analysis was taken to be a rigid container. Cost and fabrication of the container were estimated for the sample problems from limited commercial data. Provisions were made in the program for the user to input container data (i.e., Input Data Card Number Sixteen).

   In the sample problems, the specific weight of the container is 0.0017 lb/in$^3$ and the container material cost is 0.00232 $/\text{in.}^3$.

   **CAUTION**

   The cost of container, $/\text{in.}^3$, is the cost of the container material volume, not the container volume.

2. **Cost of Labor**

   The cost of fabrication of the cushioning material to the specified design dimensions, as available, is included in the cost analysis, as well as the cost of packaging of the item for shipment. These items are best initially expressed in units of time since the price of labor is generally changing, and therefore only a single dollar per hour rate is necessary to update existing data. At the present time, we are using an average rate of $3.00 per man-hour. This rate is based upon data from Area Wage Survey, U. S. Department of Labor.
3. **Cost of Shipping**

The cost of shipping is one of the more complex cost variables, in that, weight, cube, number of items to be shipped and mode of shipment can play equally important roles. When shipping by truck, train, plane, ship or any combination thereof, the package engineer must consider the limitations on weight and cargo volume of each of the possible modes of shipment. For a shipment that requires multiple modes, for example, by both train and plane, a least cost operation must consider the cost in each phase of shipment. Of course, the cushioning package will be designed to withstand the environmental conditions imposed by all required modes of shipment; however, the least cost package may not be the most cost efficient when cube and weight limitations arise in shipping.

4. **Cost of Damage Replacement**

The cost of the item being packaged enters the cost function when the cushion design accepts the possibility of some damage, by changing the item's fragility factor, and compares the excess cost of the items shipped to cover the damage against the reduced cost of the cushioning package.

Thus, the cost function is a linear sum of the above-mentioned cost variables. The general cost function then takes the form

$$ CF = n \left[ V_m C_m + C_C (W, V_c) + C_f (m, V_c) + C_p (W, V_c) + f_n C_f \right] + C_S (n, s, W, V_c) $$

(18)

where the brackets denote a function of those variables and $n$ is the number of items to be packaged, $V_m$ the volume of cushioning material including waste, $W$ the weight of the package, $V_c$ the cube of the package, $m$ denotes a particular cushioning material, $f_n$ fraction of items allowed for possible damage, and $s$ the particular mode of shipment. It should be pointed out that since a different cushioning material can be used on each of the three orthogonal surfaces, the expression $V_m C_m$ can be expanded to read

$$ V_m C_m = \sum_{i=1}^{3} V_{m_i} C_{m_i} $$

(19)

where the subscript denotes the three possible surfaces. Likewise, the possibility of multiple modes of shipping can be functionally expressed as

$$ C_S (n, s, W, V_c) = \sum_{S=1}^{4} C_S (n, s, W, V_c). $$

(20)
The value of cushioning material, \( V_m \), in itself is a function of the cushioning material properties, fragility factor of the item, and the shipping environment.

F. **Computer Software**

The actual implementation of the FORTRAN computer software into the Natick Laboratories UNIVAC 1106 Executive 8 System was the culmination of all of the work on this project.

The Computer Aided Design (CAD) of package cushioning was accomplished through the FORTRAN language. FORTRAN permits the use of:

- Mathematical expression
- Data file input/output
- Procedural subroutines
- Batch and remote processing.

Thus, a main program is used to call and manipulate the subroutines. The subroutine programs were structured so that modifications can be done with a minimum amount of difficulty. The use of subroutines permitted the segmented development of the complete package cushioning design computer program.

1. **Lagrange Interpolation of Data**

Since we knew that a large number of data files were going to be required and that interpolation of the data contained in these files was necessary, we have developed and implemented a subroutine and function for interpolation and extrapolation\(^4\). They are the following:

- LAGINT (i.e., Lagrangian Interpolation Subroutine)
- FLAGR (i.e., Lagrangian Interpolating Function)

The interpolation programs are designed to save considerable computation time in generating data by interpolating a set for a more dense set so that a realistic data is realized. The mathematical interpolation scheme used is that of a three point Lagrange with a fairing over a four point set.

**Program Theory for Lagrange Interpolation**

Given a set of matrices \( \gamma(k) \), we wish to interpolate this set to obtain a more dense set \( \Gamma(k) \). The method of interpolation to be used
is that of Lagrange by passing a parabola from the right and from the left and averaging. For those points in \( \Gamma(k) \) which are not spanned by at least two points on either side by the set \( \gamma(k) \), a single parabola will be used at these points. Higher order polynomials have been tried and have failed to yield any increase in accuracy and have often caused undesirable oscillations.

Lagrange's interpolation formula:

\[
\Gamma(k) = \sum_{i=1}^{M} \gamma(k_i) \frac{(k-k_1) \cdots (k-k_{i-1}) (k-k_{i+1}) \cdots (k-k_M)}{(k_i-k_1) \cdots (k_i-k_{i-1}) (k_i-k_{i+1}) \cdots (k_i-k_M)}
\]  

Consider the five points shown below, where the 0 denotes values from the \( \gamma(k) \) set and the X denotes the desired value for the \( \Gamma(k) \) set.

<table>
<thead>
<tr>
<th></th>
<th>Yi-1</th>
<th>Yi</th>
<th>( \Gamma )</th>
<th>Yi+1</th>
<th>Yi+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Using Lagrange's interpolation formula for a parabola from the left (use points \( k_{i-1}, k_i, k_{i+1} \))

\[
\Gamma(k)_L = \gamma(k_{i-1}) \frac{(k-k_i) (k-k_{i+1})}{(k_{i-1}-k_i) (k_{i-1}-k_i)} + \gamma(k_i) \frac{(k-k_{i-1}) (k-k_{i+1})}{(k_{i-1}-k_i) (k_{i-1}-k_i)} + \gamma(k_{i+1}) \frac{(k-k_{i+1}) (k-k_i)}{(k_{i+1}-k_{i+1}) (k_{i+1}-k_i)}
\]

and a parabola from the right (use points \( k_i, k_{i+1}, k_{i+2} \))

\[
\Gamma(k)_R = \gamma(k_i) \frac{(k-k_{i+1}) (k-k_{i+2})}{(k_i-k_{i+1}) (k_i-k_{i+2})} + \gamma(k_{i+1}) \frac{(k-k_i) (k-k_{i+2})}{(k_{i+1}-k_i) (k_{i+1}-k_{i+2})} + \gamma(k_{i+2}) \frac{(k-k_i) (k-k_{i+1})}{(k_{i+2}-k_i) (k_{i+2}-k_{i+1})}
\]

Thus, if the desired point lies between two adjacent points, we average the parabolas as
\[ \Gamma(k) = \frac{1}{2} [\Gamma(k)_L + \Gamma(k)_R] \]  \hspace{1cm} (24)

The program is set up to interpolate a single set of input matrices or input two sets, scaling the second set by a scalar and adding it to the first set, then interpolating the combination.

Copies of the main program (i.e., TEST), the subroutine LAGINT, and the function, FLAGR, are shown in the Appendix.

2. Computer Aided Design (CAD) with Program OPPACK

The following pages identify the main driver program and subroutines. The usage of each subroutine, other subroutines called, and a glossary of variables are specified.

Table III, Glossary of Variables for OPPACK, contains the alphabetical listing and description of the FORTRAN variables in the Computer Program OPPACK.
### TABLE III
GLOSSARY OF VARIABLES FOR OPPACK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Support area of item (sq in.).</td>
</tr>
<tr>
<td>A(NPTSG, NPTSB, NPTSA)</td>
<td>Input table.</td>
</tr>
<tr>
<td>AL(I)</td>
<td>Array of longest dimensions for each face of package. (CDPRO subroutine).</td>
</tr>
<tr>
<td>ALF(NPTSA)</td>
<td>Vector of independent variables.</td>
</tr>
<tr>
<td>ALI(I)</td>
<td>Actual dimensions of package.</td>
</tr>
<tr>
<td>ALL</td>
<td>Item length + container and cushion thickness.</td>
</tr>
<tr>
<td>AT</td>
<td>Environmental temperature.</td>
</tr>
<tr>
<td>BETA(NPTSB)</td>
<td>Vector of independent variables.</td>
</tr>
<tr>
<td>C1</td>
<td>Cost of material on face one.</td>
</tr>
<tr>
<td>C2</td>
<td>Cost of material on face two.</td>
</tr>
<tr>
<td>C3</td>
<td>Cost of material on face three.</td>
</tr>
<tr>
<td>C12</td>
<td>Contains the minimum cost between the materials on face one and face two.</td>
</tr>
<tr>
<td>C13</td>
<td>Contains the minimum cost between the materials on face one and face three.</td>
</tr>
<tr>
<td>C23</td>
<td>Contains the minimum cost between the materials on face two and face three.</td>
</tr>
<tr>
<td>C123</td>
<td>Contains the lowest cost of the three materials.</td>
</tr>
<tr>
<td>CA(I, J)</td>
<td>Material cost and property matrix. Contains cost of material, cost of fabrication, cost of packaging, safe low temperature, low and high static stresses, and specific weight.</td>
</tr>
</tbody>
</table>
TABLE III (Contd.)
GLOSSARY OF VARIABLES FOR OPPACK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAXIS(I, 1)</td>
<td>Cost of the packaging material for face one.</td>
</tr>
<tr>
<td>CAXIS(I, 2)</td>
<td>Cost of the packaging material for face two.</td>
</tr>
<tr>
<td>CAXIS(I, 3)</td>
<td>Cost of the packaging material for face three.</td>
</tr>
<tr>
<td>CAXIS(I, J)</td>
<td>Cost of packaging material for all three faces.</td>
</tr>
<tr>
<td>CD(I, J)</td>
<td>Container cost and property matrix. Contains specific weight of container and cost of container.</td>
</tr>
<tr>
<td>CF(I)</td>
<td>Array containing cost of fabrication to specific dimensions.</td>
</tr>
<tr>
<td>CFF</td>
<td>Cost of fabrication.</td>
</tr>
<tr>
<td>CI</td>
<td>Cost of item.</td>
</tr>
<tr>
<td>CM(I)</td>
<td>Array containing material cost.</td>
</tr>
<tr>
<td>COST</td>
<td>Total cost.</td>
</tr>
<tr>
<td>CP(I)</td>
<td>Array containing the cost of packaging.</td>
</tr>
<tr>
<td>CPP</td>
<td>Cost of packaging.</td>
</tr>
<tr>
<td>CS</td>
<td>Cost of shipment.</td>
</tr>
<tr>
<td>CSS</td>
<td>Cost of shipping the package.</td>
</tr>
<tr>
<td>CVC</td>
<td>Cost of material for corner.</td>
</tr>
<tr>
<td>DH</td>
<td>Calculated drop height.</td>
</tr>
<tr>
<td>DHH(I)</td>
<td>Drop height.</td>
</tr>
<tr>
<td>DHL(I)</td>
<td>Drop height longest length.</td>
</tr>
</tbody>
</table>
TABLE III (Contd.)
GLOSSARY OF VARIABLES FOR OPPACK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW (I)</td>
<td>Drop height upper weight limit.</td>
</tr>
<tr>
<td>DII</td>
<td>Array of drop heights.</td>
</tr>
<tr>
<td>DLH</td>
<td>Dummy parameter.</td>
</tr>
<tr>
<td>DL (I)</td>
<td>Change in package dimensions along each face.</td>
</tr>
<tr>
<td>DRPH</td>
<td>Actual drop height - stored on file.</td>
</tr>
<tr>
<td>DW : B</td>
<td>Weight added by the addition of a bearing board.</td>
</tr>
<tr>
<td>ERI</td>
<td>Modulus at center frequency.</td>
</tr>
<tr>
<td>ERJ</td>
<td>Modulus at environmental frequency.</td>
</tr>
<tr>
<td>F (I)</td>
<td>Table of dependent variables.</td>
</tr>
<tr>
<td>F2 (I)</td>
<td>1-D array of interpolated accelerations.</td>
</tr>
<tr>
<td>FE (I)</td>
<td>Work - vector.</td>
</tr>
<tr>
<td>G</td>
<td>Interpolated acceleration.</td>
</tr>
<tr>
<td>GAM (NPTSG)</td>
<td>Vector of independent variables.</td>
</tr>
<tr>
<td>GM</td>
<td>Maximum G-allowable (ft/sec/sec) (CDPRO subroutine)</td>
</tr>
<tr>
<td>GM</td>
<td>Fragility limit (acceleration). (SHOCKE subroutine)</td>
</tr>
<tr>
<td>GMF (I)</td>
<td>G-levels for each percent damage allowable.</td>
</tr>
<tr>
<td>I1</td>
<td>Array subscript for material used on face one.</td>
</tr>
<tr>
<td>I2</td>
<td>Array subscript for material used on face two.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>I3</td>
<td>Array subscript for material used on face three.</td>
</tr>
<tr>
<td>IC</td>
<td>Procedure code.</td>
</tr>
<tr>
<td>IC = 1</td>
<td>MIL-STD-810B excitation.</td>
</tr>
<tr>
<td>IC = 2</td>
<td>Multiple sine excitation.</td>
</tr>
<tr>
<td>IC = 3</td>
<td>Random excitation.</td>
</tr>
<tr>
<td>IGO</td>
<td>Code to determine type of interpolation.</td>
</tr>
<tr>
<td>II (I)</td>
<td>Contains array positions of optimum thickness for each of the three faces.</td>
</tr>
<tr>
<td>IITM</td>
<td>Item number.</td>
</tr>
<tr>
<td>IJE</td>
<td>Deletion code.</td>
</tr>
<tr>
<td>ITEM</td>
<td>Item number.</td>
</tr>
<tr>
<td>ITEMP</td>
<td>Number of temperatures considered.</td>
</tr>
<tr>
<td>MATOP (I, K)</td>
<td>Optimum material for each face. MATOP (I, K) = F (G-level, axis).</td>
</tr>
<tr>
<td>MATSC (I)</td>
<td>Material code.</td>
</tr>
<tr>
<td>M'C (I)</td>
<td>Contains material code for each of the three faces.</td>
</tr>
<tr>
<td>MIC</td>
<td>Maximum iterations for drop height weight convergence.</td>
</tr>
<tr>
<td>MITEM</td>
<td>Item number.</td>
</tr>
<tr>
<td>MOMJ</td>
<td>Number of input environment frequencies.</td>
</tr>
<tr>
<td>MOMS</td>
<td>Number of frequencies stored on the vibration file. (CDPRO subroutine)</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>MOMS</td>
<td>Number of frequencies stored on data files (VIBRTN Subroutine)</td>
</tr>
<tr>
<td>MTC</td>
<td>Material code</td>
</tr>
<tr>
<td>MTS</td>
<td>Number of temperatures stored on the vibration file. (CDPRO subroutine)</td>
</tr>
<tr>
<td>MTS</td>
<td>Number of temperatures stored on data file. (VIBRTN subroutine)</td>
</tr>
<tr>
<td>MXI(I, J, K)</td>
<td>Array containing the number of thicknesses included in the dynamic thickness array</td>
</tr>
<tr>
<td>MXIT(I, J, K)</td>
<td>Number of thicknesses stored for each axis and temperature</td>
</tr>
<tr>
<td>NMATS</td>
<td>Number of materials to be considered</td>
</tr>
<tr>
<td>NPCNT</td>
<td>Number of different percent damage allowed</td>
</tr>
<tr>
<td>NPTS</td>
<td>Number of points in table</td>
</tr>
<tr>
<td>NPTSA</td>
<td>Number of X-Y planes in input table</td>
</tr>
<tr>
<td>NPTSB</td>
<td>Number of columns in input table</td>
</tr>
<tr>
<td>NS</td>
<td>Number of static stresses. (CDPRO subroutine)</td>
</tr>
<tr>
<td>NS</td>
<td>Number of static stresses stored on file (SHOCKE subroutine)</td>
</tr>
<tr>
<td>NT</td>
<td>Number of temperatures. (CDPRO subroutine)</td>
</tr>
<tr>
<td>NT</td>
<td>Number of temperatures stored on file. (SHOCKE subroutine)</td>
</tr>
<tr>
<td>NTH</td>
<td>Number of thicknesses</td>
</tr>
<tr>
<td><strong>GLOSSARY OF VARIABLES FOR OPPACK</strong></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>OB (I)</strong></td>
<td>Array of 1-Octave band center frequencies, Hz.</td>
</tr>
<tr>
<td><strong>OCOST (I, K)</strong></td>
<td>Matrix of optimum cost for each allowed G-level. OCOST (I, K) = F(G-level, axis).</td>
</tr>
<tr>
<td><strong>OM</strong></td>
<td>Environmental frequency.</td>
</tr>
<tr>
<td><strong>OMJ (I)</strong></td>
<td>Environmental Frequencies (rad/sec)</td>
</tr>
<tr>
<td><strong>OMS (I)</strong></td>
<td>Array of frequencies stored in ascending order. (CDPRO subroutine)</td>
</tr>
<tr>
<td><strong>OMS (I)</strong></td>
<td>Frequency scale. (VIBRTN subroutine)</td>
</tr>
<tr>
<td><strong>OPSS (I)</strong></td>
<td>The optimum number of packages to be shipped in order to have one reach the destination undamaged.</td>
</tr>
<tr>
<td><strong>OTHK (I, K)</strong></td>
<td>Optimum thickness for each face. OTHK (I, K) = F(G-level, axis).</td>
</tr>
<tr>
<td><strong>PCTD (I)</strong></td>
<td>Percent of damage allowable.</td>
</tr>
<tr>
<td><strong>REPCI (I)</strong></td>
<td>Replacement cost.</td>
</tr>
<tr>
<td><strong>RHOC</strong></td>
<td>Specific weight of container material under consideration.</td>
</tr>
<tr>
<td><strong>RHOM</strong></td>
<td>Specific weight of material under consideration.</td>
</tr>
<tr>
<td><strong>S (I)</strong></td>
<td>PSD (Power Spectral Density) input for random excitation. (DAMALW subroutine)</td>
</tr>
<tr>
<td><strong>S (I)</strong></td>
<td>Array of 1-octave band power spectral densities. (VIBRTN subroutine)</td>
</tr>
<tr>
<td><strong>SI</strong></td>
<td>Static stress (W/A). (CDPRO subroutine)</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>SI</td>
<td>Interpolating stress. (SHOCKE subroutine)</td>
</tr>
<tr>
<td>SIG(I)</td>
<td>Array of static stresses in ascending order. (CDPRO subroutine)</td>
</tr>
<tr>
<td>SIG(I)</td>
<td>1-D table of static stresses (W/A). (SHOCKE subroutine)</td>
</tr>
<tr>
<td>SIT(I)</td>
<td>Work array used for sorting.</td>
</tr>
<tr>
<td>SJ</td>
<td>Sum of output excitations for one center frequency.</td>
</tr>
<tr>
<td>SLT(I)</td>
<td>Safe low temperature.</td>
</tr>
<tr>
<td>T(I)</td>
<td>Array of temperatures in ascending order. (CDPRO subroutine)</td>
</tr>
<tr>
<td>T(I)</td>
<td>1-D table of temperatures. (SHOCKE subroutine)</td>
</tr>
<tr>
<td>T1</td>
<td>Material thickness for face one.</td>
</tr>
<tr>
<td>T2</td>
<td>Material thickness for face two.</td>
</tr>
<tr>
<td>T3</td>
<td>Material thickness for face three.</td>
</tr>
<tr>
<td>TAB1(I, J, K)</td>
<td>Work array - during shock calculations it contains G = F (thickness, static stress, temperature). During vibration calculations it contains ER = modulus = F (frequency, temperature). (CDPRO subroutine)</td>
</tr>
<tr>
<td>TAB1(I, J, K)</td>
<td>3-D table of peak accelerations G = F (TH, SIG, T). (SHOCKE subroutine)</td>
</tr>
<tr>
<td>TAB1(I, J, K)</td>
<td>Table containing behavior of storage modulus (ER) ER = F (frequency, temperature). (VIBRTN subroutine)</td>
</tr>
</tbody>
</table>
TABLE III (Contd.)
GLOSSARY OF VARIABLES FOR OPPACK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAB2(I, J, K)</td>
<td>Array which contains loss tangent = F (frequency, temperature). CDPRO subroutine</td>
</tr>
<tr>
<td>TAB2(I, J, K)</td>
<td>Table containing behavior of loss tangent EL/ER = F (Frequency, Temperature). (VIBRTN subroutine)</td>
</tr>
<tr>
<td>TCC</td>
<td>Total cost of container by volume.</td>
</tr>
<tr>
<td>TCC(I)</td>
<td>Calculated thicknesses.</td>
</tr>
<tr>
<td>TCMV</td>
<td>Total cost of material by volume.</td>
</tr>
<tr>
<td>TCON</td>
<td>Thickness of container (in.).</td>
</tr>
<tr>
<td>TF(I)</td>
<td>1-D array of guess thicknesses.</td>
</tr>
<tr>
<td>TF(WI, WJ, ERI, ERJ, DJ)</td>
<td>Statement function to calculate transfer function.</td>
</tr>
<tr>
<td>THCK(A, ERI, WI, W)</td>
<td>Statement function to calculate thickness.</td>
</tr>
<tr>
<td>TH(I)</td>
<td>Array of thicknesses in ascending order. (CDPRO subroutine)</td>
</tr>
<tr>
<td>TH(I)</td>
<td>1-D table of thickness values. (SHOCKE subroutine)</td>
</tr>
<tr>
<td>THI</td>
<td>A trial thickness. (CDPRO subroutine)</td>
</tr>
<tr>
<td>THI</td>
<td>Guess thickness. (SHOCKE subroutine)</td>
</tr>
<tr>
<td>THIK(I, J)</td>
<td>Matrix of thicknesses generated during shock calculations.</td>
</tr>
<tr>
<td>THIKV(I, J)</td>
<td>Matrix of thicknesses generated during vibration calculations.</td>
</tr>
<tr>
<td>TI</td>
<td>An environmental temperature. (CDPRO subroutine)</td>
</tr>
<tr>
<td>TI</td>
<td>Interpolating temperature. (SHOCKE subroutine)</td>
</tr>
<tr>
<td><strong>TABLE III (Contd.)</strong></td>
<td><strong>GLOSSARY OF VARIABLES FOR OPPACK</strong></td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td><strong>TIII</strong></td>
<td>Environmental temperature.</td>
</tr>
<tr>
<td><strong>TMX</strong></td>
<td>Maximum allowed shock thickness.</td>
</tr>
<tr>
<td><strong>TOP</strong></td>
<td>Optimum thickness.</td>
</tr>
<tr>
<td><strong>TOPP(I)</strong></td>
<td>Array of acceptable thicknesses.</td>
</tr>
<tr>
<td><strong>TS(I)</strong></td>
<td>Array of temperatures stored in asc-</td>
</tr>
<tr>
<td></td>
<td>cending order. (CDPRO subroutine)</td>
</tr>
<tr>
<td><strong>TS(I)</strong></td>
<td>Temperature scale. (VIBRTN sub-</td>
</tr>
<tr>
<td></td>
<td>rount).</td>
</tr>
<tr>
<td><strong>TSK</strong></td>
<td>Thickness predicted by shock environ-</td>
</tr>
<tr>
<td></td>
<td>ment.</td>
</tr>
<tr>
<td><strong>TT(I)</strong></td>
<td>A thickness work array.</td>
</tr>
<tr>
<td><strong>TTHIK(I, J, K)</strong></td>
<td>Dynamic array which contains the</td>
</tr>
<tr>
<td></td>
<td>union of the thicknesses of all thr</td>
</tr>
<tr>
<td></td>
<td>ee temperature environments.</td>
</tr>
<tr>
<td><strong>TTHIK(I, J, L)</strong></td>
<td>Dynamic thickness array contains al</td>
</tr>
<tr>
<td></td>
<td>l acceptable vibration thicknesses</td>
</tr>
<tr>
<td></td>
<td>for each material, axis, and tempe</td>
</tr>
<tr>
<td></td>
<td>rature.</td>
</tr>
<tr>
<td><strong>V1</strong></td>
<td>Volume of packaging material needed</td>
</tr>
<tr>
<td></td>
<td>for face one.</td>
</tr>
<tr>
<td><strong>V2</strong></td>
<td>Volume of packaging material needed</td>
</tr>
<tr>
<td></td>
<td>for face two.</td>
</tr>
<tr>
<td><strong>V3</strong></td>
<td>Volume of packaging material needed</td>
</tr>
<tr>
<td></td>
<td>for face three.</td>
</tr>
<tr>
<td><strong>VAL</strong></td>
<td>Interpolated value.</td>
</tr>
<tr>
<td><strong>W</strong></td>
<td>Weight of item.</td>
</tr>
<tr>
<td><strong>WI</strong></td>
<td>Weight of item (lb) (CDPRO subroutine)</td>
</tr>
<tr>
<td><strong>WII</strong></td>
<td>1-octave band center frequency.</td>
</tr>
<tr>
<td></td>
<td>(VIBRTN subroutine)</td>
</tr>
<tr>
<td><strong>WII</strong></td>
<td>Weight of item.</td>
</tr>
</tbody>
</table>
## TABLE III (Contd.)

### GLOSSARY OF VARIABLES FOR OPPACK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W(K)</td>
<td>Work array containing function weights.</td>
</tr>
<tr>
<td>WW</td>
<td>Item weight + container and cushion weight.</td>
</tr>
<tr>
<td>XB</td>
<td>Horizontal argument (interpolating value).</td>
</tr>
<tr>
<td>XDD(I)</td>
<td>Calculated output excitation.</td>
</tr>
<tr>
<td>XDDA</td>
<td>Maximum allowable G-level.</td>
</tr>
<tr>
<td>XDJ(I)</td>
<td>Environmental G-levels.</td>
</tr>
<tr>
<td>XIK(I)</td>
<td>Table of independent variables to be interpolated.</td>
</tr>
<tr>
<td>XK</td>
<td>Interpolating value.</td>
</tr>
<tr>
<td>XL</td>
<td>Width (in.)</td>
</tr>
<tr>
<td>YG</td>
<td>Vertical argument (interpolating value).</td>
</tr>
<tr>
<td>YL</td>
<td>Height (in.) - shortest dimension.</td>
</tr>
<tr>
<td>ZA</td>
<td>Depth (interpolating value).</td>
</tr>
<tr>
<td>ZL</td>
<td>Length (in.) - longest dimension.</td>
</tr>
</tbody>
</table>
MAIN DRIVER AND SUBPROGRAMS

OPPACK -- Main Driver

Usage:

(1) Read first four input cards from problem card deck.

(2) Initialize appropriate variables.

(3) Print and define input data.

Subroutines called:

TEMPEV
PROGRAM OPPACK (INPUT, OUTPUT, TAPE1, TAPE2, TAPE3, TAPE4, TAPES, 1 TAPE6, TAPE7, TAPE8, TAPE9, TAPE10)

C OPTIMIZATION PACKAGE MAIN PROGRAM

C ROUTINE READS CARD INPUT DATA

000003 COMMON /CSTM/ CA(10,7), CD(10,2), CS, CI, MII
000003 COMMON /VPA6/ NIC, IC, IITM, MIC, MXI, MOMJ, TCON, TEML, TEMH
000003 DIMENSION OM(11), S(11), XDJ(11)
000003 READ 1000, NIC, IC, IITM, MIC, MXI, MOMJ, CS, CI, TCON, TEML, TEMH
000003 READ 1020, (OMJ(I), I=1, MOMJ)
000003 READ 1020, (S(I), I=1, MOMJ)
000003 READ 1020, (XDJ(I), I=1, MOMJ)

000004 PRINT 1070

000005 PRINT 1030, NIC, IC, IITM, MIC, MXI, MOMJ, CS, CI, TCON, TEML, TEMH
000005 PRINT 1040, (OMJ(I), I=1, MOMJ)
000005 PRINT 1050, (S(I), I=1, MOMJ)
000005 PRINT 1060, (XDJ(I), I=1, MOMJ)

000006 CALL TEMPEV(UMJ, S, XDJ)

001000 1000 FORMAT (6I2, 5E10.0)
001000 1010 FORMAT (4D12)
001000 1020 FORMAT (11E7.0)
001000 1040 FORMAT (1H0, I8, 50H (RAD/SEC) = OMJ(I) ALL OF THE ENVIRONMENTAL FREQ.)
001000 1050 FORMAT (1H0,3H PSD INPUT FOR RANDOM EXCITATION 1/11E11.5)
001000 1060 FORMAT (1H0,92H (G'S) = XDJ(I) — ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE OMJ(I)S/ 11E11.5)
001000 1070 FORMAT (1H1, // 30X, 65M*** OPTIMIZATION PROCEDURE FOR DESIGN OF 1PACKAGE CUSHIONING ***//)
001000 STOP
001002 END
OPPACK

PROGRAM LENGTH INCLUDING I/O BUFFERS
031022

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
1000 - 000226  1010 - 000231  1020 - 000233  1030 - 000235
1040 - 000346  1050 - 000357  1060 - 000370  1070 - 000405

BLOCK NAMES AND LENGTHS
COSTM - 000135  VPASS - 000011

VARIABLE ASSIGNMENTS
CA = 000000C01  CD = 000106C01  CI = 000133C01  CS = 000132C01
I = 0004471  IC = 000001C02  ITM = 000052172  MIC = 000003C02
MOMJ = 000005C02  MXI = 000004C01  NIM = 000000C02  OMJ = 000470
S = 000443  TCON = 000006C02  TEMH = 000010C02  TEML = 000007C02
XDJ = 000456

START OF CONSTANTS
000204

START OF TEMPORARIES
000420

START OF INDIRECTS
000430

UNUSED COMPILER SPACE
04240D
TEMPEV - Subroutine

Usage:

This subroutine is used to initialize the three temperatures to be considered.

Subroutines called:

DAMALW
SUBROUTINE TEMPEV(OMJ,S,XDJ)

COMMON /VPASS/ NIC,IC,ITM,MIC,MXJ,MOMJ,TCON,TEML,TEMH
COMMON /COSTH/ CA(10,7),CO(10,2),CS,CI,WII
COMMON /TEMPH/ TTHIK(10,3,11),IH,IAxs,ITEMP,IE,TMX
DIMENSION TI(3)
DIMENSION OMJ(11),S(10),XDJ(11)

TMX=12.
ITEMP=3
TI(1)= TEML
TI(2)= 0.5*(TEMH*TEML)
TI(3)= TEMH
IF((TEMH-TEML).LT.20.)ITEMP=1
CALL DMALE(NIC,IC,ITM,TCON,ITM,MIC,MXJ,MOMJ,S,XDJ)
RETURN
END
TEMPEV

SUBPROGRAM LENGTH
000055

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS
VPASS = 000011   COSTM = 000135   TEMPT = 000517

VARIABLE ASSIGNMENTS
CD = 0000000CD  IC = 000010CD  ITM = 0000010C01
IC = 0000140C03  IC = 0000030C01  MXI = 0000040C01
MIC = 0000050C01  TCON = 0000060C01  TEML = 0000070C01
MX = 000000052  TMK = 0000516C03  TTHK = 0000000C03

START OF CONSTANTS
000000

START OF TEMPORARIES
000000

START OF INDIRECTS
000000

UNUSED COMPILER SPACE
043700
DAMALW - Subroutine

Usage:

1. Reads remainder of problem data deck.
2. Prints input and explanation of input.
3. Determines materials to be considered.
4. Determines best shipping policy.
5. Prints appropriate information concerning the best shipping policy.

Subroutines called:

CDPRO
Glossary of Variables for DAMALW

CA(I, J) - - - Material cost and property matrix. Contains cost of material, cost of fabrication, cost of packaging, safe low temperature, low and high static stresses, and specific weight.

CD(I, J) - - - Container cost and property matrix. Contains specific weight of container and cost of container.

CI - - - - Cost of item.

CS - - - - Cost of shipment.

GMF(I) - - - G-levels for each percent damage allowable.

I1 - - - - Array subscript for material used on face one.

I2 - - - - Array subscript for material used on face two.

I3 - - - - Array subscript for material used on face three.

MATOP(I, K) - - Optimum material for each face.
MATOP(I, K) = F(G-level, axis).

MATSC(I) - - Material code.

NMATS - - Number of materials to be considered.

NPCNT - - Number of different percent damage allowed.

OCOST(I, K) - - Matrix of optimum cost for each allowed G-level,
OCOST(I, K) = F(G-level, axis)

OMJ(I) - - - Environmental frequencies (rad/sec)

OPSS(I) - - - The optimum number of packages to be shipped in order to have one reach the destination undamaged.

OTHK(I, K) - - Optimum thickness for each face.
OTHK(I, K) = F(G-level, axis)

PCTD(I) - - - Percent of damage allowable.

REPCI(I) - - - Replacement cost.
S(I) - - - - PSD (Power Spectral Density) input for random excitation.

T1 - - - - Material thickness for face one.

T2 - - - - Material thickness for face two.

T3 - - - - Material thickness for face three.

WII - - - - Weight of item.

XDJ(I) - - - - The environmental G-levels.
SUBROUTINE DAMALW(NIC,IC, T1M,TCON,TI,MIC, Mx,OMJ,MOMJ,S,1 XDJ)
C BASED UPON THE ALLOWED DAMAGE.
C CA(I,J) = COST AND PROPERTY MATRIX - CONTAINS COST OF MATERIAL,
C COST OF FABRICATION, COST OF PACKAGING, SAFE LOW TEMP,
C LOW AND HIGH STATIC STRESSES, SPECIFIC WEIGHT.
C CD(I,J) = COST AND PROPERTY MATRIX - CONTAINS SPECIFIC WT OF
C CONTAINER AND COST OF CONTAINER.
C CI = COST OF ITEM
C CS = COST OF SHIPPING
C DAMALW
C GMF(I) = ALLOWED G-LEVELS FOR EACH PER-CENT DAMAGE ALLOWABLE
C I1 = ARRAY SUBSCRIP-FOR MATERIAL USED ON FACE ONE (1)
C I2 = ARRAY SUBC.RIF FOR MATERIAL USED ON FACE TWO (2)
C I3 = ARRAY SUBSCRIP FOR MATERIAL USED ON FACE THREE (3)
C MATOP(I,K) = OPTIMUM MATERIAL FOR EACH FACE
C MATSC(I) = MATERIAL CODE
C OCOST(I,J) = MATRIX OF OPTIMUM COST FOR EACH ALLOWED G-LEVEL
C OMJ(I) = ENVIRONMENTAL FREQUENCIES (RAD/SEC)
C OTMK(I,K) = OPTIMUM THICKNESS FOR EACH FACE
C PCTD(I) = PER-CENT OF DAMAGE ALLOWABLE
C REPCI(I) = REPLACEMENT COST
C S(I) = PSD INPUT - FOR RANDOM EXCITATION
C SUBROUTINE READS FRAGILITY DATA FOR DAMAGE ALLOWABLE
C SUBROUTINE READS MATERIAL COST AND PROPERTY FILE
C THEN IT ITERATES ON COPRO FOR DIFFERENT FRAGILITY DATA
C THEN IT DETERMINES THE OPTIMUM SHIPPING STRATEGY
C THE REMAINING INPUT VARIABLES ARE OFFINE IN THE OUTPUT FORMATS
C T1 = MATERIAL THICKNESS FOR FACE ONE
C T2 = MATERIAL THICKNESS FOR FACE TWO
C T3 = MATERIAL THICKNESS FOR FACE THREE
C WII = WEIGHT OF ITEM
C XDJ(I) = THE ENVIRONMENTAL G-LEVELS

C DIMENSION T1(3)
C DIMENSION OPS(10),OCOST(10,2),OMJ(10,3),MATOP(10,3)
C DIMENSION GMF(10),PCTD(10),REPCI(10),MATSC(10),OMJ(10),S(I),
C XD(10)
C COMMON /OPT/ I1,I2,I3,T1,T2,T3
C COMMON /COSTM/ CA(10,?),CD(10,2),CS,CI,WII
C READ COST FILE
C READ 500, NC, MITEM, MMATS
C PRINT 1010, NC, MITEM, MMATS
C READ 10, ((CA(I,J),J=1,?), I=1 ,MMATS)
C READ 10, ((CO(I,J),J=1,2), I=1,NC)
C PRINT 402U, ((CA(I,J),J=1,?), I=1, MMATS )
C PRINT 403U, ((CO(I,J),J=1,2), I=1, NC )
C RHOCS=CM(NIC,1)
C READ FRAGILITY DATA FOR DAMAGE ALLOWABLE
C CONTINUE
C READ 5, ITEM, WI, XL, YL, ZL, NPCNT
C PRINT 404U, ITEM, WI, XL, YL, ZL, NPCNT
C USING THE RANGE OF OPTIMUM STRESSES DETERMINE THE MATERIALS TO BE
C CONSIDERED
C X=XL
C Y=YL
C Z=ZL
C M=W
CHANGE PCF TO PCI
CHANGE COST/CF TO COST/CI

000211  DO 25 I=1,NMATS
000216  CA(I,7)=CA(I,7)/1728.
000220  25 CA(I,1)=CA(I,1)/1728.
000224  26 CONTINUE

000224  S1 = W/(X * Y)
000227  S2 = W/(X * Z)
000232  S3 = W/(Z * Y)
000235  S11= AMIN1(S1,S2,S3)
000242  S22= AMAX1(S1,S2,S3)
000246  NMATS=0
000247  DO 28 I=1,NMATS

C SELECT MATERIAL TO BE CONSIDERED

000250  IF(S11.GT.CA(I,6).OR.S11.LT.CA(I,5))GO TO 28
000261  IF(S22.GT.CA(I,6).OR.S22.LT.CA(I,5))GO TO 28
000272  IF(CA(I,4).GT.TI(1)) GO TO 28
000276  NMATS=NMATS + 1
000277  MAT3C(NMATS)=I
000301  28 CONTINUE

000304  IF(NMATS.EQ.0)PRINT 4000
000314  IF(NMATS.EQ.0)STOP
000317  PRINT 4060,(MAT3C(I),I=1,NMATS)
000332  W1=W
000334  IF(ITEM.NE.IITM)PRINT 3000
000350  READ ?, (GMF(I),PCTD(I),REPCI(I),I=1,NPCNT)
000367  PRINT 4050, (GMF(I), PCTD(I), REPCI(I),I=1, NPCNT)
000446  DO 40 IT=1,NPCNT
000448  40 CONTINUE

000452  IF(T1(1).EQ.1500.)GO TO 45
000455  45 CONTINUE

C COST OF OVERSHIPPING

000471  OCOST(IT,1)=COST*OPSS(IT)
000474  OCOST(IT,2)=COST*OPSS(IT)
000476  PRINT 1000, PCTD(IT),GM,COST,OPSS(IT),OCOST(IT,1),OCOST(IT,2)

000515  40 CONTINUE

000523  IF(IT(1).EQ.1500.)NPCNT=IT-1
000527  IF(NPCNT.EQ.0)PRINT 4070
000540  IF(NPCNT.EQ.0)RETURN
000542  IT=1
000543  0SB=OCOST(IT,1)
000545  DO 50 I=1,NPCNT
000546  50 CONTINUE

C COST OF ALLOWING DAMAGE

000551  OSH=OCOST(IT,1)
000553  IT=1
000554  50 CONTINUE

000557  PRINT 11000
000562  PRINT 15000, OSH,GMF(IT),PCTD(IT),OPSS(IT)

49
000576  PRINT 200U,0THK(II,1),MATOP(II,1),0THK(II,2),MATOP(II,2),
  1 0THK(II,3),MATOP(II,3)
000616  II=1
000617  OVSRS=0SB
000621  OSB=OCOST(I,2)
000622  DD 60  I=1,NPCT
000627  IF(OSB.LE.OCOST(I,2)) GO TO 60
000632  OSB=OCOST(I,2)
000634  II=1
000635  60 CONTINUE
000640  PRINT 1600, 0SB,GMF(II),PCTD(II),REPCI(II)
000653  PRINT 200U,0THK(II,1),MATOP(II,1),0THK(II,2),MATOP(II,2),
  1 0THK(II,3),MATOP(II,3)
000673  IF(OVERS.GT.OSB) GO TO 70
000702  PRINT 1800
000705  PRT 12000
000711  RETURN
000712  70 CONTINUE
000716  PRINT 1400
000720  PRT 12000
000722  RETURN
000723  5 FORMAT(I4,2X,9E10.0,2X,I2)
000723  7 FORMAT(9E10.0)
000723  10 FORMAT(E5.0,E5.0,F6.0,E6.0,3E15.5)
000723  500 FORMAT(4D12)
000723  1000 FORMAT(2X,3HFOR1X,F6.2,1X,22MPER-CENT DAMAGE AND A
  1 1MHFRAGILITY RATE OF F4.1,1X,3HGM'S/
  2 2X,11MTHE COST ISIX,F9.2,1X,7MHOOLLARS WITH A
  3 25MULTIPICATION FACTOR OF 1X,F6.2,1X,9MTIMES ONE /
  4 2X,20MWITH A FINAL COST OF1X,F9.2,1X,7MHOOLLARS
  5 17MFOR OVER SHIPPING /
  6 2X,31MFOR ALLOWING DAMAGE THE COST IS 1X,F9.2,1X,
    12HOOLLARS/ITEM )/
000723  1500 FORMAT(2X,9H0VER SHPPING DATA /
  1 2X,19MTHE OXIMIN COST ISIX,F9.2,1X,7MHOOLLARS /
  2 2X,21MTHE FRAGILITY RATE ISIX,F4.1,1X,3HGM'S /
  3 2X,22M THE PER-CENT DAMAGE IS F6.1 /
  4 2X,28MTHE MULTIPICATION FACTOR ISIX,F5.1/
000723  1600 FORMAT(2X,21HM0AMAGE ALLOWABLE DATA /
  1 2X,19MTHE OXIMIN COST ISIX,F9.2,1X,7MHOOLLARS /
  2 2X,21MTHE FRAGILITY RATE ISIX,F4.1,1X,3HGM'S /
  3 2X,22M THE PER-CENT DAMAGE ISIX,F6.1 /
  4 2X,22M THE REPAIR COST/ITEM =1X,F9.2,1X,7MHOOLLARS/
000723  1800 FORMAT(3MHOVERSHPPING IS THE BEST POLICY/) /
000723  1900 FORMAT(4M0THE ABOVE PER-CENTAGE DAMAGE IS THE BEST POLICY/) /
000723  2000 FORMAT(2X,3HTHE OXIMUM THICKNESS FOR FACE ONE ISIX,F7.3,1X,
  1 6HINCHE3X,11HM MATERIAL1X12,1X,7HIS USED/
  2 2X,37MTHE OXIMUM THICKNESS FOR FACE TWO ISIX,F7.3,1X,
  3 6HINCHE3X,11HM MATERIAL1X12,1X,7HIS USED/
  4 2X,34MTHE OXIMUM THICKNESS FOR FACE THREE ISIX,F7.3,1X,
  5 6HINCHE3X,11HM MATERIAL1X12,1X,7HIS USED/
000723  3000 FORMAT(2X,4SH*THE ITEM IDENTIFICATION NUMBER DOES NOT AGREE*
  133H*WITH THAT OF THE FRAGILITY DATA*)
000723  4000 FORMAT(2X,52HNO MATERIAL IS IN THE RANGE OF OXIMUM STRESS—STOP)
000723  4010 FORMAT (1H0,18,30H = NC --- NUMBER OF CONTAINERS/
  11X,18,24H = MITEM --- ITEM NUMBER/
  21X, 18,40H = MMATS--- NUMBER OF MATERIALS ON FILE )
000723  4020 FORMAT (1H0,2X, 85H CST-MAT CST-FAB CST-PAK SL-TEMP

50
1 LW-STRS HI-STRS GAMMA / (E11.4,0.113.4))

000723 4030 FORMAT (1H0,2X,27H GAMMA CST-CONTAINER / (E11.4,6E13.4))

000723 4040 FORMAT (1H0,2X,18,12H ITEM NUMBER /3X,E11.4,29H=HEIGHT OF ITEM #1( POUNDS ) /3X,E11.4,65H= DIMENSION PARALLEL TO X-AXIS 2ND LONGEST 2 DIMENSION XL (INCHES) /3X,E11.4,65H= DIMENSION PARALLE TO Y-AXIS 3RD LONGEST DIMENSION YL (INCHES) /3X,E11.4,61H= DIMENSION PARALLE 3RD LONGEST DIMENSION YL (INCHES) /3X,E11.4,61H= DIMENSION PARALLE 3RD LONGEST DIMENSION YL (INCHES) /3X,9HNUMBER = 18)

000723 4050 FORMAT ( 1H0,8X, 35H MAX-G PCNT-DAM REPLACE-CST /
1(3X,3E12.4) // 2(120(1H*))// )

000723 4060 FORMAT(1H02X,30H MATERIAL CODES CONSIDERED ARE 10(1X,12,2H, ))

000723 4070 FORMAT(50H NONE OF THE DATA IS ACCEPTABLE FOR THIS PROBLEM )

000723 11000 FORMAT (/ 120(1H*/ )

000723 12000 FORMAT ( // (120(1H* )/ / 1H1 )

000723 END
DAMALW

SUBPROGRAM LENGTH
001706

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
S = 000735 7 = 000741 10 = 000743 20 = 000143
Zb = 000224 28 = 000301 45 = 000523 50 = 000554
b0 = 000635 70 = 000712 500 = 000747 1000 = 000751
1EOO = 001032 1600 = 001072 1800 = 001133 1900 = 001140
bO = 001147 3000 = 001216 4000 = 001231 4010 = 001241
b1 = 001264 4030 = 001301 4040 = 001310 4050 = 001352
1COb = 001365 4070 = 001374 11000 = 001404 12000 = 001407

NAMES AND LENGTHS
OUT = 000006 COSTM = 000135

VARIABLE ASSIGNMENTS
CA = 000000C02 CO = 000106C02 COST = 001702 GM = 001701
GMF = 001602 I = 001655 II = 001703 IT = 001700
ITEM = 001660 II = 000000C01 I2 = 000001C01 I3 = 000C02C01
J = 001656 MATCP = 001544 MATSC = 001640 MITEM = 001653
MNMATS = 001654 MOMJ = 000002 MXI = 000000 NC = 001652
NMATS = 001677 NPCNT = 001665 OCOSt = 001462 OMJ = 000001
OPSS = 001450 O3B = 001704 OTHk = 001506 OVER5 = 001705
PCTD = 001614 REPCL = 001626 RHOC = 001657 S = 000003
S1 = 001672 SI1 = 001675 S2 = 001673 S22 = 001676
S3 = 001674 T1 = 000003C01 T2 = 000004C01 T3 = 000005C01
W = 001671 WI = 001661 WII = 000139C02 X = 001664
XDJ = 000004 XL = 001662 Y = 001667 YL = 001663

START OF CONSTANTS
U00725

START OF TEMPORARIES
001414

START OF INDIRECTS
001430

UNUSED COMPILED SPACE
037500
CDPRO - Subroutine

Usage:

(1) Reads material files.

(2) Stores material thicknesses by material and axis for the shock and vibration environments.

(3) Deletes materials that do not protect in all temperature regions.

Subprograms called:

(1) DHGHT

(2) SHOCKE

(3) VIBRTN

(4) COSTMT
### Glossary of Variables for CDPRO

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL(I)</td>
<td>Array of longest dimensions for each face of package.</td>
</tr>
<tr>
<td>ALI(I)</td>
<td>Actual dimensions of package.</td>
</tr>
<tr>
<td>DH</td>
<td>Calculated drop height.</td>
</tr>
<tr>
<td>DII</td>
<td>Array of drop heights.</td>
</tr>
<tr>
<td>DLH</td>
<td>Dummy parameter.</td>
</tr>
<tr>
<td>DL(I)</td>
<td>Change in package dimensions along each face.</td>
</tr>
<tr>
<td>DRPH</td>
<td>Actual drop height - stored on file.</td>
</tr>
<tr>
<td>DWB</td>
<td>Weight added by the addition of a bearing board.</td>
</tr>
<tr>
<td>GM</td>
<td>Maximum G-allowable (ft/sec/sec).</td>
</tr>
<tr>
<td>IJE</td>
<td>Deletion code.</td>
</tr>
<tr>
<td>ITEMP</td>
<td>Number of temperatures considered.</td>
</tr>
<tr>
<td>MIC</td>
<td>Maximum iterations for drop height weight convergence.</td>
</tr>
<tr>
<td>MOMS</td>
<td>Number of frequencies stored on the vibration file.</td>
</tr>
<tr>
<td>MTS</td>
<td>Number of temperatures stored on the vibration file.</td>
</tr>
<tr>
<td>MXIT(I, J, K)</td>
<td>Number of thicknesses stored for each axis and temperature.</td>
</tr>
<tr>
<td>NMATS</td>
<td>Number of materials to be considered.</td>
</tr>
<tr>
<td>NS</td>
<td>Number of static stresses.</td>
</tr>
<tr>
<td>NT</td>
<td>Number of temperatures.</td>
</tr>
<tr>
<td>OMS(I)</td>
<td>Array of frequencies stored in ascending order.</td>
</tr>
<tr>
<td>RHOC</td>
<td>Specific weight of container material under consideration.</td>
</tr>
<tr>
<td>RHOM</td>
<td>Specific weight of material under consideration.</td>
</tr>
<tr>
<td>SI</td>
<td>Static stress (W/A).</td>
</tr>
<tr>
<td>SIG(I)</td>
<td>Array of static stresses in ascending order.</td>
</tr>
</tbody>
</table>
Glossary of Variables for CDBRC (Cont.)

T (I) - - - - Array of temperatures in ascending order.

TAB1 (I, J, K) - Work array—during shock calculations it contains \( G = F \) (thickness, static stress, temperature). During vibration calculations it contains \( ER = \text{modulus} = F \) (frequency, temperature).

TAB2 (I, J, K) - Array which contains loss tangent = \( F \) (frequency, temperature).

TCON - - - Thickness of container (in.).

TH(I) - - - Array of thicknesses in ascending order.

THI - - - A trial thickness.

THIK (I, J) - - Matrix of thicknesses generated during shock calculations.

THIKV (I, J) - - Matrix of thicknesses generated during vibration calculations.

TI - - - An environmental temperature.

TIII - - - Environmental temperature.

TMX - - - Maximum allowed shock thickness.

TS(I) - - - Array of temperatures stored in ascending order.

TSK - - - Thickness predicted by shock environment.

TTHIK (I, J, K) - Dynamic array which contains the union of the thicknesses of all three temperature environments.

WI - - - Weight of item (lbs).

XL - - - Width (in.).

YL - - - Height (in.) - shortest dimension.

ZL - - - Length (in.) - longest dimension.
SUBROUTINE CDPRO(XL,YL,ZL,TCON,TI,WI,NMATS,RHOC,MIC,MI,COST,
    1 MATSC,GM,OMJ,MOMJ,S,XDJ,IC,NIC)
C  CUSHION DESIGN PROCEDURE
C  GM ----- MAX G=ALLOWABLE (FT./SEC/SEC)
C  MATSC----- VECTOR OF MATERIAL CODES
C  MIC ----- MAX ITERATIONS FOR WEIGHT CONVERGENCE
C  MXI ----- MAX ITERATIONS FOR GM CONVERGENCE
C  NMATS----- NUMBER OF MATERIALS TO BE CONSIDERED
C  NS ----- NUMBER OF STRESSES
C  NT ----- NUMBER OF TEMPERATURES
C  NTH ----- NUMBER OF THICKNESSES
C  RHOC ----- SPEC. W OF CONTAINER UNDER CONSIDERATION (PCI)
C  RHOM ----- SPEC. W OF MATERIAL UNDER CONSIDERATION (PCI)
C  SI ----- STATIC STRESS -CALCULATED
C  TCON ----- THICKNESS OF CONTAINER (INCHES)
C  THI ----- GUESS THICKNESS -CALCULATED
C  THIK ----- ARRAY OF THICKNESSES WORK ARRAY
C  THIKV----- ARRAY OF THICKNESSES WORK ARRAY
C  TI ----- INTERPOLATING TEMPERATURE
C  WI ----- WEIGHT OF ITEM
C  XL ----- WIDTH (INCHES)
C  YL ----- HEIGHT (INCHES)
C  ZL ----- LENGTH (INCHES)

COMMON /MMM/ MXIT(10,3,3)
COMMON /THK/ TSK,ITEM
COMMON /TEMPT/ TTHK(10,3,11),IM,IAXS,ITEMP,IJE,TMX
COMMON /N/ NT,NS,NTH,SI,THI,TTII
DIMENSION TI(3)
DIMENSION TH(10),SIG(10),T(10),TAB1(10,10,10),MATSC(10),TS(10)
DIMENSION OMS(10),THIK(10,3),DII(5),THIKV(10,3),TAB2(10,10,10)
DIMENSION OMJ(11),XDJ(11),FE(10),S(10),AL(3),ALI(11),DL(3)
EQUIVALENCE(TH,TS),(SIG,OMS),(T,FE)
INTEGER DRPH
INTEGER DH,DII
DATA OIl/18,24,30,36,48/
STATEMENT FUNCTION TO CALCULATE WEIGHT CHANGES
WITH(T1,T2,T3,RC,RM)=2.*((RC*TC0N+RM*T1)*(Z +2.*(TC0N+T1))
   1 (Y +2.*(TC0N+T2))*X +2.*(TC0N+T2))*Z +2.*(TC0N+T3))*X
   2 (X +2.*(TC0N+T3))
   3 (X +2.*(TC0N+T3)))
C
ITIME = 0
DWH=0.0
DO 130 ITEM=1,ITEMP
 130 TIIL = TI(ITEM)
XDDA=GM
AL(1)=ZL
AL(2)=RX
AL(3)=XL
X=XL
Y=YL
Z=ZL
PRINT 1100
DO 50 IM=1,NMATS
 50 MS = MATSC(IM)
REWIND MS
DO 4 IAXS=1,3
4
4  THIKV(IM,IAX3)=0.0
5  CONTINUE

1.5  THI=3.5
1.52  THIK(IM,1)=THI
1.54  THIK(IM,2)=THI
1.55  THIK(IM,3)=THI
1.56  DLH=0
1.56  T1= THI
1.57  T2= THI
1.60  T3= THI
1.61  TT1= T1
1.62  TT2= T2
1.64  TT3= T3
1.65  DL(1)=2.*(THI + TCON)
1.70  DL(2)=2.*(THI + TCON)
1.73  DL(3)=2.*(THI + TCON)
1.76  READ(MS,12)RHOM,DRPH,ICODE
2.07  RHOM=RHOM/12.*3
2.11  DO 16 ICOUNT=1,MIC
2.16  DO 15 IAXS=1,3
2.17  THI=THIK(IM,IAXS)
2.23  ALI(IAXS)=AL(IM,IAXS)+DL(IAXS)
2.26  IF(IAXS.EQ.1)AYZ2
2.32  IF(IAXS.EQ.2)AYZ2
2.36  IF(IAXS.EQ.3)AYZX
2.42  WW = WI + MF(TT1,TT2,TT3,RHOC,RHOM) + DWB
2.55  DH= DHGHT(WW,ALI(IAXS))
2.63  IJ=0
2.64  11 CONTINUE
2.66  IJ=IJ+1
2.66  IF(IJ.GT.*)PRINT 1000
3.03  READ(MS,20)NT,NTH,NS
3.15  READ(MS,10)(T(I),I=1,NT)
3.30  READ(MS,10)(SIG(I),I=1,NS)
3.35  DO 1000 K=1,NT
3.63  DO 1000 I=1,NTH
3.64  1000 READ(MS,12)TAB1(I,J,K),J=1,NS
3.69  IF(DH.NE.DII(IJ))RETO 11
3.70  IF(DH.NE.DII(IJ))GO TO 13
3.72  IF(DH.NE.DII(IJ))GO TO 11
3.83  13 CONTINUE
3.84  REWIND MS
3.86  READ(MS,12)RHOM,DRPH,ICODE
3.86  RHOM=RHOM/12.*3
3.86  SIG=1/A
3.86  THIK(IM,IAXS)= SHOCKE(TAB1,TH,SIG,T,GM,MXI)
4.76  TT1 = THIK(IM,1)
4.80  TT2 = THIK(IM,2)
4.80  TT3 = THIK(IM,3)
4.93  DL(1)=2.*(TT3+TCON)
4.93  DL(2)=2.*(TT3+TCON)
4.94  DL(3)=2.*(TT1+TCON)
5.14  CONTINUE

C  CALCULATE DELTA LENGTH FOR LONGEST DIMENSION

5.51  15 CONTINUE
5.52  IF(ABS(T1-TT1).LE.1.E-1.AND.ABS(T2-TT2).LE.1.E-1.AND.ABS(T3-TT3).LE.1.E-1) GO TO 45

57
PRINT 7001,T1,T2,T3,TT1,TT2,TT3
T1 = TT1
T2 = TT2
T3 = TT3
16 CONTINUE
C PRINT APPROPRIATE MESSAGE FOR NON-CONVERGENCE
PRINT 7000,MATSC(IM)
MATSC(IM)=0
GO TO 50
45 CONTINUE
IF(TT3.LE.TMX)GO TO 50
ITIME = ITIME+1
IF(ITIME.NE.1)GO TO 50
REWIND MS
Y=YL+2.*T2
PRINT 8000,XL,Y,ZL,/,IM
C CALCULATE WEIGHT OF (1/4) INCH PLYWOOD FOR EACH AXIS
DB=0.0098*(Y*Z + Y*X)
GO TO 5
50 CONTINUE
C
DO 56 IM=1,NMATS
IF(MATSC(IM).EQ.0)GO TO 56
MS=MATSC(IM)
C READ TO BEGINNING OF VIBRATION FILES
REWIND MS
DO 55 IR=1,4
READ(MS,12)RH0M,DRPH,ICODE
READ(MS,20)NT,NTH,NS
READ(MS,10)(T(I),I=1,NT)
READ(MS,10)(TH(I),I=1,NTH)
READ(MS,10)(SIG(I),I=1,NS)
DO 55 K=1,NT
DO 55 I=1,NTH
55 READ(MS,10)(TAB1(I,J,K),J=1,MTS)
CONTINUE
DO 70 IAXS=1,3
THIKV(IM,IAXS)=THIK(IM,IAXS)
IF(IAXS.EQ.1)A=Y*Z
IF(IAXS.EQ.2)A=X*Z
IF(IAXS.EQ.3)A=Y*X
M=M+1
65 CONTINUE
70 READ(MS,14)(TAB2(I,J,1),J=1,MTS)
CONTINUE
DO 70 IAXS=1,3
THIKV(IM,IAXS)=THIK(IM,IAXS)
58
CALL VIBRTN(TAB1,TAB2,TS,OMS,TOP,OMJ,FE,OMMJ,XDDA,A,WW,S,IC,XDJ)

IF(IJE.EQ.0) GO TO 75

THIKV(IM,IAXS)=TOK

CONTINUE

CONTINUE

CONTINUE

IF(IJE.EQ.0)MATSC(IM)=0

CONTINUE

PRINT THICKESES

PRINT 5000,((THIKV(I, J), J=1, 3), I=1, NMATS)

ELIMINATE MATERIALS THAT DO NOT OVERLAP ALL TEMP REGIONS

IK=0

UP-DATE THICKNESS ARRAY

IF(MATSC(IM),EQ,0) GO TO 120

IK=IK+1

DO 110 IA=1,3

MX=MXI(T(IM,IA,ITEM))

DO 110 IU=1,MXX

TTHIK(IK,IA,IU)=TTHIK(IM,IA,IU)

MXI(TK,IA,ITEM)=MXX

IF(ITEMP,EQ,1)GO TO 110

MXI(TK,IA,ITEM+1)=MXI(IK,IA,ITEM+1)

CONTINUE

110 CONTINUE

CONTINUE

SORT OUT DELETIONS

DO 125 I=1,NMATS

DO 125 J=I,NMATS

IF(MATSC(J),LT,MAT3C(I))GO TO 125

SAVE=MATSC(J)

MATSC(J)=MATSC(I)

MATSC(I)=SAVE

125 CONTINUE

NMATS=IK

IF(NMATS,NE,0) GO TO 126

PRINT 6000

TI(1)=1500.

RETURN

CONTINUE

SORT MATSC(I) BACK INTO ASCENDING ORDER

DO 127 I=1,NMATS

DO 127 J=I,NMATS

IF(MATSC(J),GT,MAT3C(I))GO TO 127

SAVE=MATSC(J)

MATSC(J)=MATSC(I)

MATSC(I)=SAVE

127 CONTINUE

CONTINUE

DO 135 I=1,NMATS

DO 135 IA=1,3

MXII=MXI(T(I,IA,ITEM))

IF(ITEMP,EQ,1)MXII=1

THIKV(I,IA)=TTHIK(I,IA,MI)

CONTINUE

CONTINUE

CALL COSTMT(THIKV,X,Y,Z, TCON,THIK,MATSC,NMATS,COST,NIC)

RETURN

10 FORMAT(11E7.0)

12 FORMAT(E7.0,5I2)
14 FORMAT(11E11.4)
20 FORMAT(S12)
5000 FORMAT(2X,3HMINIMUM THICKNESS FOR MATERIAL BY AXIS /
1 10(2X,3E15.4/))
6000 FORMAT(1X,S8H ALL MATERIALS DELETED --- NO OVERLAP BETWEEN TEMPERA
ITURES 29H-OPTIMIZE ON DATA ACCUMULATED )
7000 FORMAT(5SH CAN NOT DETERMINE THICKNESS FOR DROP HGT. CALCULATIONS
1 2X,15HMATERIAL CODE #I3,2X,21HMTHIS MATERIAL DELETED)
7001 FORMAT(2X,3HT1=E11.4,2X,3HT2=E11.4,2X,3HT3=E11.4,
1 2X,4HT1=E11.4,2X,4HT2=E11.4,2X,4HT3=E11.4)
8000 FORMAT(2X,30HPLYWOOD BEARING BOARD 1/4 INCH/
13X,10HDIMENSIONS F5.2,3H X F5.2,2X,6HSIDE 3
23X,10HDIMENSIONS F5.2,3H X F5.2,2X,6HSIDE 1 3X,15HMATERIAL NUMBER
3 13)
10000 FORMAT(1H0 25HCAN NOT FIND DROP HEIGHT )
11000 FORMAT (/ 120(1H*)/ )
END
CDPRO

SUBPROGRAM LENGTH
006032

FUNCTION ASSIGNMENTS
WF  =  U00034

STATEMENT ASSIGNMENTS
   4  =  000142  S  =  000150  10  =  001466  11  =  000264
   12  =  001470  13  =  000442  14  =  001473  20  =  001476
   45  =  000614  50  =  000654  56  =  001012  69  =  001156
   75  =  001214  100  =  001220  110  =  001312  120  =  001317
   125  =  001340  126  =  001360  127  =  001377  5000  =  001900
   6000  =  001511  7000  =  001525  7001  =  001542  8000  =  001554
   10000  =  001603  11000  =  001610

BLOCK NAMES AND LENGTHS
MMM  =  000132  THK  =  000002  TEMPT  =  000517  N  =  00006b

VARIABLE ASSIGNMENTS
A  =  006012  AL  =  00575b  ALI  =  005761  COST  =  00004
DM  =  005770  DII  =  003743  DL  =  005764  DLM  =  005771
DRPH  =  005767  DWH  =  00577b  FE  =  001723  GM  =  00006b
I  =  006015  IA  =  006025  IAXS  =  00513C03  IC  =  00013
ICODE  =  006010  ICOUNT  =  006011  IJ  =  006014  IJE  =  00515C03
IK  =  006024  IM  =  00512C03  IR  =  006020  ITEM  =  000001C02
ITEM  =  000514C03  ITIME  =  005775  IU  =  006027  J  =  006017
K  =  006016  MATSC  =  000005  MIC  =  000002  MOMJ  =  000010
MOMS  =  006022  MA  =  006000  MTS  =  006021  MXI  =  000003
MXI  =  006031  MXIT  =  000000C01  MXX  =  006026  NIC  =  000014
NMATS  =  000000  NS  =  000001C07  NT  =  000000C0  NTH  =  000002C04
OMJ  =  000007  OMS  =  001711  RHOC  =  000001  RHOM  =  006007
S  =  000011  SAVE  =  006030  SI  =  000003C0  SIG  =  001711
T  =  001723  TAB1  =  001735  TAB2  =  004006  TM  =  001677
THI  =  000004C0  THIK  =  003705  THIKV  =  003750  TIII  =  000005C04
TMX  =  00016C03  TOP  =  006023  TS  =  001677  TSK  =  000000C02
TTHIK  =  00000C03  TT1  =  006004  TT2  =  006005  TT3  =  006006
T1  =  006001  T2  =  006002  T3  =  006003  WW  =  006013
X  =  005774  XDA  =  005777  XDJ  =  000012  Y  =  005773
Z  =  005772

START OF CONSTANTS
U01454

START OF TEMPORARIES
001613

START OF INDIRECTS
001671

UNUSED COMPILER SPACE
036300

61
DHGHT - Function Subprogram

Usage:

Picks drop height using criterion set forth in the MIL-Standard.

Subroutines called:

None
Glossary of Variables for DHGHT

ALL - - - - Item length + container and cushion thickness.
DH - - - - Calculated drop height.
DHH (I) - - - Drop height.
DHL (I) - - - Drop height longest length.
DHW (I) - - - Drop height upper weight limit.
WW - - - - Item weight + container and cushion weight.
FUNCTION DHGHT(WW, ALL)
      DIMENSION DHW(7), DML(7), DHH(7)
      ALL = ITEM LENGTH + CONTAINER AND CUSHION THICKNESS
      DH = DROP HEIGHT
      DML = DROP HEIGHT MAXIMUM LENGTH
      DHH = DROP HEIGHT UPPER WEIGHT LIMIT
      WM = ITEM WEIGHT + CONTAINER AND CUSHION WEIGHT
      DATA DHW/100. .100. .200. .200. .1000. .1000. .1000. /
      DATA DML/36. .500. .36. .500. .36. .500. .60. .600. /
      THIS FUNCTION PICKS THE APPROPRIATE DROP HEIGHT
      DO 7 I=1,7
        DM = 18.
        IF(WW.GT.1000.)GO TO 20
        DO 10 I=1,7
          II=I
          IF(WW.GT.DHW(II))GO TO 10
          IF(ALL.LT.DML(II))GO TO 18
          IF(DHH(II).LT.DHW(II+1))GO TO 18
          II=II+1
          GO TO 7
          CONTINUE
        10 CONTINUE
        DM=DHH(II)
        18 DM=DHH(II)
        20 DHGHT=DM+U.1
      RETURN
END
SUBPROGRAM LENGTH
000101

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
7     -  000013    10     -  000025    18     -  000027    20     -  000031

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS
DH     -  000076    DHGHT  -  000050    DHH     -  000048    DHL     -  000060
DHW    -  000051    I      -  000077    II      -  000100

START OF CONSTANTS
000036

START OF TEMPORARIES
000042

START OF INDIRECTS
000044

UNUSED COMPILER SPACE
043300
COSTMT - Subroutine

Usage:

(1) Calculates cost of packing materials by axis.
(2) Calculates cost of container.
(3) Calculates cost of fabrication of package material.
(4) Calculates total cost.
(5) Prints total cost and cost by material and axis.

Subroutines called:

MINCOS
### Glossary of Variables for COSTME

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL(I)</td>
<td>Area of the perpendicular face of the package.</td>
</tr>
<tr>
<td>C1</td>
<td>Cost of material on face one.</td>
</tr>
<tr>
<td>C2</td>
<td>Cost of material on face two.</td>
</tr>
<tr>
<td>C3</td>
<td>Cost of material on face three.</td>
</tr>
<tr>
<td>C12</td>
<td>Contains the minimum cost between the materials on face one and face two.</td>
</tr>
<tr>
<td>C13</td>
<td>Contains the minimum cost between the materials on face one and face three.</td>
</tr>
<tr>
<td>C23</td>
<td>Contains the minimum cost between the materials on face two and face three.</td>
</tr>
<tr>
<td>C123</td>
<td>Contains the lowest cost of the three materials.</td>
</tr>
<tr>
<td>CAXIS(I, 1)</td>
<td>Cost of the packaging material for face one.</td>
</tr>
<tr>
<td>CAXIS(I, 2)</td>
<td>Cost of the packaging material for face two.</td>
</tr>
<tr>
<td>CAXIS(I, 3)</td>
<td>Cost of the packaging material for face three.</td>
</tr>
<tr>
<td>CF(I)</td>
<td>Array containing cost of fabrication to specific dimensions.</td>
</tr>
<tr>
<td>CFF</td>
<td>Cost of fabrication.</td>
</tr>
<tr>
<td>CM(I)</td>
<td>Array containing material cost.</td>
</tr>
<tr>
<td>COST</td>
<td>Total cost.</td>
</tr>
<tr>
<td>CP(I)</td>
<td>Array containing the cost of packaging.</td>
</tr>
<tr>
<td>CPP</td>
<td>Cost of packaging.</td>
</tr>
<tr>
<td>CSS</td>
<td>Cost of shipping the package.</td>
</tr>
<tr>
<td>CVC</td>
<td>Cost of material for corners.</td>
</tr>
<tr>
<td>II(I)</td>
<td>Contains array positions of optimum thickness for each of the three faces.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>MC(I)</td>
<td>Contains material code for each of the three faces.</td>
</tr>
<tr>
<td>MTC</td>
<td>Material code.</td>
</tr>
<tr>
<td>SLT(I)</td>
<td>Safe low temperature.</td>
</tr>
<tr>
<td>T1</td>
<td>Optimum thickness for face one.</td>
</tr>
<tr>
<td>T2</td>
<td>Optimum thickness for face two.</td>
</tr>
<tr>
<td>T3</td>
<td>Optimum thickness for face three.</td>
</tr>
<tr>
<td>TCC</td>
<td>Total cost of container by volume.</td>
</tr>
<tr>
<td>TCMV</td>
<td>Total cost of material by volume.</td>
</tr>
<tr>
<td>V1</td>
<td>Volume of packaging material needed for face one.</td>
</tr>
<tr>
<td>V2</td>
<td>Volume of packaging material needed for face two.</td>
</tr>
<tr>
<td>V3</td>
<td>Volume of packaging material needed for face three.</td>
</tr>
</tbody>
</table>
SUBROUTINE COST MT(TM1K, XL, YL, ZL, TCON, CAXIS, MATSC, NMATS, COST, IC)

C CC ---- 1-D ARRAY COST/UNIT VOLUME OF CONTAINER MATERIAL
C CF ---- 1-D ARRAY CONTAINING COST OF FABRICATION TO
C SPECIFIC DIMENSION (0.05=MIN)
C CI ---- CUST OF ITEM
C CM ---- 1-D ARRAY CONTAINING MATERIAL COST/UNIT VOLUME
C COSTMT
C CP ---- 1-D ARRAY COST OF PACKING ITEM FOR SHIPMENT
C CS ---- COST OF SHIPMENT
C GAMAC ---- 1-D ARRAY CONTAINING SPECIFIC WEIGHT OF CONTAINER
C MATERIAL
C ROS1 ---- 1-D ARRAY LOW END OF THE RANGE OF OPTIMUM
C STRESS OF EACH MATERIAL
C ROS2 ---- 1-D ARRAY HIGH END OF THE RANGE OF OPTIMUM
C STRESS OF EACH MATERIAL
C SLT ---- 1-D ARRAY OF SAFE LOW TEMPERATURE FOR EACH MATERIAL

COMMON /COST/ CA(10,7), CD(10,2), CS, CI,*II
COMMON /OPT/ I1, I2, I3, T1, T2, T3
DIMENSION MATSC(10)
DIMENSION CM(10), CF(10), CP(10), Slt(10), ROS1(10), ROS2(10), MC(3)
DIMENSION GAMAC(10), CI(10), TM1K(10,3), CAXIS(10,3), AL(3), II(3)
EQUIVALENCE (CA(1,1), CM), (CA(1,2), CF), (CA(1,3), CP), (CA(1,4), Slt),
1 (CA(1,5), ROS1), (CA(1,6), ROS2)
EQUIVALENCE (CD(1,1), GAMAC), (CD(1,2), CC), (MC, AL)
AL(1) = ZL*YL
AL(2) = ZL*XL
AL(3) = XL*YL
DO 20 I = 1, NMATS
MTC = MATSC(I)
V1 = AL(1) * TM1K(I, 1)
V2 = AL(2) * TM1K(I, 2)
V3 = AL(3) * TM1K(I, 3)
CAXIS(I, 1) = V1 * CM(MTC)
CAXIS(I, 2) = V2 * CM(MTC)
CAXIS(I, 3) = V3 * CM(MTC)
20 CONTINUE
CALL MINC0S(II, IS, NMATS)
Determine cost of packing material
DO 30 I = 1, 3
II(I) contains array positions
IL = II(I)
MC(I) contains mat. code
MC(I) = MATSC(IL)
30 CONTINUE
I, J, K contains mat. code
I = MC(1)
J = MC(2)
K = MC(3)
Calculate min. cost for corner and edge cushioning
C123 = AMIN1(CM(I), CM(J), CM(K))
C12 = AMIN1(CM(I), CM(J))
C13 = AMIN1(CM(I), CM(K))
C23 = AMIN1(CM(J), CM(K))
I1 = II(1)
I2 = II(2)
I3 = II(3)
T1 = TM1K(II, 1)
TE = THIKV(I2, 2)
T3 = THIKV(I3, 3)
CSS = (ZL*YL*T1*CA(I1, 7)*ZL*YL*T2*CA(I2, 7)*ZL*YL*T3*CA(I3, 7))*CS + CS*WI

PRINT 2000, MC(1), THIKV(I1, 1), MC(2), THIKV(I2, 2), MC(3), THIKV(I3, 3)
C1 = ZL*THIKV(I1, 1)*THIKV(I2, 2)*C12
C2 = XL*THIKV(I2, 2)*THIKV(I3, 3)*C23
C3 = YL*THIKV(I3, 3)*THIKV(I1, 1)*C13

CVC = THIKV(I1, 1)*THIKV(I2, 2)*THIKV(I3, 3)*C123

C TOTAL COST OF MATERIAL BY VOLUME
TCMV = ZL*(CAXIS(I1, 1)*CAXIS(I2, 2)*CAXIS(I3, 3))
1 + .4*CVC**.4*(C1*C2*C3)

C TOTAL COST OF CONTAINER BY VOLUME
TCC = CC(1)*TCUN = (2.*ZL + 2.*THIKV(I3, 3)) * (YL + 2.*THIKV(I2, 2)) +
1 + .2*(ZL + 2.*THIKV(I3, 3)) * (XL + 2.*THIKV(I1, 1)) +
2 + .2*(XL + 2.*THIKV(I1, 1)) * (YL + 2.*THIKV(I2, 2))

C COST OF FABRICATION BASED ON A RATE OF 3 INCHES/MIN AND THE ASSUMPTION
THAT IT TAKES 1/2 AS MUCH TIME TO CUT THE EDGE FILLER AS TO CUT
THE SURFACE.

C TOTAL COST
CFF = (CF(I)*(YL)*CF(J)*(XL)*CF(K)*(YL))

C TOTAL COST
CPP = (CP(I)*(ZL)*CP(J)*(XL))*CPP

C TO BE CONTINUED LATER
**********
P'INT 1000, COST, (MATSC(IA, JA), (CAXIS(JA, JA) = 1, 3), IA = 1, N MATS)
RETURN

100 FORMAT (2X, 16H TOTAL COST/ITEM = F8.2, 2X, 12HMATERIAL = INPUT /
1 MX, 6MCOST MATRIX = MATERIAL VERTICAL, AXIS HORIZONTAL /
2 10(2X, 12HMATERIAL CODE = F8.3)

200 FORMAT (2X, 15HMATERIAL CODE = F8.3, 2X, 4THICKNESS FOR FACE ONE = F8.3)
1 , 1X, HMINCHES/
2 2X, 15HMATERIAL CODE = F8.3, 2X, 4THICKNESS FOR FACE TWO = F8.3
3 , 1X, HMINCHES/
4 2X, 15HMATERIAL CODE = F8.3, 2X, 5THICKNESS FOR FACE THREE =
5 F8.3, 1X, HMINCHES/)
**COSTM**

**SUBPROGRAM LENGTH**
000701

**FUNCTION ASSIGNMENTS**

**STATEMENT ASSIGNMENTS**
1000 - 000422 2000 - 000444

**BLOCK NAMES AND LENGTHS**
COSTM - 000135 OPT - 000006

**VARIABLE ASSIGNMENTS**

<table>
<thead>
<tr>
<th>AL</th>
<th>000049</th>
<th>CA</th>
<th>000000C01</th>
<th>CC</th>
<th>000120C01</th>
<th>CD</th>
<th>000106C01</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>000012C01</td>
<td>CP</td>
<td>000675</td>
<td>CI</td>
<td>000133C01</td>
<td>CM</td>
<td>000000C01</td>
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<tr>
<td>COST</td>
<td>000002</td>
<td>C13</td>
<td>000672</td>
<td>C12</td>
<td>000676</td>
<td>C3</td>
<td>000132C01</td>
</tr>
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<td>C95</td>
<td>000666</td>
<td>CVC</td>
<td>000664</td>
<td>C2</td>
<td>000670</td>
<td>C23</td>
<td>000b65</td>
</tr>
<tr>
<td>C123</td>
<td>000662</td>
<td>C13</td>
<td>000664</td>
<td>C2</td>
<td>000670</td>
<td>C23</td>
<td>000b65</td>
</tr>
<tr>
<td>C3</td>
<td>000671</td>
<td>GAMAC</td>
<td>000106C01</td>
<td>I</td>
<td>000652</td>
<td>IA</td>
<td>000b77</td>
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<tr>
<td>IC</td>
<td>000003</td>
<td>II</td>
<td>000647</td>
<td>IL</td>
<td>000657</td>
<td>I1</td>
<td>000000C02</td>
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<tr>
<td>I2</td>
<td>000001C02</td>
<td>I3</td>
<td>000002C02</td>
<td>J</td>
<td>000660</td>
<td>IA</td>
<td>006700</td>
</tr>
<tr>
<td>K</td>
<td>000b61</td>
<td>MATSC</td>
<td>000000</td>
<td>MC</td>
<td>000644</td>
<td>MTC</td>
<td>000b53</td>
</tr>
<tr>
<td>NMATS</td>
<td>000001</td>
<td>ROS1</td>
<td>00050C01</td>
<td>ROS2</td>
<td>000062C01</td>
<td>9LT</td>
<td>000035C01</td>
</tr>
<tr>
<td>TCC</td>
<td>000624</td>
<td>TCMV</td>
<td>000673</td>
<td>T1</td>
<td>00003C02</td>
<td>T2</td>
<td>000004C02</td>
</tr>
<tr>
<td>T3</td>
<td>000005C02</td>
<td>V1</td>
<td>000654</td>
<td>V2</td>
<td>000655</td>
<td>V3</td>
<td>000b56</td>
</tr>
</tbody>
</table>

**START OF CONSTANTS**
000414

**START OF TEMPORARIES**
000510

**START OF INDIRECTS**
000574

**UNUSED COMPILER SPACE**
041:00
MINCOS - Subroutine

Usage:

Picks the material that has the minimum cost for each axis.

Subroutines called:

None
Glossary of Variables for MINCOS

CAXIS(1, J) - - Cost of packaging material for all three faces.

II(I) - - - Contains array positions of optimum thicknesses for each face.

SIT(I) - - - Work array used for sorting.
SUBROUTINE MINC03T(I,MATS)
  C
  MIN COST
  C
  SUBROUTINE PICKS THE MATERIAL FOR EACH AXIS WHICH
  HAS THE MINIMUM COST
  C
  DIMENSION II(1),CAXIS(10,3),SIT(10)
  DO 50 IAXIS=1,3
  DO 30 I=1,NMATS
  30 SIT(I)=CAXIS(I,IAXIS)
  II(IAXIS)=1
  DO 40 IM=1,NMATS
  IF(SIT(I).LT.SIT(IM)) GO TO 40
  II(IAXIS)=IM
  SAVE=SIT(I)
  SIT(I)=SIT(IM)
  SIT(IM)=SAVE
  40 CONTINUE
  CONTINUE
  RETURN
  END
MINCOS

SUBPROGRAM LENGTH
000070

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
30   -  000010   40   -  000034

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS
I   -  000065   IAXIS   -  000064   IM   -  000066   SAVE   -  000047
SIT   -  000052

START OF CONSTANTS
000043

START OF TEMPORARIES
000044

START OF INDIRECTS
00004b

UNUSED COMPILER SPACE
043400
SHOCKE - Function Subprogram

Usage:

Calculates the material thickness required to protect the packaged item in the given shock environment.

Procedure:

(1) Given: a table $G = F$ (thickness, static stress),

(2) build a one-dimensional table thickness $= F(G)$.

(3) Interpolate or extrapolate to find desired thickness.

Subprograms called:

LAGINT

FLAGR
Glossary of Variables for SHOCKE

F2(I) - - - - 1-D array of interpolated accelerations.
G - - - - Interpolated acceleration.
GM - - - - Fragility limit (acceleration).
NS - - - - Number of static stresses stored on file.
NT - - - - Number of temperatures stored on file.
NTH - - - - Number of thicknesses.
SI - - - - Interpolating stress.
SIG(I) - - - - 1-D table of static stresses (W/A).
T(I) - - - - 1-D table of temperatures.
TAB1(I, J, K) - - 3-D table of peak accelerations
G = F (TH, SIG, T).
TF(I) - - - - 1-D array of guess thicknesses.
TH(I) - - - - 1-D table of thickness values.
THI - - - - Guess thickness.
TI - - - - Interpolating temperature.
FUNCTION SHOCKE(TAB1,THSIG,T,GM,MAX)

COMMON /N/ NT,NS,NTH,SI,THI,TI

DIMENSION TAB1(10,10,10),TH(10),SIG(10),T(10),F(10)

C GM -- FRAGILITY LIMIT (ACCELERATION)
C NS -- NUMBER OF STRESSES MUST BE AT LEAST 3 UNLESS EXTRAPOLATING
C NT -- NUMBER OF TEMPERATURES MUST BE AT LEAST 1
C NTH -- NUMBER OF THICKNESS VALUES MUST BE AT LEAST 1
C T -- 1-D TABLE OF TEMPERATURES (FAHRENHEIT)
C TAB1 -- 3-D TABLE OF PEAK ACCELERATIONS
C TH -- 1-D TABLE OF THICKNESS VALUES (PTS. AT WHICH DATA WAS TAKEN)
C THI -- (INITIAL THICKNESS) (GUESS)
C TI -- (TEMPERATURE) INTERPOLATING VALUE
C SI -- (STRESS) INTERPOLATING VALUE
C SIG -- 1-D TABLE OF STATIC STRESS W/A (PTS. AT WHICH DATA WAS TAKEN)
C UNLESS EXTRAPOLATING--THEN 2 ARE NEEDED

10 CONTINUE

DO 120 I=1,5

THI=FLOAT(I)

TF(I)=FLOAT(I)

CALL LAGINT(TAB1,T,THI,G,F)

FLG(I)=G

IF(ABS(G-GM).LT.0.1)GO TO 15

120 CONTINUE

SHOCKE=FLAGR(5,TF,G)

RETURN

15 CONTINUE

SHOCKE=THI

RETURN

END
SHOCKE

SUBPROGRAM LENGTH
  U00112

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
  15 = 000045 110 = 000011

BLOCK NAMES AND LENGTHS
  N = 000006

VARIABLE ASSIGNMENTS
  F = 000004  F2 = 000103  G = 000111  I = 000110
  SHOCKE = 000063  TF = 000076  THI = 000004C0

START OF CONSTANTS
  U00051

START OF TEMPORARIES
  000054

START OF INDIRECTS
  000062

UNUSED COMPILER SPACE
  043300
VIBRTN - Subroutine

Usage:

1. Determines thickness needed to protect in the vibration environment.
2. Determines the union of the temperature dependent thicknesses.

Options:

1. Physical optimization based on MIL-STD-810B excitation.
2. Physical optimization based on multiple sine excitation.
3. Physical optimization based on random excitation.

Subroutines called:

LAGINT
Glossary of Variables for VIERTX

A - - - - - - Support area of item (sq in.).
AT - - - - - - Environmental temperature.
ERI - - - - - - Modulus at center frequency.
ERJ - - - - - - Modulus at environmental frequency.
FE(I) - - - - - - 'ork - vector.
IC - - - - - - Procedure code.
IC = 1 - - - - - - MIL-STD-810B excitation.
IC = 2 - - - - - - Multiple sine excitation.
IC = 3 - - - - - - Random excitation.
MOMJ - - - - - - Number of input environment frequencies.
MOMS - - - - - - Number of frequencies stored on data files.
MTS - - - - - - Number of temperatures stored on data file.
MXI(I,J,K) - - - - Array containing the number of thicknesses included in the dynamic thickness array.
OB(I) - - - - - - Array of 1-octave band center frequencies, Hz.
OM - - - - - - Environmental frequency.
OMJ(I) - - - - - - Environmental frequencies.
OMS(I) - - - - - - Frequency scale.
S(I) - - - - - - Array of 1-octave band power spectral densities.
SJ - - - - - - Sum of output excitations for one center frequency.
TAB1(I,J,K) - - - Table containing behavior of storage modulus (ER);
                   ER = F (frequency, temperature).
TAB2(I,J,K) - - - Table containing behavior of loss tangent
                   EL/ER = F (frequency, temperature).
TCC(I) - - - - Calculated thicknesses.

TF (WI, WJ, ERI, ERJ, DJ) - Statement function to calculate transfer function.

THCK(A, ERI, WI, W) - Statement function to calculate thickness.

TOP - - - - Optimum thickness.

TOPP(I) - - - - Array of acceptable thicknesses.

TS(I) - - - - Temperature scale.

TSK - - - - Thickness predicted by shock environment.

TT(I) - - - - A thickness work array.

TTHIK(I, J, L) - - Dynamic thickness array contains all acceptable vibration thicknesses for each material, axis, and temperature.

W - - - - Weight of item.

WI - - - - 1-octave band center frequency.

XDD(I) - - - - Calculated output excitation.

XDDA - - - - Maximum allowable G-level.

XDJ(I) - - - - Environmental G-levels.
SUBROUTINE VIBRTN(TAB1,TAH2,TS,OMS,OMJ,FE,M0MJ,XDDA,A,W,S, 
IC,XDJ) / 
C SUBROUTINE CALCULATED THE OPTIMUM THICKNESS FOR THE VIBRATION
C ENVIRONMENT
000021 DIMENSION (AHI(10,10,10),TAB2(10,10,10),OB(11),TS(1),OMS(1), 
OMJ(1),S(1),FE(1),XDD(11),TCC(11),XDJ(1),TOPP(11) ,TT(22)
000021 COMMON /MM/ MXI (10,3,3) 
000021 COMMON /TEMPT/ TTHIK(10,3,11),IM,IAx,ITEMP,IJ,TMX 
0000?1 COMMON /THK/ TS,OMS,AT,OM,ZA 
0000E1 DATA OB/1.2,8.1b,1.5,b3,.125,.250,.500,.1000. 
C ******** 
C FE ----- WORK - VECTOR 
C OMJ ----- NUMBER OF INPUT ENVIRONMENT FREQ. 
C OMJ ----- ENVIRONMENTAL FREQUENCIES - VECTOR 
C OMS ----- FREQUENCY SCALE (PTS. AT WHICH INFO. IS RECORDED) - VECTOR 
C TAB1 ----- TWO - D TABLE (CURVES) CONTAINING BEHAVIOR OF STORAGE 
C TAB2 ----- TWO - D TABLE (CURVES) CONTAINING BEHAVIOR OF LOSS 
C TANGENT (DJ) DJ=EL/ER =F(TEMP,FREQ) 
C TOP ----- OPTIMUM THICKNESS 
C TS ----- TEMPERATURE SCALE (PTS. AT WHICH INFO. IS RECORDED) - VECTOR 
C XDDA ----- MAXIMUM ALLOWABLE G - LEVEL * 
C A ----- SUPPORTED AREA OF ITEM *** (SQ. INCHES) 
C ** S ----- WEIGHT OF ITEM **** 
C I ----- ENVIRONMENTAL G-LEVELS - VECTOR ***** 
C IC ----- PROCEEDURE CODE VALUE=1,8,OR 3 ***  
C AT ----- ENVIRONMENTAL TEMPERATURE 
C IC=1 ----- PHYSICAL OPTIMIZATION FOR MIL - STD 810B EXCITATION 
C IC=2 ----- PHYSICAL OPTIMIZATION FOR MULTIPLE SINE EXCITATION 
C IC=3 ----- PHYSICAL OPTIMIZATION FOR RANDOM EXCITATION 
C OMS ----- ENVIRONMENTAL FREQ OMJ(J) 
C MOMS ----- NUMBER OF VALUES ALONG FREQ. SCALE (OMS) 
C MTS-----NUMBER OF TEMPERATURES STORED ON FILE 
C ** 
C TAB1 AND TAB2 ARE ASSUMED TO USE THE SAME TS AND OMS VECTORS 
C ******** 
000021 TF(WI,WJ,ERI,ERJ,OJ)= SQRT((1.+DJ**2)/(1.-(WJ/WI)**2*ERI/ERJ)**2 
1 + DJ**2)) 
0000?7 THCK(A,ERI,WI,WJ)= 38b.40**A*ERI/(WJ**2) 
0000b1 M=1 
0000b2 ZA=0.0 
0000b3 DO 50 J=1,11 
0000b5 SJ = 0.0 
0000b6 WJ=2.931853*0B(I) 
000070 OM = #1 
000071 XDD(I)=1.E10 
000073 IF(OM.LT.OMS(1))GO TO 50 
000076 CALL LAGINT(TAB1,DUMY,TS,OMS,ERI,FE) 
000101 TCC(I) = THCK(A,ERI,MI,W) 
000115 GO TO (10,20,30) , IC 
000124 CONTINUE 
C IC=1 MIL STD 810 - B EXCITATION 
000126 CALL LAGINT(TAB2,DUMY,TS,OMS,DI,FE) 
000130 SJ = TF(WI,OM,ERI,ERI,DI)*XDJ (I)
000147    GO TO 45
000147   20 CONTINUE

C MULTIPLE SINE EXCITATION
000151  OM = OM(J)
000153  IF(OM.LT.OMS(1).OR.OM.GT.OMS(M0M3))GO TO 25
000154  CALL LAGINT(TAB1,DUMY,TS,OMS,ERJ,FE)
000155  CALL LAGINT(TAB2,DUMY,TS,OMS,0J,FE)
000156  SJ = 3J + TF(WI,OM,ERI,ERJ,0J) * XDJ(J)
000157  25 CONTINUE
000158  GO TO 45
000159  30 CONTINUE

C RANDOM EXCITATION (PSD INPUT)
000222  DO 35 J=1,M0M3
000224  CALL LAGINT(TAB1,DUMY,TS,OMS,ERJ,FE)
000226  CALL LAGINT(TAB2,DUMY,TS,OMS,0J,FE)
000228  SJ = SJ + 3(J) * TF(WI,OM,ERI,ERJ,0J) * 2
000230  35 CONTINUE
000231  SJ = 2.5 * SQRT(SJ)
000237  45 CONTINUE
000239  XDD(I) = SJ
000241  GO TO 50
000247  50 CONTINUE

000277  II=0
000300  CT=1.
000301  00 60  I =1,11
000303  IF(XDD(I).EQ.1.E10)GO TO 60
000304  IF(XDD(I).GT.XDDA)GO TO 60
000312  II=II+1
000313  IF(CT.EQ.1.)TOP=TCC(I)
000317  TOP = AMIN1(TOP,TCC(I))
000323  TOPP(II)=TCC(I)
000325  CT = 0.0
000326  60 CONTINUE

C SORT THICKNESSES INTO ASCENDING ORDER
000330  00 65  I=1,11
000332  00 65  J=1,II
000333  IF(TOPP(J).GT.TOPP(I))GO TO 65
000340  SAVE=TOPP(J)
000341  TOPP(J)=TOPP(I)
000344  TOPP(I)=SAVE
000345  65 CONTINUE

C COMPARE SHOCK THICKNESS TO VIBRATION THICKNESS
000352  IF(TOP.LT.TSK)GO TO 62
000354  TSK=TOP
000355  III=1
000356  GO TO 80
000359  62 CONTINUE
000356  00 70  I=1,II
000360  III=I
000361  IF(TSK.LE.TOPP(III))GO TO 75
000365  70 CONTINUE

C PRINT APPROPRIATE ERROR MESSAGE
000367  PRINT 1000
000372  PRINT 2000, TSK, TOP
000405  PRINT 3000, IM
000413  IJ=0
000414  RETURN

84
000415    75 TSK=TOPP(III)
000417    80 CONTINUE

C CHECK OPTIMUM THICKNESS AGAINST MAX ALLOWABLE OPTIMUM
000417    IF(TSK.GT.TMX)IJ=0
000422    IF(TSK.GT.TMX)PRINT 3000,IM
000442    IF(TSK.GT.TMX)PRINT 5000,TSK,TMX
000460    IF(TSK.GT.TMX)RETURN

C DETERMINE THE UNION OF THE TEMPERATURE DEPENDENT THICKNESSES
000463    IF(ITEM.EQ.1)GO TO 105
000465    MXII=MXI(IM,IAX,ITEM-1)
000472    IJ=0
000473    DO 85 IM=III,II
000475    IV=IM+(I-III)
000477    IF(TTHIK(IM,IAX,1).GE.TOPP(IV))GO TO 85
000495    IJ=IJ+1
000507    TT(IJ)=TOPP(IV)
000512    85 CONTINUE
000515    IF(IJ.EQ.0)
000515       IF(IJ.EQ.0)GO TO 3000,IM
000527    IF(IJ.EQ.0)
000532    IF(IJ.EQ.0)RETURN
000542    IPRINT 4000
000543    IJ=0
000543    DO 90 IM=1,MXII
000545    IF(TTHIK(IM,IAX,1).GE.TT(I))GO TO 90
000555    IK = IK + 1
000556    TT(IJ+IK)=TTHIK(IM,IAX,1)
000564    90 CONTINUE
000567    IJK = IJ + IK
000571    DO 45 IM=1,IJK
000572    DO 45 J=1,IJK
000573    IF(TT(J).GT.TT(I))GO TO 45
000560    SAVE = TT(J)
000561    TT(J)= TT(I)
000564    TT(I)= SAVE
000565    45 CONTINUE
000566    IF(IJK.GT.11)IJK=11
000567    DO 100 I=1,IJK
000577    TTHIK(IM,IAX,1) = TT(I)
000587    100 CONTINUE
000591    MXI(IM,IAX,ITEM)=IJK
000596    RETURN
000606    105 CONTINUE
000636    IT = II-III +1
000641    DO 110 I=1,IT
000642    II=III+I-1
000645    TTHIK(IM,IAX,1) = TOPP(I+1)
000653    110 CONTINUE
000655    MXI(IM,IAX,1)=IT
000660    IJ=1
000661    RETURN
000661    500 FORMAT(2X,BE15.6)
000661    1000 FORMAT(5X,SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS)
000661    2000 FORMAT(2X,16HSHOCK THICKNESS = E15.4,2X,28HOPTIMUM VIBRATION THICK
000661       1NESS = E15.4)
000661    3000 FORMAT(13X,17H IS BEING DELETED )
000661    4000 FORMAT(24H NO TEMPERATURE OVERLAP )
000661    5000 FORMAT(2OH OPTIMUM THICKNESS = E15.5,2X)
1 33HMAX ALLOWABLE OPTIMUM THICKNESS = E15.5,/
END
VIRTUAL

SUBPROGRAM LENGTH
001133

FUNCTION ASSIGNMENTS
TF = 000027 TMCK = 000053

STATEMENT ASSIGNMENTS
10 = 000124 20 = 000147 25 = 000217 30 = 000222
45 = 000267 50 = 000271 60 = 000326 65 = 000356
65 = 000345 75 = 000415 80 = 000417 85 = 000512
90 = 000564 95 = 000605 105 = 000636 500 = 000672
1000 = 000675 2000 = 000704 3000 = 000715 4000 = 000722

BLOCK NAMES AND LENGTHS
MMM = 000122 TEMPT = 000517 TMK = 000002 N = 000006

VARIABLE ASSIGNMENTS
A = 000003 CT = 001123 OJ = 001117 DUMY = 001115
ERI = 001116 ERJ = 001121 FE = 000000 I = 001112
IAX = 000513C02 IC = 000004 II = 001122 III = 001125
IJ = 000515C02 IJK = 001131 IK = 001130 IM = 000512C02
IT = 001132 ITFM = 000001C03 IV = 001127 J = 001120
M = 000000C04 MOMJ = 000001 MOMS = 000002C04 MXI = 000000C01
MXII = 001126 OB = 001010 OM = 000004C04 S = 000005
SAVE = 001124 SJ = 001113 TCC = 001036 TMX = 000516C02
TOPP = 001051 TSK = 000000C03 TT = 001044 TTMK = 000000C02
W = 000004 WI = 001114 X00 = 001023 X00A = 000002
X0J = 000007 ZA = 00005C04

START OF CONSTANTS
000063

START OF TEMPORARIES
0000743

START OF INDIRECTS
001001

UNUSED COMPILER SPACE
040600
LAGINT - Subroutine

Usage:

(1) Determine the number of dimensions of the input array.

(2) Builds the appropriate interpolated table.

(3) Returns the final interpolated value.

Subprograms called:

FLAGR
Glossary of variables for LAGINT

A(NPTSG, NPTSB, NPTSA) - - Input table.

ALF(NPTSA) - - - - Vector of independent variables.

BETA(NPTSB) - - - - Vector of independent variables.

GAM(NPTSG) - - - - Vector of independent variables.

NPTSA - - - - - Number of X-Y planes in input table.

NPTSB - - - - - Number of columns in input table.

VAL - - - - - Interpolated value.

XB - - - - - Horizontal argument (interpolating value).

YG - - - - - Vertical argument (interpolating value).

ZA - - - - - Depth (interpolating value).
SUBROUTINE LAGINT(A,ALF,BETA,GAM,VAL,F)
C A(NPTSG,NPTSB,NPTSA) ---- INPUT TABLE
C ALF(NPTSA) ----- VECTOR OF INDEPENDENT VARIABLES
C BETA(NPTSB)---- VECTOR OF INDEPENDENT VARIABLES
C GAM(NPTSG) ---- VECTOR OF INDEPENDENT VARIABLES
C IF NPTSA NOT EQ TO 1 INPUT TABLE IS 3-D
C IF NPTSB EQ 1 AND NPTSA EQ 1 TABLE IS 1-D
C IF NPTSB NE 1 AND NPTSA EQ 1 TABLE IS 2-D
C NPTSA ----- NUMBER OF X-Y PLANES IN INPUT TABLE DEPTH
C NPTSB ----- NUMBER OF COLUMNS IN INPUT TABLE HORIZONTAL
C NPTSG ----- NUMBER OF ROWS IN INPUT TABLE VERTICAL
C VAL------- INTERPOLATED VALUE
C XB ------- HORIZONTAL ARGUMENT
C YG ------- VERTICAL ARGUMENT
C ZA ------- DEPTH
DIMENSION A(10,10,10),B(10,10),F(1),ALF(1),
1 BETA(1),GAM(1)
COMMON /N/ NPTSA, NPTSB,NPTSG, XB, YG, ZA
C CHECK FOR THREE DIMENSIONS
IF(NPTSA.EQ.1)GO TO 100
C SOLVE THREE DIMENSIONAL CASE
DO 10 I=1,NPTSG
DO 10 J=1,NPTSB
DO 5 K=1,NPTSA
5 F(K) = A(I,J,K)
CONTINUE
GO TO 120
C CHECK FOR TWO DIMENSIONS
10 CONTINUE
IF(NPTSB.EQ.1)GO TO 200
DO 110 I=1,NPTSG
DU 110 J=1,NPTSB
110 B(I,J)=A(I,J,1)
C SOLVE TWO DIMENSIONAL CASE
120 CONTINUE
DO 130 I=1,NPTSG
DO 130 J=1,NPTSB
130 F(J) = B(I,J)
C SOLVE ONE DIMENSIONAL CASE
140 CONTINUE
DO 210 I=1,NPTSG
210 B(I,1)=A(I,1,1)
C SOLVE ONE DIMENSIONAL CASE
220 CONTINUE
VAL = FLAGR(NPTSG,GAM,B,YG)
RETURN
END
LAGINT

SUMPRAGRAM LENGTH
000322

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS:
5 = 000016 100 - 000050 110 - 000055 120 - 000071
140 = 000074 200 - 000120 210 - 000127 220 - 000131

BLOCK NAMES AND LENGTHS
N = 000004

VARIABLE ASSIGNMENTS
B = 000153 I = 000317 J = 000320 K = 000321
NPTSA = 000000C01 NPTSB = 000001C01 NPTSG = 000002C01 XB = 000003C01
YG = 000004C01 ZA = 000005C01

START OF CONSTANTS
000143

START OF TEMPORARIES
000144

START OF INDIRECTS
000150

UNUSED COMPILER SPACE
003000
FLAGR - Function Subprogram

Usage:
LAGRANGE interpolating function interpolates through a one-dimensional table and returns an interpolated value.

Options:
1. Two point linear extrapolation to the left.
2. Three point interpolation from left.
3. Three point interpolation from left and right.
4. Three point interpolation from right.
5. Two point linear extrapolation to right.

Procedure:
For option one, a constant slope is assumed.
For option two a parabola is passed through the three nearest points (two at the left and one on the right of the interpolating value).
For option three a parabola is passed from the left and from the right with the final value being the average of the two.
For option four a parabola is passed from the right (two points on the right and one on the left of the interpolating value).

Subprograms called:
None.
Glossary of variables for FLAGR

F(I) - - - - - Table of dependent variables.
IGO - - - - - Code to determine type of interpolation.
NPTS - - - - - Number of points in table.
W(K) - - - - - Work array containing function weights.
XIK(I) - - - - - Table of independent variables to be interpolated.
XK - - - - - Interpolating value.
FUNCTION FLAGR(NPTS, XI, F, XK)  
DIMENSION XIK(1), F(1), W(3)  
C  
LAGRANGE INTERPOLATING FUNCTION  
000007 00 200 I=1, NPTS  
000010 IT=I  
000011 IF(XK LE XI(I))GO TO 210  
000014 200 CONTINUE  
000016 FLAGR=F(NPTS)+XI-XIK(NPTS))*F(NPTS)-F(NPTS-1))  
1 /(XIK(NPTS)-XIK(NPTS-1))  
000030 RETURN  
000030 205 CONTINUE  
000030 FLAGR=F(1)+(XK-XIK(I))*(F(1)-F(2))  
1 /(XIK(1)-XIK(2))  
000040 RETURN  
000040 210 IF(XK.EQ.XI(I))GO TO 500  
000043 IGO = 3  
000047 IF(IGO.LE.2)IGO=1  
000047 IF(IT.LE.NPTS) IGO = 2  
000052 B=0.0  
000053 IF(XGO.EQ.2) GO TO 350  
000055 PARABOLA FROM THE RIGHT  
000057 IF(IT.EQ.1)GO TO 205  
000060 U0 300 I=1,3  
000062 WEIGHT = 1.  
000064 DO 240 J=1,3  
000065 IF(J.EQ.I)GO TO 240  
000067 JARG = IT - 2 + J  
000070 WEIGHT = WEIGHT* (XK-XIK(JARG))/ (XIK(IARG)-XIK(JARG)))  
000077 290 CONTINUE  
000079 W(I) = WEIGHT  
000083 300 CONTINUE  
000085 DO 310 K=1,3  
000090 IARG = IT-2+K  
000096 B = B + W(K)*F(IARG)  
000097 310 CONTINUE  
000099 IF(IGO.EQ.1)GO TO 600  
000107 PARABOLA FROM THE LEFT  
000111 350 CONTINUE  
000114 DO 400 I=1,3  
000127 IARG = IT-3+I  
000133 WEIGHT = 1.0  
000137 DO 390 J=1,3  
000139 IF(J.EQ.I)GO TO 390  
000145 JARG = IT-3+J  
000148 WEIGHT = WEIGHT* (XK-XIK(JARG))/ (XIK(IARG)-XIK(JARG)))  
000147 390 CONTINUE  
000149 W(I) = WEIGHT  
000150 B = B + W(K)*F(IARG)  
000154 400 CONTINUE  
000158 DO 410 K=1,3  
000163 IARG = IT-3+K  
000169 B = B + 0.5  
000175 GO TO 600  
000179 500 CONTINUE  
94
<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>000166</td>
<td>$B = F(IT)$</td>
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<tr>
<td>000170</td>
<td>600 CONTINUE</td>
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<td>000170</td>
<td>FLAGR = 3</td>
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<td>000172</td>
<td>RETURN</td>
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<td>000172</td>
<td>END</td>
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FLAGR

SUBPROGRAM LENGTH
000231

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
205 - 000030  210 - 000040  240 - 000077  350 - 000121
390 - 000142  500 - 000166  600 - 000170

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS
B - 000223  FLAGR - 000214  I - 000220  IARG - 000224
T - 000222  IT - 000221  J - 000226  JARG - 000227
W - 000230  WEIGHT - 000225

START OF CONSTANTS
000174

START OF TEMPORARIES
000177

START OF INDIRECTS
000207

UNUSED COMPILER SPACE
043000
**SCOPE 3.9 = CONTROL-CARD-INITIATED LOAD**

**PROGRAM AND BLOCK ASSIGNMENTS**

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<th>FILE</th>
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<td>41144</td>
<td>4032</td>
<td>BINPAK</td>
</tr>
<tr>
<td>ONLYR</td>
<td>42576</td>
<td>101</td>
<td>BINPAK</td>
</tr>
<tr>
<td>COSTH</td>
<td>4274</td>
<td>701</td>
<td>BINPAK</td>
</tr>
<tr>
<td>WINGOR</td>
<td>43177</td>
<td>70</td>
<td>BINPAK</td>
</tr>
<tr>
<td>SNOCKEL</td>
<td>45267</td>
<td>112</td>
<td>BINPAK</td>
</tr>
<tr>
<td>VIGHTN</td>
<td>45001</td>
<td>1133</td>
<td>BINPAK</td>
</tr>
<tr>
<td>AGENT</td>
<td>45534</td>
<td>322</td>
<td>BINPAK</td>
</tr>
<tr>
<td>FLGAR</td>
<td>45054</td>
<td>231</td>
<td>BINPAK</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>45307</td>
<td>1125</td>
<td>SL=NUCLEUS</td>
</tr>
<tr>
<td>AGOER</td>
<td>4639</td>
<td>12</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>UETRA</td>
<td>46446</td>
<td>17</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>CHEK1</td>
<td>46445</td>
<td>32</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>SURT</td>
<td>46517</td>
<td>45</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>INPUT</td>
<td>46514</td>
<td>104</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>DUTPC</td>
<td>46670</td>
<td>104</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>ASK11H</td>
<td>46774</td>
<td>115</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>KNAER</td>
<td>47111</td>
<td>1091</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>KUGER</td>
<td>50102</td>
<td>1254</td>
<td>SL-LIB33</td>
</tr>
<tr>
<td>S10S</td>
<td>51421</td>
<td>1431</td>
<td>SL-SYS10</td>
</tr>
</tbody>
</table>

**LOAD TIME**

1.144 CP SECONDS LOAD TIME

**NOTES:**

- 280318 WORDS WERE REQUIRED FOR LOADING
- 3.7327 on 10/10/73 14:49:34, SCOPE 3.9 COMPASS 3.73297

---

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3. **Input Data to OPPACK Program**

Input consists of problem card data deck(s) and material files stored on disk. The form of the data stored on the material disk files will be discussed later. Data contained in the problem card data deck(s) consist of integers and real numbers. All integers must be right adjusted in the proper card field. Real numbers must contain a decimal point in the proper position.

The content of each card in a problem deck is as follows:

**Input Data - Card Deck**

Card Number One is read according to statement 100 FORMAT (612, 5E 10.0)

**Columns**

- 2 NIC - Code number of container material to be used.
- 3-4 IC  - Code denoting type of optimization to be used:
  - IC = 1, MIL-STD-810B excitation
  - IC = 2, Multiple sine excitation
  - IC = 3, Random excitation.
- 5-6 IITM - Item number which is an arbitrary number assigned to the item being shipped. IITM must not be greater than two digits (i.e., 99). The condition IITM = MITEM = ITEM must exist.
- 7-8 MIC - Maximum number of iterations needed for convergence of drop height calculations.
- 9-10 MXIšt - Maximum number of iterations needed for convergence in shock environment.
- 11-12 MOMJ - Maximum number of environmental frequencies (Max. = 11).
- 13-22 CS  - Cost of shipping ($/lb).
- 23-32 CI  - Cost of item ($).

*Not needed. Set equal to 0.*
Columns

33-42 TCON - Thickness of container (in.).
43-52 TEML* - Low environmental temperature (°F).
53-62 TEMH* - High environmental temperature (°F).

Card Number Two is read according to statement 1020 FORMAT
(11 E 7.0)

Columns

1-77 (OMJ(I), I = 1, MOMJ) - Environmental frequencies
(rad/sec) - in ascending order.

Card Number Three is read according to statement 1020 FORMAT
(11 E 7.0)

Columns

1-77 (S(I), I = 1, MOMJ) - Environmental Power Spectral Density,
(PSD). g²/Hz each corresponding to one of the
above environmental frequencies.

This card is blank unless "IC = 3."

Card Number Four is read according to statement 1020 FORMAT
(11 E 7.0)

Columns

1-77 (XDJ(I), I = 1, MOMJ) - Environmental acceleration levels,
g, each corresponding to one of the above environ-
mental frequencies.

Card Number Five is read according to statement 500 FORMAT (40I 2)

Columns

1 - 2 NC - Number of containers (Max. = 10).
3 - 4 MITEM - Item number (see IITM on Card Number One).

* If (TEMH-TEML) is less than 20°F, make TEMH = TEML.
Columns

5-6  MNMATS - Number of materials on file (Max. = 10).

Cards Number Six through Fifteen are read according to statement 10 FORMAT (E5.0, 3E6.0, 3E15.5).

Columns

1-68  ((CA(I, J), J = 1, 7), I = 1, MNMATS) - Cost and property matrix.

1-5   Cost of material ($/ft^3).

6-11  Cost of fabrication ($/min).

12-17 Cost of packaging ($/min).

18-23 Safe low temperature (°F).

24-38 Low stress\(^{(1)}\) (lb/in.\(^2\)).

39-53 High stress\(^{(1)}\) (lb/in.\(^2\)).

54-68 Gamma (lb/ft\(^3\)).

Card Number Sixteen is read according to statement 10 FORMAT (E5.0, 3E6.0, 3E15.5).

Columns

1-11  ((CD(I, J), J = 1, 2), I = 1, NC) - Cost and property matrix - container material.

1-5   Gamma (i.e., specific weight) of container (lb/in.\(^3\)).

---

* Must have one card for each material.

** May have one to ten container material cards.

(1) From range of optimum stress of a particular material.
Columns

6-11  Cost of container ($/in.³).  CAUTION: This is cost of container material volume, not container volume.

Card Number Seventeen is read according to statement 5 FORMAT (I4, 2X, 4E10.0, 2X, 12).

Columns

1- 4  ITEM - Item number (see IITM on Card Number One).

7-16  WI - Weight of item.

17-26  XL
        X-length (2nd longest length) in inches.

27-36  YL
        Y-length (shortest length) in inches.

37-46  ZL
        Z-length (longest length) in inches.

49-50  NPCNT - Number different percent damage allowable cases (Max. = 10).

Card Number Eighteen through... are read according to statement 7 FORMAT (3E10.0).

Columns

1-30  (GMF(I), PCTD(I), REPCI(I), I = 1, NPCNT).

1-10  (GMF(I) - Fragility in units of acceleration, g.

11-20  PCTD(I) - Percent damage at above acceleration level.

21-30  REPCI(I) - Replacement cost for above percent damage ($/item).

---

---
The program is set up to handle one to ten cataloged disk files. Each file contains the shock and vibration information needed for a meaningful scrutiny of the candidate material.

Each material file is assigned a two-digit numerical material code which is linked to the logical device on which that material file is cataloged through the ASG control card and the USK control card. Once execution starts, the material is referenced through the use of the numerical material code.

The file structure is the same for all material files. The front portion contains the shock environment information, and the rear portion contains the vibration environment information. The content and read sequence of each section is as follows:

**Input Data - Disk File**

**Shock Environment - 18-Inch Drop Height**

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E7, 0, 512)</td>
<td>RHOM, DRPH, ICODE</td>
</tr>
<tr>
<td>E7, 0</td>
<td>RHOM - Specific weight of the material (lpcf)</td>
</tr>
<tr>
<td>12</td>
<td>DRPH - Drop height</td>
</tr>
<tr>
<td>12</td>
<td>ICODE - Code used in updating files</td>
</tr>
<tr>
<td>(512)</td>
<td>NT, NTH, NS</td>
</tr>
<tr>
<td>12</td>
<td>NT - Number of temperatures (Max. = 5)</td>
</tr>
<tr>
<td>12</td>
<td>NTH - Number of thicknesses (Max. = 10)</td>
</tr>
<tr>
<td>12</td>
<td>NS - Number of stresses (Max. = 10)</td>
</tr>
<tr>
<td>(11E7, 0)</td>
<td>(T(i), i = 1, NT)</td>
</tr>
<tr>
<td>E7, 0</td>
<td>T(i) - One of the temperatures at which data is recorded (degrees fahrenheit)</td>
</tr>
<tr>
<td>(11E7, 0)</td>
<td>(TH(i), i = 1, NTH)</td>
</tr>
<tr>
<td>E7, 0</td>
<td>TH(i) - One of the material thicknesses considered during data gathering.</td>
</tr>
</tbody>
</table>
(11E7.0) (SIG(I), I = 1, 'S')

E7.0 SIG(I) - Static stress at a point
DO XX K = 1, NT
DO XX I = 1, NTH

(11E7.0) XX READ (MS, F) (TAB1(I, J, K), J = 1, NS)
TAB1(I, J, K) = G = F (Thickness, Stress, Temperature)

The preceding type of information is also stored for the 24-inch, 30-inch, and 36-inch drop heights, respectively.

Next is the vibration environment which consists of the following:

Input Data - Disk Files

Vibration Environment

Format

(E7.0, 512) RHOM, MTS, MOMS

E7.0 RHOM - Specific weight of the material (PCF)
I2 MTS - Number of temperatures (Max. = 10)
I2 MOMS - Number of frequencies (Max. = 10)

(11E11.4) (TS(I), I = 1, MTS)

E11.4 TS(I) - A temperature at which data is recorded (degrees fahrenheit)

(11E11.4) (QMS(I), I = 1, MOMS)

E11.4 QMS(I) - A frequency at which data is recorded (rad/sec)
DO X I = 1, MOMS

(11E11.4) X READ (MS, F1) (TAB1(I, J, 1), J = 1, MTS)
TAB1(I, J, 1) = ER = F (Temp., Freq.)
DO XX I = 1, MOMS

(11E11.4) XX READ (MS, F2) (TAB2(I, J, 1), J = 1, MTS)
TAB2(I, J, 1) = EL/ER = F (Temp., Freq.)

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4. Description of Output

Output Item #1

This output item consists of a listing and definition of all the card data input. The first four output tables of this item are printed in the main program of OPPACK. The last five tables are printed in the subroutine DAMALW.

Output Items #2.1 - 2.5

These output items consist of the results of some of the intermediate calculations done in the subroutines CDPRO, COSTMT, and DAMALW. The first two output tables are printed in the subroutine CDPRO. They are Item #2.1 and Item #2.2.

Item #2.1 - consists of the thicknesses calculated by the function subprogram SHOCKE. At the end of each drop height iteration, the thicknesses T1, T2, and T3 are compared to the corresponding newly calculated thicknesses TT1, TT2, and TT3, respectively. If the change in the corresponding thicknesses is greater than the allotted tolerance, the thicknesses are printed and another iteration is initiated. The amount of output in this item is purely a function of the number of iterations required for the drop height convergence and the number of materials being considered.

Item #2.2 - is a $N \times 3$ table of minimum thicknesses where the rows correspond to materials and the columns correspond to different axis. Items #2.1 and #2.2 are repeated for each of the three possible temperatures.

Items #2.3 and #2.4 - are output from the subroutine COSTMT.

Item #2.3 - shows the optimum thicknesses and the materials to be used with these thicknesses.

Item #2.4 - shows the total cost of shipping one item. This cost includes everything except the cost for allowing damage. Item #2.4 also contains the material cost matrix where each row corresponds to a different material and each column to a different perpendicular face of the package.

Item #2.5 - is output in the subroutine DAMALW. This output is self-explanatory.

Output Items #2.1 - 2.5 are repeated for each percent damage allowed.
Output Items #3.1 - 3.5

Output Items #3.1 - 3.5 are all printed in the subroutine DAMALW and are considered to be self-explanatory. Item #3.5 may appear in two different ways. If Item #3.5 reads "overshipping is the best policy," the information in Items #3.1 - #3.2 is considered to be the optimum information. If Item #3.5 reads "the above percent damage is the best policy," then the information contained in Items #3.3 - #3.4 is the optimum information.

These output item numbers correspond with the circled item numbers on the following nine sample problems. Tables IV through XII contain the input data cards for the sample problems. Each table appears prior to the OPPACK Program output for each of the nine sample problems.
# TABLE IV

**SAMPLE PROBLEM NUMBER ONE**

**INPUT DATA CARDS**

<table>
<thead>
<tr>
<th>Card No.</th>
<th>Card Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>
1 = NIC --- CODE NO. OF CONTAINER MATERIAL TO BE USED
2 = T.C. --- OPTIMIZATION CODE
   1 = ITM. --- ITM. NUMBER
   2 = MAX. NO. OF ITERATIONS FOR DROP HT. CALC.
   3 = MAX. NO. OF ITERATIONS FOR CONVERGENCE
   4 = VSH. --- NUMBER OF ENVIRONMENTAL FREQUENCIES
   5, 6, (1) = CS, --- COST OF SHIPMENT
   7, 8, (1) = NIC, --- CODE NO. OF CONTAINER
   9, 10 = T.C. --- THICKNESS OF CONTAINER
   11, 12 = T, --- TEMPERATURE, LOWEST ENVIRONMENTAL TEMPERATURE

(SMPY/SLC) = ON[J(I)] ALL OF THE ENVIRONMENTAL FREQ.
   283.00E+00, 283.00E+00, 283.00E+00, 283.00E+00, 283.00E+00, 283.00E+00, 283.00E+00

FD5 INPUT FOR RANDOM EXCITATION

1 = NC --- NUMBER OF CONTAINERS
10 = MATS --- NUMBER OF MATERIALS ON FILE

<table>
<thead>
<tr>
<th>CST-MAT</th>
<th>CST-FAK</th>
<th>CST-RAX</th>
<th>SL-TEMP</th>
<th>LN-STRS</th>
<th>HI-STRS</th>
<th>GAMMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.490E+04</td>
<td>5.0000E-00</td>
<td>1.0000E+00</td>
<td>2.0000E+01</td>
<td>1.0000E+00</td>
<td>1.0000E+00</td>
<td>1.0000E+00</td>
</tr>
<tr>
<td>2.1000E+04</td>
<td>5.0000E+00</td>
<td>1.0000E+00</td>
<td>2.0000E+01</td>
<td>3.0000E+00</td>
<td>3.0000E+00</td>
<td>3.0000E+00</td>
</tr>
</tbody>
</table>

GAMMA = CST-CONTAINER

1.5000E+03 2.5000E+03

1 = ITEM NUMBER
1.0000E+00 WEIGHT OF ITEM IN (POUNDS)
1.0000E+00 DIMENSION PARALLEL TO X-AXIS AND LONGEST DIMENSION X1 (INCHES)
1.0000E+00 DIMENSION PARALLEL TO Y-AXIS AND LONGEST DIMENSION Y1 (INCHES)
1.0000E+00 DIMENSION PARALLEL TO Z-AXIS AND LONGEST DIMENSION Z1 (INCHES)

MAT. CODES CONSIDERED ARE

<table>
<thead>
<tr>
<th>NUM.</th>
<th>MAT. CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5000E+01</td>
</tr>
<tr>
<td>2</td>
<td>4.0000E+01</td>
</tr>
<tr>
<td>3</td>
<td>3.5000E+01</td>
</tr>
<tr>
<td>4</td>
<td>3.0000E+01</td>
</tr>
</tbody>
</table>

MAX-G = PCT-GA = REPLACE = CST
5.5000E+01 0.0
4.0000E+01 5.4000E+00 0.0
4.5000E+01 4.0000E+00 1.0
7.0000E+01 6.0000E+00 1.5

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**SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS**

**SHOCK THICKNESS**: 2.86E+00
**OPTIMUM VIBRATION THICKNESS**: 3.21E+00

---

### MATERIAL 1

#### MINIMUM THICKNESS FOR MATERIAL BY AXIS

- **VERTICAL**: 3.1U00E+00
- **HORIZONTAL**: 3.1U00E+00

#### MATERIAL CODE

- **THICKNESS FOR FACE ONE**: 3.010 INCHES
- **THICKNESS FOR FACE TWO**: 3.010 INCHES
- **THICKNESS FOR FACE THREE**: 2.944 INCHES

#### TOTAL COST/ITEM

- **81.01 DOLLARS**

---

### MATERIAL 2

#### MINIMUM THICKNESS FOR MATERIAL BY AXIS

- **VERTICAL**: 3.1U00E+00
- **HORIZONTAL**: 3.1U00E+00

#### MATERIAL CODE

- **THICKNESS FOR FACE ONE**: 4.739 INCHES
- **THICKNESS FOR FACE TWO**: 4.739 INCHES
- **THICKNESS FOR FACE THREE**: 3.984 INCHES

#### TOTAL COST/ITEM

- **88.45 DOLLARS**

---

### MATERIAL 3

#### MINIMUM THICKNESS FOR MATERIAL BY AXIS

- **VERTICAL**: 3.1U00E+00
- **HORIZONTAL**: 3.1U00E+00

#### MATERIAL CODE

- **THICKNESS FOR FACE ONE**: 3.110 INCHES
- **THICKNESS FOR FACE TWO**: 2.624 INCHES

#### TOTAL COST/ITEM

- **89.50 DOLLARS**

---

The cost is **81.01 DOLLARS** with a multiplication factor of **1.00 TIMES ONE**

**FUR ALLDING DAMAGE THE COST IS 81.01 DOLLARS/ITEM**
**Table 1: Optimum Material Thickness**

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.575 inches</td>
<td>0.575 inches</td>
<td>3.880 inches</td>
</tr>
<tr>
<td>2</td>
<td>1.750 inches</td>
<td>1.750 inches</td>
<td>1.750 inches</td>
</tr>
<tr>
<td>3</td>
<td>3.010 inches</td>
<td>3.010 inches</td>
<td>2.000 inches</td>
</tr>
</tbody>
</table>

**Total Cost/Item:** 87.98 dollars

**Material-Input Cost:** (Material Vertical, Horizontal Axis)

<table>
<thead>
<tr>
<th>1</th>
<th>1.25</th>
<th>1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.75</td>
<td>1.75</td>
</tr>
</tbody>
</table>

For 20.0% percent damage and a fragility rate of 5.0 G's, the cost is 87.98 dollars with a multiplication factor of 1.25 times one.

The optimum cost is 81.01 dollars.

The optimum thickness for face one is 3.010 inches if material 4 is used.

The optimum thickness for face two is 3.010 inches if material 4 is used.

The optimum thickness for face three is 2.000 inches if material 4 is used.
3.3 Damage Allowable Data
The optimum cost is 81.01 dollars.
The fragility rate is 55.0 G's.
The percentage damage is 0.0.
The repair cost/Item = 0.00 dollars.

3.4 The optimum thickness for face one is 3.010 inches if material 4 is used.
The optimum thickness for face two is 3.010 inches if material 4 is used.
The optimum thickness for face three is 2.994 inches if material 4 is used.

3.5 Overshipping is the best policy.

*******************************************************************************
<table>
<thead>
<tr>
<th>Card No.</th>
<th>0102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE PROBLEM NUMBER TWO</td>
<td>INPUT DATA CARDS</td>
</tr>
<tr>
<td><strong>Card</strong></td>
<td><strong>No.</strong></td>
</tr>
<tr>
<td>1.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>2.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>3.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>4.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>5.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>6.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>7.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>8.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>9.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>10.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>11.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>12.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>13.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>14.</td>
<td>010110.102012075110.3549001459.000000.0.12500.34.50 0.0 12.0.0</td>
</tr>
<tr>
<td>15.</td>
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### OPTIMIZATION PROCEDURE FOR DESIGN OF PACKAGE CUSHIONING

**SAMPLE PROBLEM #2 (MULTIPLE SINE EXCITATION) VARYING TEMPERATURE**

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**CST-MAT**

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**INPUT FOR RANDOM EXCITATION**

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**MATERIAL CODES CONSIDERED ARE**

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**DIMENSION PARALLEL TO X-AXIS**

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**DIMENSION PARALLEL TO Y-AXIS**

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**DIMENSION PARALLEL TO Z-AXIS**

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**RESULT**

112
Material 2 is being deleted.

Optimum Thickness = 1.20E+01
Max Allowable Thickness = 1.20E+01

Minimum Thickness for Material by Axis
7.45E+00
7.45E+00
7.27E+00

Material Code = 2
Thickness for Face One = 20.542 Inches
Thickness for Face Two = 20.542 Inches

Material Code = 2
Thickness for Face Three = 10.296 Inches

Total Cost/Item = 465.40

Cost Matrix = Material Vertical, Axis Horizontal

For 0.00 Per-Cent Damage and a Fragility Rate of 55.0 g's with a Final Cost of 465.40 Dollars for Over Shipping the Cost is 465.40 Dollars/Item

Minimum Thickness for Material by Axis
3.85E+00
3.85E+00
3.7283E+00

Minimum Thickness for Material by Axis
2.87E+00
2.87E+00
2.87E+00

Minimum Thickness for Material by Axis
3.85E+00
3.85E+00
3.7283E+00

Minimum Thickness for Material by Axis
1.06E+01
1.06E+01
1.06E+01

Minimum Thickness for Material by Axis
1.13E+01
1.13E+01
1.13E+01

Total Cost/Item = 465.40

Cost Matrix = Material Vertical, Axis Horizontal

For 0.00 Per-Cent Damage and a Fragility Rate of 55.0 g's with a Final Cost of 465.40 Dollars for Over Shipping the Cost is 465.40 Dollars/Item
ALL MATERIALS DELETED --- no overlap between temperatures-optimize on data accumulated

OVER SHIPPING DATA

3.1. The optimum cost is $495.40 dollars
The fragility rate is 55.0 G's
The repair cost/item = 0.00 dollars

3.2. The optimum thickness for face one is 20.542 inches if material 2 is used.
The optimum thickness for face two is 20.542 inches if material 2 is used.
The optimum thickness for face three is 10.246 inches if material 2 is used.

DAMAGE ALLOWABLE DATA

3.3. The optimum cost is $485.40 dollars
The fragility rate is 55.0 G's
The repair cost/item = 0.00 dollars

3.4. The optimum thickness for face one is 20.542 inches if material 2 is used.
The optimum thickness for face two is 20.542 inches if material 2 is used.
The optimum thickness for face three is 10.246 inches if material 2 is used.

3.5. Overshipping is the best policy

-----------------------------------------------------------------------------------

114
TABLE VI
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115
SAMPLE PROBLEM #3

101L4.11B-STD 810B

EXCITATION CONSTANT TEMPERATURE

<table>
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<tr>
<th>N</th>
<th>L</th>
<th>H</th>
<th>L</th>
<th>H</th>
<th>DATA</th>
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<tbody>
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</table>

MATERIALS DATA

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<th>DATA</th>
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SAMPLE PROBLEM #3

EVALUATION PROCEDURE FOR DESIGN OF PACKAGE EXCITATION

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MATERIALS DATA

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</table>

116
2.1

MATERIAL IS BEING DELETED

OPTIMUM THICKNESS CHANGES IN MATERIAL BY AXES

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.635E+00</td>
<td>0.635E+00</td>
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<td>2</td>
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</table>

MAX ALLOWABLE OPTIMUM THICKNESS = 1.200000E+01

2.2

MATERIAL IS BEING DELETED

OPTIMUM THICKNESS CHANGES IN MATERIAL BY AXES

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.635E+00</td>
<td>0.635E+00</td>
<td>0.635E+00</td>
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<tr>
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</tr>
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</table>

MAX ALLOWABLE OPTIMUM THICKNESS = 1.200000E+01

2.3

MATERIAL IS BEING DELETED

OPTIMUM THICKNESS CHANGES IN MATERIAL BY AXES

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
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<td>0.635E+00</td>
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MAX ALLOWABLE OPTIMUM THICKNESS = 1.200000E+01

2.4

COST MATERIAL VERTICAL AXIS HORIZONTAL

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<tr>
<th>Face One</th>
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<tbody>
<tr>
<td>0.635</td>
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<td>0.635</td>
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2.5

FOR 90 PERCENT DAMAGE AND A FRAGILITY RATE OF 0.0 G/TA, THE COST IS 42.01 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE

FOR ALLOWING DAMAGE THE COST IS 42.01 DOLLARS/ITEM

----------------------------------------

TOTAL COST/S/ITEM 92.01

MULTIPLIER 1.00

COST MATERIAL VERTICAL AXIS HORIZONTAL

<table>
<thead>
<tr>
<th>Face One</th>
<th>Face Two</th>
<th>Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.635</td>
<td>0.635</td>
<td>0.635</td>
</tr>
</tbody>
</table>

FOR 90 PERCENT DAMAGE AND A FRAGILITY RATE OF 0.0 G/TA, THE COST IS 47.44 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE

FOR ALLOWING DAMAGE THE COST IS 47.44 DOLLARS/ITEM

----------------------------------------

117
THICKNESS FOR MATERIAL BY AXIS

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.575 INCHES
MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 4.575 INCHES
MATERIAL CODE = 1 THICKNESS FOR FACE THREE = 3.484 INCHES

TOTAL COST/ITEM = 67.48
MINUS INPUT
COST MATRIX=MATERIAL VERTICAL,AXIS HORIZONTAL

1 1.46 1.46 .04

FOR 20.0 PERCENT DAMAGE AND A FRAGILITY RATE OF 70.0 G/S
THE COST IS 87.48 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.25 TIMES ONE
WITH A FINAL COST OF 104.92 DOLLARS FOR OVER SHIPING
FOR ALLOWING DAMAGE THE COST IS 91.48 DOLLARS/ITEM

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

THICKNESS FOR MATERIAL BY AXIS

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.575 INCHES
MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 4.575 INCHES
MATERIAL CODE = 1 THICKNESS FOR FACE THREE = 3.484 INCHES

TOTAL COST/ITEM = 67.48
MINUS INPUT
COST MATRIX=MATERIAL VERTICAL,AXIS HORIZONTAL

1 1.46 1.46 .04

FOR 80.0 PERCENT DAMAGE AND A FRAGILITY RATE OF 70.0 G/S
THE COST IS 87.48 DOLLARS WITH A MULTIPLICATION FACTOR OF 5.00 TIMES ONE
WITH A FINAL COST OF 434.40 DOLLARS FOR OVER SHIPING
FOR ALLOWING DAMAGE THE COST IS 104.98 DOLLARS/ITEM

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

OVER SHIPING DATA

THE OPTIMUM COST IS 92.01 DOLLARS
THE FRAGILITY RATE IS 10.0 G/S
THE PERCENT DAMAGE IS 0.0
THE MULTIPLICATION FACTOR IS 1.0

THE OPTIMUM THICKNESS FOR FACE ONE IS 5.406 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 5.406 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 4.354 INCHES IF MATERIAL 1 IS USED

THE OPTIMUM THICKNESS FOR Face ONE IS 5.406 INCHES IF MATERIAL 1 IS Used
THE OPTIMUM THICKNESS FOR FACE TWO IS 5.406 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 4.354 INCHES IF MATERIAL 1 IS USED

DAMAGE ALLOWABLE DATA

THE OPTIMUM COST IS 88.98 DOLLARS
THE FRAGILITY RATE IS 10.0 G/S
THE PERCENT DAMAGE IS 5.0
THE REPAIR COST/ITEM IS 1.00 DOLLARS

THE OPTIMUM THICKNESS FOR FACE ONE IS 4.575 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 4.575 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.484 INCHES IF MATERIAL 1 IS USED

THE OPTIMUM THICKNESS FOR Face ONE IS 4.575 INCHES IF MATERIAL 1 IS Used
THE OPTIMUM THICKNESS FOR FACE TWO IS 4.575 INCHES IF MATERIAL 1 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.484 INCHES IF MATERIAL 1 IS USED

118
THE ABOVE PERCENTAGE DAMAGE IS THE BEST POLICY

**************************»**********************<**************
TABLE VII
SAMPLE PROBLEM NUMBER FOUR
INPUT DATA CARDS

<table>
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</table>
1. A = V, 1 = 1.8%. V. OF CONTAINER MATERIAL TO BE USED
   2. E. = 1.8% (Watters T."H -Z."""""
   3. A = 1.8%. (G. "..M.
   4. A = 1.8%. (K. "..M.
   5. A = 1.8%. (L. "..M.
   6. A = 1.8%. (M. "..M.
   7. A = 1.8%. (N. "..M.
   8. A = 1.8%. (O. "..M.
   9. A = 1.8%. (P. "..M.
   10. A = 1.8%. (Q. "..M.

---

SAMPLE PROBLEM #4 (RANDOM EXCITATION) CONSTANT TEMPERATURE

---

1. V. --- MAX. % OF CONTAINER MATERIAL TO BE USED
2. E. = 1.8% (Watters T."H -Z.""""
3. A = 1.8% (G. "..M.
4. A = 1.8% (K. "..M.
5. A = 1.8% (L. "..M.
6. A = 1.8% (M. "..M.
7. A = 1.8% (N. "..M.
8. A = 1.8% (O. "..M.
9. A = 1.8% (P. "..M.
10. A = 1.8% (Q. "..M.

---

121
### Table 1

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<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
</tr>
<tr>
<td>2.1</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
</tr>
</tbody>
</table>

The thickness of the material is 2.300 inches for all faces.

---

### Table 2

<table>
<thead>
<tr>
<th>Minimum Thickness for Material at Axis</th>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
</tr>
<tr>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
</tr>
<tr>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
</tr>
</tbody>
</table>

The thickness of the material is 2.300 inches for all faces.

---

### Table 3

<table>
<thead>
<tr>
<th>Minimum Thickness for Material at Axis</th>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
</tr>
<tr>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
</tr>
<tr>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
</tr>
</tbody>
</table>

The thickness of the material is 2.300 inches for all faces.

---

### Table 4

<table>
<thead>
<tr>
<th>Minimum Thickness for Material at Axis</th>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
</tr>
<tr>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
</tr>
<tr>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
</tr>
</tbody>
</table>

The thickness of the material is 2.300 inches for all faces.

---

### Table 5

<table>
<thead>
<tr>
<th>Minimum Thickness for Material at Axis</th>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
<td>2.500 E+00</td>
</tr>
<tr>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
<td>2.400 E+00</td>
</tr>
<tr>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
<td>2.300 E+00</td>
</tr>
</tbody>
</table>

The thickness of the material is 2.300 inches for all faces.
The optimum thickness for face one is 3.010 inches if material 4 is used.

The optimum thickness for face two is 3.010 inches if material 4 is used.

The optimum thickness for face three is 2.444 inches if material 4 is used.

Over shipping data:

The optimum cost is 81.01 dollars.

The fragility rate is 15.0 G's.

The percentage damage is 0.0.

The multiplication factor is 1.0.

The optimum thickness for face one is 3.010 inches if material 4 is used.

The optimum thickness for face two is 3.010 inches if material 4 is used.

The optimum thickness for face three is 2.444 inches if material 4 is used.
3.3 DAMAGE ALLOWABLE DATA
THE OPTIMUM COST IS $1.01 DOLLARS
THE FRAGILITY RATE IS 15.0 G/S
THE PERCENT DAMAGE IS 0.0
THE REPAIR COST/ITEM = 0.00 DOLLARS

3.4 THE OPTIMUM THICKNESS FOR FACE ONE IS 3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 2.944 INCHES IF MATERIAL 4 IS USED

3.5 OVERSHIPPING IS THE BEST POLICY

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

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# TABLE VIII

## SAMPLE PROBLEM NUMBER FIVE

### INPUT DATA CARDS

<table>
<thead>
<tr>
<th>Card No.</th>
<th>0102</th>
<th>120</th>
<th>60</th>
<th>21.00</th>
<th>72.00</th>
<th>0.36285</th>
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<tbody>
<tr>
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<td>6</td>
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<td>0.14</td>
<td>1.50</td>
<td>2.0</td>
<td>2</td>
<td>0.36285</td>
</tr>
<tr>
<td>3</td>
<td>2.16</td>
<td>0.03</td>
<td>0.30</td>
<td>2.4</td>
<td>3</td>
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</tr>
<tr>
<td>4</td>
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<td>0.36285</td>
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<tr>
<td>5</td>
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</tr>
<tr>
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<tr>
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<td>0.36285</td>
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<td>0.10</td>
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<td>9</td>
<td>0.36285</td>
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<td>0.36285</td>
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<td>8</td>
<td>0.36285</td>
</tr>
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</table>
### Optimization Procedure for Design of Package Cushioning

#### Sample Problem #5 (Multiple Sine Excitation) Constant Temperature

<table>
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<tr>
<th>Layer</th>
<th>CST-Fan</th>
<th>CST-Max</th>
<th>NL-Temp</th>
<th>Lw-Strs</th>
<th>Hw-Strs</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1.5000E-02</td>
<td>1.5000E-02</td>
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<td>1.5000E-02</td>
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</table>

Gamma CST=Container

<table>
<thead>
<tr>
<th>Layer</th>
<th>CST-Fan</th>
<th>CST-Max</th>
<th>NL-Temp</th>
<th>Lw-Strs</th>
<th>Hw-Strs</th>
<th>Material</th>
<th>Notes</th>
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<td>1.5000E-02</td>
<td>1.5000E-02</td>
<td>1.5000E-02</td>
</tr>
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<td>1.5000E-02</td>
<td>1.5000E-02</td>
<td>1.5000E-02</td>
<td>1.5000E-02</td>
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<td>1.5000E-02</td>
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<td>1.5000E-02</td>
<td>1.5000E-02</td>
<td>1.5000E-02</td>
</tr>
</tbody>
</table>

**Material Options Considered**

- **CST**
- **CST**
- **CST**
- **CST**

**Material Notes**

- *CST*
- *CST*
- *CST*
- *CST*
- *CST*
- *CST*
<table>
<thead>
<tr>
<th>MINIMUM THICKNESS FOR MATERIAL BY AXIS</th>
<th>1.05</th>
<th>81.6</th>
<th>2.00 \times 10^{-3}</th>
<th>4.22</th>
<th>0.06</th>
<th>1.05</th>
<th>81.6</th>
<th>2.00 \times 10^{-3}</th>
<th>4.22</th>
<th>0.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTL CODE = 5</td>
<td>THICKNESS FOR FACE ONE</td>
<td>3,021 INCHES</td>
<td>MTL CODE = 5</td>
<td>THICKNESS FOR FACE TWO</td>
<td>3,021 INCHES</td>
<td>MTL CODE = 5</td>
<td>THICKNESS FOR FACE THREE</td>
<td>3,021 INCHES</td>
<td>TOTAL COST/ITEM</td>
<td>87.94</td>
</tr>
</tbody>
</table>

**Material Code**

- 5: For Collars
- 10: For shipping

**Total Cost/Item**

- 59.12
- 59.12
- 59.12

**Damage Factor**

- 1.00
- 1.00
- 1.00

**Material Code**

- 5
- 5
- 5

**Material Code**

- 10
- 10
- 10

**Total Cost/Item**

- 87.94
- 87.94
- 87.94

**Material Code**

- 5
- 5
- 5

**Material Code**

- 10
- 10
- 10

**Total Cost/Item**

- 87.94
- 87.94
- 87.94

**Damage Factor**

- 1.00
- 1.00
- 1.00
## Table 1: Material Costs and Shipping Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Material Code</th>
<th>Thickness (in.)</th>
<th>Final Cost/Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
<tr>
<td>2</td>
<td>3.5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
<tr>
<td>5</td>
<td>3.5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
</tbody>
</table>

**Total Material Cost:** 239.70

### Material Code Details

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Material Vertical/Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.121</td>
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<tr>
<td>3.121</td>
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<tr>
<td>3.121</td>
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</tr>
</tbody>
</table>

### Shipping Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost/Item</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>60.44</td>
</tr>
<tr>
<td>2</td>
<td>60.44</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
<td>60.44</td>
</tr>
<tr>
<td>5</td>
<td>60.44</td>
</tr>
</tbody>
</table>

**Total Shipping Cost:** 302.20

### Total Cost/Item

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness (in.)</th>
<th>Total Cost/Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.021</td>
<td>47.94</td>
</tr>
<tr>
<td>2</td>
<td>3.021</td>
<td>47.94</td>
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<tr>
<td>5</td>
<td>3.021</td>
<td>47.94</td>
</tr>
</tbody>
</table>

**Total Cost/Item:** 239.70

### Multiplication Factor

The cost is 47.94 dollars with a multiplication factor of 1.25 times one.

**Final Cost/Item:** 59.93

### Total Cost/Item

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness (in.)</th>
<th>Total Cost/Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.021</td>
<td>60.44</td>
</tr>
<tr>
<td>2</td>
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<td>60.44</td>
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<tr>
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<td>60.44</td>
</tr>
<tr>
<td>5</td>
<td>3.021</td>
<td>60.44</td>
</tr>
</tbody>
</table>

**Total Cost/Item:** 302.20

### Additional Notes

- Material code: 3 thickness for material axis
- Material code: 4 thickness for face one
- Material code: 4 thickness for face two
- Material code: 4 thickness for face three
FOR 80.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 20.0 G'S
THE COST IS $57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 5.00 TIMES ONE
WITH A FINAL COST OF $289.72 DOLLARS FOR OVER SHIPING
FOR ALLOWING DAMAGE THE COST IS $72.94 DOLLARS/ITEM

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

3.1 OVER SHIPING DATA
THE OPTIMUM COST IS $59.12 DOLLARS
THE FRAGILITY RATE IS 20.0 G'S
THE PER-CENT DAMAGE IS 0.0
THE MULTIPLICATION FACTOR IS 1.0

THE OPTIMUM THICKNESS FOR FACE ONE IS 2.443 INCHES IF MATERIAL 10 IS USED
THE OPTIMUM THICKNESS FOR Face THREE IS 2.443 INCHES IF MATERIAL 10 IS USED

3.3 DAMAGE ALLOWABLE DATA
THE OPTIMUM COST IS $54.12 DOLLARS
THE FRAGILITY RATE IS 20.0 G'S
THE PER-CENT DAMAGE IS 0.0
THE REPAIR COST/ITEM = $0.00 DOLLARS

THE OPTIMUM THICKNESS FOR FACE ONE IS 2.443 INCHES IF MATERIAL 10 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 2.443 INCHES IF MATERIAL 10 IS USED

3.5 OVER SHIPING IS THE BEST POLICY

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

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## TABLE IX
SAMPLE PROBLEM NUMBER SIX
INPUT DATA CARDS

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</tbody>
</table>
*** OPTIMIZATION PROCEDURE FOR DESIGN OF PACKAGE CUSHIONING ***

SAMPLE PROBLEM 6: MULTIPLE SINE EXCITATION, VARYING TEMPERATURE

1 = MIC --- CODE NO. OF CONTAINER MATERIAL TO BE USED
2 = IC --- OPTIMIZATION CODE

1 = ITEM --- ITEM NUMBER
2 = NIC --- MAXIMUM NO. OF ITERATIONS FOR DROP HT. CALC.
3 = HN --- MAXIMUM NO. OF ITERATIONS FOR CONVERGENCE

1, M, N --- NO. OF ENVIRONMENTAL FREQUENCIES
2, E, O = 1, 2 --- COST OF ITEM
3, R, P = 1, 2 --- T/C NO. OF CONTAINER
4, P, F = 1, 2 --- TEMPERATURE --- LOWEST ENVIRONMENT TEMPERATURE
5, L, J = 1, 2 --- HIGHEST ENVIRONMENT TEMPERATURE

(CS1/SEC) IN WHICH ALL OF THE ENVIRONMENTAL FREQUENCIES ARE APPLIED

P, R, O = 1, 2 --- ENVIRONMENTAL FREQUENCIES, EACH CORRESPONDING TO ONE OF THE ABOVE O|N|S

1 = NC --- NUMBER OF CONTAINERS
2 = NOH --- NUMBER OF MATERIALS ON FILE

CST-MAT CST-PACK CST-PACK 3-L TEMP 4-L TEMP 5-L TEMP 6-L TEMP GAMMA
1.4979E+01 5.4050E+01 5.4050E+01 0.0000E+00 0.0000E+00 1.0000E+00 1.0000E+00 1.5000E+00
5.0000E+01 5.0000E+01 5.0000E+01 0.0000E+00 0.0000E+00 1.0000E+00 1.0000E+00 1.5000E+00
1.4979E+01 5.4050E+01 5.4050E+01 0.0000E+00 0.0000E+00 1.0000E+00 1.0000E+00 1.5000E+00
1.4979E+01 5.4050E+01 5.4050E+01 0.0000E+00 0.0000E+00 1.0000E+00 1.0000E+00 1.5000E+00
5.0000E+01 5.0000E+01 5.0000E+01 0.0000E+00 0.0000E+00 1.0000E+00 1.0000E+00 1.5000E+00

GAMMA CST-CONTAINER
1.7000E-03 2.0000E-08

ITEM NO
1.0000E00 DIMENSION OF ITEM No. 1
1.0000E00 DIMENSION PARALLEL TO X-AXIS AND LONGEST DIMENSION X (IN INCHES)
1.0000E00 DIMENSION PARALLEL TO Y-AXIS AND LONGEST DIMENSION Y (IN INCHES)
1.0000E00 DIMENSION PARALLEL TO Z-AXIS AND LONGEST DIMENSION Z (IN INCHES)

NUMBER = N

MATERIAL CODES CONSIDERED ARE 1, 2, 3, 4, 5.

MAX = 9: PENT-COM REPLACEMENT
1, 2, 3, 4, 5, 6, 7, 8, 9
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>MINIMUM THICKNESS FOR MATERIAL BY AXIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.38B0E+00</td>
</tr>
<tr>
<td>7</td>
<td>7.857E+00</td>
</tr>
<tr>
<td>2</td>
<td>2.097E+00</td>
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</table>

**SHOCK THICKNESS IS LARGER THAN VARIATION THICKNESS**

\[3.218E+00\]

**MATERIAL 3 IS BEING DELETED**

**OCCURED THICKNESS**

\[1.29401E+02\] MAX ALLOWABLE OCCURED THICKNESS = \[1.20000E+01\]

**MINIMUM THICKNESS FOR MATERIAL BY AXIS**

\[4.791E+00\] \[4.791E+00\] \[3.483E+00\] \[7.845E+00\] \[7.845E+00\] \[1.772E+00\] \[2.028E+00\] \[\_\] \[\_\]

**MINIMUM THICKNESS FOR MATERIAL BY AXIS**

\[4.557E+00\] \[4.557E+00\] \[3.483E+00\] \[7.845E+00\] \[7.845E+00\] \[1.772E+00\] \[2.028E+00\] \[\_\] \[\_\]

**MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 7.448 INCHES**

**MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 7.448 INCHES**

132
TOTAL COST/ITEM = 100.88
MATERIAL INPUT
COST MATRIX = MATERIAL VERTICAL AXIS \( \times \) HORIZONTAL

\[
\begin{array}{c|cccc}
\text{MATERIAL} & 1 & 2 & 3 & 4 \\
\hline
1 & 2.43 & 2.35 & .5 & .5 \\
2 & 2.43 & 2.35 & .5 & .5 \\
3 & .5 & .5 & 2.43 & 2.35 \\
4 & .5 & .5 & 2.43 & 2.35 \\
\end{array}
\]

FOR 0.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 5.0 G/S
THE COST IS 100.82 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE

\[\text{MT. A FINAL COST OF 100.82 DOLLARS FOR OVER SHIPPING FOR ALL DAMAGE THE COST IS 100.82 DOLLARS/ITEM}\]

********************************************
\[\text{T1 = 3.5000E+00 T2 = 3.5000E+00 T3 = 2.998E+00 T4 = 2.998E+00 T5 = 2.998E+00}\]
\[\text{MINIMUM THICKNESS FOR MATERIAL BY AXIS}\]
\[\times.5755E+00 \\
.5755E+00 \\
.5755E+00 \\
.5755E+00 \]

********************************************
\[\text{T1 = 3.5000E+00 T2 = 3.5000E+00 T3 = 5.5000E+00 T4 = 2.1400E+00 T5 = 2.1400E+00 T6 = 2.1400E+00}\]
\[\text{MATERIAL 1 IS BEING DELETED NO TEMPERATURE OVERLAP}\]
\[\text{MINIMUM THICKNESS FOR MATERIAL BY AXIS}\]
\[.5755E+00 \\
.5755E+00 \\
.5755E+00 \]
\[\text{ALL MATERIALS DELETED --- NO OVERLAP BETWEEN TEMPERATURES OPTIMIZE ON DATA ACCUMULATED}\]

********************************************
\[\text{OVER SHIPPING DATA}\]
\[\text{THE OPTIMUM COST IS 100.82 DOLLARS}\]
\[\text{THE FRAGILITY RATE IS 5.0 G/S}\]
\[\text{THE PERCENT DAMAGE IS 0.0}\]
\[\text{THE MULTIPLICATION FACTOR IS 1.0}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE ONE IS 7.948 INCHES IF MATERIAL 1 IS USED}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE TWO IS 7.948 INCHES IF MATERIAL 1 IS USED}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE THREE IS 3.984 INCHES IF MATERIAL 1 IS USED}\]

********************************************
\[\text{DAMAGE ALLOWABLE DATA}\]
\[\text{THE OPTIMUM COST IS 100.82 DOLLARS}\]
\[\text{THE FRAGILITY RATE IS 5.0 G/S}\]
\[\text{THE PERCENT DAMAGE IS 0.0}\]
\[\text{THE REPAIR COST/ITEM = 0.00 DOLLARS}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE ONE IS 7.948 INCHES IF MATERIAL 1 IS USED}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE TWO IS 7.948 INCHES IF MATERIAL 1 IS USED}\]
\[\text{THE OPTIMUM THICKNESS FOR FACE THREE IS 3.984 INCHES IF MATERIAL 1 IS USED}\]

********************************************
\[\text{OVERSHIPPING IS THE REST POLICY}\]

********************************************
### Table X
SAMPLE PROBLEM NUMBER SEVEN
INPUT DATA CARDS

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<tr>
<th>Card No.</th>
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<tr>
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<tr>
<td>4</td>
<td>0.3 0.5 1.2</td>
</tr>
<tr>
<td>5</td>
<td>10.0 10.0 10.0</td>
</tr>
<tr>
<td>6</td>
<td>0.3 0.6 0.9 1.2 1.5 1.8</td>
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<tr>
<td>7</td>
<td>0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0</td>
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<tr>
<td>8</td>
<td>0.5 0.9 1.3 1.7 2.1 2.5 2.9 3.3 3.7 4.1</td>
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<tr>
<td>9</td>
<td>0.6 1.0 1.4 1.8 2.2 2.6 3.0 3.4 3.8 4.2</td>
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<tr>
<td>10</td>
<td>0.7 1.1 1.5 1.9 2.3 2.7 3.1 3.5 3.9 4.3</td>
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<td>11</td>
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<tr>
<td>12</td>
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<td>13</td>
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<tr>
<td>14</td>
<td>1.1 1.5 1.9 2.3 2.7 3.1 3.5 3.9 4.3 4.7</td>
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<tr>
<td>15</td>
<td>1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4 4.8</td>
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<tr>
<td>21</td>
<td>70.0 50.0 15.0</td>
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</tbody>
</table>
### Optimization Process for Design of Package Conditioning

#### Sample Problem 47 (MIL-STD 810B)

**Excitation Constant Temperature**

**Optimization Process for Design of Package Conditioning**

1. **NIC** - Code no. of container material to be used
2. **ITM** - Item number
3. **IIM** - Item number on multiple-dimensional output
4. **IEX** - Item number on multiple-dimensional output for enclosure
5. **IG** - Item number on multiple-dimensional output for enclosure, if any
6. **IIP** - Item number on multiple-dimensional output for enclosure, if any
7. **IN** - Item number on multiple-dimensional output for enclosure, if any
8. **ICS** - Item number on multiple-dimensional output for enclosure, if any
9. **IEF** - Item number on multiple-dimensional output for enclosure, if any
10. **IEO** - Item number on multiple-dimensional output for enclosure, if any

**Sample Problem 47 (MIL-STD 810B)**

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<th>CST</th>
<th>EAF</th>
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<th>RHS</th>
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</tr>
</tbody>
</table>

**Gamma**

- **CST** - Container
- **CST** - Container
- **CST** - Container
- **CST** - Container

**Input**

- All of the environmental freq.
- Sample problem 17 (MIL-STD 810B)

**Output**

- Random excitation
- Input
- Item number

**Materials**

1. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
2. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
3. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
4. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
5. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
6. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
7. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
8. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
9. **EX** - Environmental excitations each corresponding to one of the above CSE(s)
10. **EX** - Environmental excitations each corresponding to one of the above CSE(s)

**Material Codes Considered**

- **CST** - Container
- **CST** - Container
- **CST** - Container
- **CST** - Container

**Notes**

- **CST** - Container
- **CST** - Container
- **CST** - Container
- **CST** - Container

135
### Material 1 is Being Deleted

#### Thickness for Material by Axis

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
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</thead>
<tbody>
<tr>
<td>1.00</td>
<td>3.010 inches</td>
<td>6.944 inches</td>
<td>3.010 inches</td>
</tr>
</tbody>
</table>

#### Total Cost/Item 81.01

**Total Cost:** 81.01

**Material:** Material Vertical Axis Horizontal

**Cost:** 81.01

**Factor:**

- 1.00 Times One

#### AVOID DAMAGE AND A SHAKABILITY RATE OF 55.0 G/S

The cost is 81.01 dollars with a multiplication factor of 1.00 times one. With a final cost of 81.01 dollars for shipping, an allowance made the cost is 81.01 dollars/ITEM.

---

### Material 3 is Being Deleted

#### Thickness for Material by Axis

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.2000e+01</td>
<td>1.2000e+01</td>
<td>1.2000e+01</td>
</tr>
</tbody>
</table>

#### Total Cost/Item 84.50

**Total Cost:** 84.50

**Material:** Material Vertical Axis Horizontal

**Cost:** 84.50

**Factor:**

- 1.05 Times One

#### AVOID DAMAGE AND A SHAKABILITY RATE OF 55.0 G/S

The cost is 84.50 dollars with a multiplication factor of 1.05 times one. With a final cost of 84.50 dollars for shipping, an allowance made the cost is 84.50 dollars/ITEM.
MINIMUM THICKNESS FOR MATERIAL BY AXIS

T1 =  3.5000E+00  T2 =  3.5000E+00  T3 =  3.5000E+00  
TT1 =  2.1222E+00  TT2 =  2.1222E+00  TT3 =  2.7872E+00
T1 =  3.5000E+00  T2 =  3.5000E+00  T3 =  3.5000E+00  
TT1 =  1.2538E+00  TT2 =  1.2538E+00  TT3 =  1.5740E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS

4.5755E+00  4.5755E+00  4.5755E+00
1.9587E+00  1.9587E+00  1.9587E+00

MATERIAL CODE =  1  THICKNESS FOR FACE ONE =  4.575  INCHES
MATERIAL CODE =  1  THICKNESS FOR FACE TWO =  4.575  INCHES
MATERIAL CODE =  1  THICKNESS FOR FACE THREE =  3.984  INCHES

TOTAL COST/ITEM =  87.48
MINCOS=INPUT
COST MATERIAL VERTICAL, AXE HORIZONTAL
1  1.46  1.46  1.69
2  1.76  1.76  .97

FOR 20.0% PER-CEMT DAMAGE AND A FRAGILITY RATE OF 5.0 G's
THE COST IS  87.48 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.25 TIMES ONE
WITH A FINAL COST OF  109.97 DOLLARS FOR OVER SHIPPING
FOR ALLOWING DAMAGE THE COST IS  47.98 DOLLARS/ITEM

TOTAL COST/ITEM =  47.98
MINCOS=INPUT
COST MATERIAL VERTICAL, AXE HORIZONTAL
1  1.46  1.46  1.69
2  1.76  1.76  .97

FOR 80.0% PER-CEMT DAMAGE AND A FRAGILITY RATE OF 70.0 G's
THE COST IS  47.98 DOLLARS WITH A MULTIPLICATION FACTOR OF 5.0 TIMES ONE
WITH A FINAL COST OF  239.40 DOLLARS FOR OVER SHIPPING
FOR ALLOWING DAMAGE THE COST IS  102.98 DOLLARS/ITEM

5.1 OVER SHIPPING DATA
THE OPTIMUM COST IS  81.01 DOLLARS
THE FRAGILITY RATE IS  55.0 G's
THE PER-CENT DAMAGE IS  0.0
THE MULTIPLICATION FACTOR IS  1.0

THE OPTIMUM THICKNESS FOR FACE ONE IS  3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS  3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS  2.444 INCHES IF MATERIAL 4 IS USED

137
DAMAGE ALLOWABLE DATA
THE OPTIMUM COST IS $81.01 DOLLARS
THE FRAGILITY RATE IS 55.0 G's
THE PER-CENT DAMAGE IS 0.0
THE REPAIR COST/ITEM = 0.00 DOLLARS

THE OPTIMUM THICKNESS FOR FACE ONE IS 3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 3.010 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 2.994 INCHES IF MATERIAL 4 IS USED

OVERSHIPPING IS THE BEST POLICY

******************************************************************************
## SAMPLE PROBLEM NUMBER EIGHT

### INPUT DATA CARDS

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</table>
**OPTIMIZATION PROCEDURE FOR DESIGN OF PACKAGING CUSHIONING**

**SAMPLE PROBLEM 8 RANDOM EXCITATION CONSTANT TEMPERATURE**

1. **NC** --- LUG NO. OF CONTAINER MATERIAL TO BE USED
2. **IC** --- IDENTIFICATION CODE
3. **ITEM** --- ITEM NUMBER

**MAX** --- MAXIMUM NO. OF ITERATIONS FOR CONVERGENCE

**GAMMA** --- NUMBER OF ENVIRONMENTAL FREQUENCIES

1. **CS** --- COST OF SHIPMENT
2. **CL** --- COST OF ITEM

**LODE NO. OF CONTAINER MATERIAL TO USE**

1. **CT** --- CONTAINER
2. **CST** --- COST-CONTAINER

**CST-FAA** --- COST-FAA
**CST-FA** --- COST-FA

**SL-TEMP** --- SL-TEMP
**LN-STRS** --- LN-STRS
**HI-STRS** --- HI-STRS

**GAMMA** --- GAMMA"
Tl = 3.500E+00  T2 = 3.500E+00  T3 = 3.500E+00  TT1 = 2.550E+00  TT2 = 2.550E+00  TT3 = 3.030E+00
Tl = 3.500E+00  T2 = 3.500E+00  T3 = 3.500E+00  TT1 = 2.531E+00  TT2 = 2.531E+00  TT3 = 2.205E+00
Tl = 3.500E+00  T2 = 3.500E+00  T3 = 3.500E+00  TT1 = 2.154E+00  TT2 = 2.154E+00  TT3 = 2.094E+00

Shock thickness is larger than vibration thickness

Material 3 is being deleted

OPTIMUM VIBRATION THICKNESS = 3.500E+00

Minimum thickness for material by axis

3.500E+00  3.500E+00  3.500E+00

Material code = 4

THICKNESS FOR FACE ONE = 3.010 INCHES
THICKNESS FOR FACE TWO = 3.010 INCHES
THICKNESS FOR FACE THREE = 2.944 INCHES

Total cost/ITEM = 81.01

Material 3 is being deleted

Optimum thickness = 3.500E+00

Minimum thickness for material by axis

4.731E+00  4.731E+00  3.483E+00
7.490E+00  7.490E+00  3.727E+00
2.081E+00  0.0  0.0

Material code = 1

THICKNESS FOR FACE ONE = 3.984 INCHES
THICKNESS FOR FACE THREE = 3.984 INCHES

Total cost/ITEM = 88.50

Material 3 is being deleted

Optimum thickness = 3.500E+00

Minimum thickness for material by axis

4.731E+00  4.731E+00  3.483E+00
7.490E+00  7.490E+00  3.727E+00
2.081E+00  0.0  0.0

Material code = 1

THICKNESS FOR FACE ONE = 4.732 INCHES
THICKNESS FOR FACE TWO = 4.732 INCHES

Material code = 1

THICKNESS FOR FACE THREE = 3.984 INCHES

Total cost/ITEM = 88.50

MINCOS=INPUT

cost matrix=material vertical/axis horizontal

1  1.51  1.51  1.49
2  6.71  6.71  1.48

For 5.00 per cent damage and a fragility rate of 50.0 G's
The cost is 88.50 dollars with a multiplication factor of 1.05 times one
WITH A FINAL COST OF 94.50 DOLLARS/ITEM FOR OVER SHIPPING

FOR ALLOWING DAMAGE THE COST IS 88.50 DOLLARS/ITEM
<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5755E+00</td>
<td>3.5755E+00</td>
<td>3.9834E+00</td>
</tr>
<tr>
<td>2</td>
<td>1.587E+00</td>
<td>1.4926E+00</td>
<td>1.7874E+00</td>
</tr>
</tbody>
</table>

**Material Code: 1**

**Material Code: 2**

**Material Code: 3**

**Minimum Thickness for Material by Axis:**

- **Material Code: 1**
  - Face One: 3.5755 inches
  - Face Two: 3.5755 inches
  - Face Three: 3.48 inches

**Minimum Thicknesses:**

- A.575 inches
- 1.75 inches
- 1.75 inches

**Total Cost/Item:** 87.98

**Minimum Input Cost Matrix-Material Vertical, Axis Horizontal:**

<table>
<thead>
<tr>
<th>Code</th>
<th>1</th>
<th>1.5</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4%</td>
<td>1.4%</td>
<td>1.4%</td>
</tr>
<tr>
<td>2</td>
<td>1.7%</td>
<td>1.7%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

**For 0.00 percent damage and a fragility rate of 60.0 G's:**

- The cost is 87.98 dollars with a multiplication factor of 1.25 times one.
- With a final cost of 104.97 dollars for over shipping, allowing damage the cost is 97.98 dollars/ITEM.

**Minimum Input Cost Matrix-Material Vertical, Axis Horizontal:**

<table>
<thead>
<tr>
<th>Code</th>
<th>1</th>
<th>1.5</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4%</td>
<td>1.4%</td>
<td>1.4%</td>
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<tr>
<td>2</td>
<td>1.7%</td>
<td>1.7%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

**For 0.00 percent damage and a fragility rate of 70.0 G's:**

- The cost is 87.98 dollars with a multiplication factor of 5.00 times one.
- With a final cost of 436.40 dollars for over shipping, allowing damage the cost is 102.48 dollars/ITEM.

**3.1 Over Shipping Data**

- The optimum cost is 81.01 dollars.
- The fragility rate is 55.0 G's.
- The percent damage is 0.0.
- The multiplication factor is 1.0.

**The optimum thickness for face one is 3.01E+00 inches if material 4 is used.**

**The optimum thickness for face two is 3.01E+00 inches if material 4 is used.**

**The optimum thickness for face three is 2.44 inches if material 4 is used.**

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3.3 Damage Allowable Data
The optimum cost is $81.01 dollars.
The fragility rate is 55.0 G's.
The percent damage is 0.0.
The repair cost/item = 0.00 dollars.

3.4 The optimum thickness for face one is 3.010 inches if material 4 is used.
The optimum thickness for face two is 3.010 inches if material 4 is used.
The optimum thickness for face three is 2.994 inches if material 4 is used.

3.5 Overshipping is the best policy.

******************************************************************************************************************
**SAMPLE PROBLEM NUMBER NINE**

**INPUT DATA CARDS**

<table>
<thead>
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<th>Card No.</th>
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</tr>
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<tbody>
<tr>
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<td>20</td>
<td>1.00</td>
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<tr>
<td>21</td>
<td>1.00</td>
</tr>
</tbody>
</table>
WITH A FINAL COST OF $58.94 DOLLARS/FUR OVER SHIPPING
FOR ALLOWING DAMAGE THE COST IS $58.94 DOLLARS/ITEM

**Minimum Thickness for Material by Axis**

<table>
<thead>
<tr>
<th></th>
<th>Thickness for Face One</th>
<th>Thickness for Face Two</th>
<th>Thickness for Face Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>2</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>3</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>4</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>5</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>6</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>7</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>8</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>9</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
<tr>
<td>10</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
<td>3.50H in.</td>
</tr>
</tbody>
</table>

**Material Code = Thickness**

- **MATERIAL CODE = Thickness for Face One = 3.021 inches**
- **MATERIAL CODE = Thickness for Face Two = 3.021 inches**
- **MATERIAL CODE = Thickness for Face Three = 3.021 inches**

**Total Cost/Item = $57.94**

**COST MATRIX**

**MATERIAL VERTICAL, AXIS HORIZONTAL**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>.75</td>
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</tbody>
</table>

**FOR 20 PERCENT DAMAGE AND A FRAILITY RATE OF 65.0 G's**

**The Cost is $57.94 with a Multiplication Factor of 1.25 Times One**

**With a Final Cost of $72.49 DOLLARS/FUR OVER SHIPPING**

**For allowing damage the cost is $61.94 DOLLARS/ITEM**

**Total Cost/Item = $57.94**

**COST MATRIX**

**MATERIAL VERTICAL, AXIS HORIZONTAL**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>.75</td>
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</tr>
</tbody>
</table>
FOR 80.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 70.0 G'S
THE COST IS $7.94 DOLLARS WITH A MULTIPLICATION FACTOR OF $5.00 TIMES ONE
WITH A FINAL COST OF $289.72 DOLLARS FOR OVER SHIPPING.
FOR ALLOWING DAMAGE, THE COST IS $7.94 DOLLARS/ITEM.

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

OVER SHIPPING DATA
2.1 THE OPTIMUM COST IS $57.94 DOLLARS
THE FRAGILITY RATE IS 55.0 G'S
THE PER-CENT DAMAGE IS 0.0
THE MULTIPLICATION FACTOR IS 1.0
THE OPTIMUM THICKNESS FOR FACE ONE IS 3.021 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 3.021 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.021 INCHES IF MATERIAL 4 IS USED

DAMAGE ALLOWABLE DATA
3.3 THE OPTIMUM COST IS $57.94 DOLLARS
THE FRAGILITY RATE IS 55.0 G'S
THE PER-CENT DAMAGE IS 0.0
THE REPAIR COST/ITEM = $0.00 DOLLARS
THE OPTIMUM THICKNESS FOR FACE ONE IS 3.021 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE TWO IS 3.021 INCHES IF MATERIAL 4 IS USED
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.021 INCHES IF MATERIAL 4 IS USED

3.5 OVER SHIPPING IS THE BEST POLICY

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
G. Material Selection and Cataloging

1. Literature

The literature on cushioning materials is very large and being expanded. Most of the cushioning material data is empirical; however, work has been done to improve the generation of material data through analytical methods. Cushioning materials can be divided into three broad groups:

1) RESILIENT materials - These materials absorb relatively small amounts of energy and recover most of the cushion thickness in a short time. An example is a lightweight open-celled plastic foam.

2) QUASI-RESILIENT materials - These materials remain resilient under small excursions; however, under large distortions do not recover completely.

3) NON-RESILIENT materials - These materials are used for one-time absorption of very large amounts of energy and the material performs its function once. This type of material is not applicable to this project.

The data on materials was available primarily from researchers with very little data obtained from the manufacturer. The most common practice is to present the data in terms of peak acceleration (\(a_p\) in g's) versus static stress (\(\sigma_s\) in psi). These curves are normally illustrated parametrically in terms of cushion thickness, \(T_c\) in inches, and drop height, \(h\) in inches.

2. Selection

The selection of materials to be cataloged was based on information gathered throughout this effort. Table XIII lists the materials selected and cataloged. For each material (Table XIII) which was cataloged into the materials data computer file, there is a material code. For each material code there are a number of parameters which describe the cushioning material used. Tables XIV through XXIII provide the user with physical descriptions of particularly coded materials. For example, if the selected material code from the program was 1, the user would know that the material was a urethane foam (ether type) with a density of 2.0 lb/ft\(^3\). The user would know that the SHOCK DATA in the computer program was cataloged from the indicated Data Reference Source, for a density of 2.0 lb/ft\(^3\), for the four listed drop heights, for the listed thicknesses, and for a temperature of 72°F. Also, as a part of the cataloged file is the
TABLE XIII
CATALOGED MATERIALS

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urethane Foam</td>
</tr>
<tr>
<td>2</td>
<td>Foamed Polyethylene</td>
</tr>
<tr>
<td>3</td>
<td>Felt</td>
</tr>
<tr>
<td>4</td>
<td>Expanded Resilient Polystyrene</td>
</tr>
<tr>
<td>5</td>
<td>Rubberized Hair</td>
</tr>
<tr>
<td>6</td>
<td>Cellulosic</td>
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<tr>
<td>7</td>
<td>Vinyl Foam</td>
</tr>
<tr>
<td>8</td>
<td>Fiber Glass</td>
</tr>
<tr>
<td>9</td>
<td>Rubber Foam</td>
</tr>
<tr>
<td>10</td>
<td>Air Bubbles</td>
</tr>
</tbody>
</table>

range of Optimum Static Stress of 0, 10 to 1.00 lb/in.², and the Safe Low Temperature of -22°F. Likewise, the user would know that for the cataloged VIBRATION DATA, data were obtained from the indicated Data Reference Source for the parameters of Density, Static Stress, Thickness, and Temperature listed.

Figure 9 illustrates the typical data form for peak acceleration versus static stress curves. This data form was converted into digital tabulation for computer compatibility. The previously described interpolation program will be used for the material data. This program uses a sophisticated and accurate Lagrangian parabolic interpolation technique(4). Thus, with a minimum amount of digitized data, these empirical curves can be represented for computer usage.

Figure 10 illustrates the availability of recorded optimum static stresses. The inclusion of this data reduces the iterative process within the physical optimization routine of the computer program because it readily eliminates some candidate materials.
### TABLE XIV

**URETHANE DATA**

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Urethane Foam (Ether Type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>1</td>
</tr>
<tr>
<td>Density in Data File:</td>
<td>(lb/ft$^3$) 2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk. 304 (5)</td>
<td>Density: (lb/ft$^3$) 2.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thickness: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: ($^\circ$F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in.$^2$) 0.10 to 1.00</td>
</tr>
<tr>
<td>Mustin, SVM-2 (1)</td>
<td>Safe Low Temperature: ($^\circ$F) -22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB 167 372, Zell (6)</td>
<td>Density: (lb/ft$^3$) 2.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Static Stress: (lb/in.$^2$) 0.16</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thickness: (in.) 2.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: ($^\circ$F) 72.0</td>
</tr>
</tbody>
</table>

| Commercial Quote to SwRI | Material Cost: ($/ft^3$) 1.62 |
| Estimated               | Fabrication Cost: ($/min) 0.05 |
| Estimated               | Packing Cost: ($/min) 0.01 |
**TABLE XV**

**POLYETHYLENE DATA**

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Polyethylene Foam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>2</td>
</tr>
<tr>
<td>Density in Data Fib. (lb/ft³)</td>
<td>2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk. 304 (5)</td>
<td>Density: (lb/ft³) 2.0</td>
</tr>
<tr>
<td></td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td></td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>Estimated</td>
<td>Range of Optimum Static Stress: (lb/in.²) 0.14 to 1.50</td>
</tr>
<tr>
<td>Estimated</td>
<td>Safe Low Temperature: (°F) -60</td>
</tr>
</tbody>
</table>

**Parameters for VIBRATION DATA**

| Estimated | Density: (lb/ft³) 2.1 |
| Estimated | Static Stress: (lb/in.²) 1.0 |
| Estimated | Thickness: (in.) 2.0 |
| Estimated | Temperature: (°F) 72 |

**COST DATA**

<p>| Commercial Quote to SwRI | Material Cost: ($/ft³) 5.40 |
| Estimated               | Fabrication Cost: ($/min) 0.05 |
| Estimated               | Packing Cost: ($/min) 0.61 |</p>
<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Wood Fiber Felt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>3</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft$^3$)</td>
<td>2.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk 304 (5)</td>
<td>Density: (lb/ft$^3$) 2.4</td>
</tr>
<tr>
<td></td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td></td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td></td>
<td>Temperature: ($^\circ$F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in.$^2$) 0.03 to 0.30</td>
</tr>
<tr>
<td>Mustin, SVM-2 (1)</td>
<td>Safe Low Temperature: ($^\circ$F) -34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Density: (lb/ft$^3$) 1.8</td>
</tr>
<tr>
<td>Estimated Static Stress: (lb/in.$^2$) 0.08</td>
</tr>
<tr>
<td>Estimated Thickness: (in.) 4.0</td>
</tr>
<tr>
<td>Estimated Temperature: ($^\circ$F) 72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Quote to SwRI Material Cost: ($/ft^3$) 2.16</td>
</tr>
<tr>
<td>Estimated Fabrication Cost: ($/min) 0.05</td>
</tr>
<tr>
<td>Estimated Packing Cost: ($/min) 0.01</td>
</tr>
</tbody>
</table>
### TABLE XVII
POLYSTYRENE DATA

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Polystyrene (Expanded Resilient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>4</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft$^3$)</td>
<td>0.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk. 304 (5)</td>
<td>Density: (lb/ft$^3$) 0.4 to 1.5</td>
</tr>
<tr>
<td></td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td></td>
<td>Thicknesses: (in.) 1, 1.5, 2, 3, 4, 6</td>
</tr>
<tr>
<td></td>
<td>Temperature: ($^\circ$F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in.$^2$) 0.20 to 1.50</td>
</tr>
<tr>
<td>Mustin, SVM-2 (1)</td>
<td>Safe Low Temperature: ($^\circ$F) -60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB 167 372, Zell (6)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Quote to SwRI</td>
</tr>
<tr>
<td>Estimated Fabrication Cost: ($/min) 0.05</td>
</tr>
<tr>
<td>Estimated Packing Cost: ($/min) 0.01</td>
</tr>
</tbody>
</table>

*1 inch only for 18, 24, 36 inch drops.*
### TABLE XVIII
#### RUBBER HAIR DATA

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Rubberized Hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>5</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft(^3))</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk. 304 (5)</td>
<td>Density: (lb/ft(^3)) 1.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in.(^2)) 0.03 to 0.30</td>
</tr>
<tr>
<td>Mustin, SVM-2 (1)</td>
<td>Safe Low Temperature: (°F) -40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>Density: (lb/ft(^3))</td>
</tr>
<tr>
<td>Static Stress: (lb/in.(^2))</td>
</tr>
<tr>
<td>Thickness: (in.)</td>
</tr>
<tr>
<td>Temperature: (°F)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Quote to SwRI</td>
</tr>
<tr>
<td>Material Cost: ($/ft(^3))</td>
</tr>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>Fabrication Cost: ($/min)</td>
</tr>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>Packing Cost: ($/min)</td>
</tr>
</tbody>
</table>
TABLE XIX
CELLULOSE DATA

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Cellulose Wadding, Asphalt Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>6</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft³)</td>
<td>3.0 (Estimated)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk, 304 (5)</td>
<td>Density: (lb/ft³) 2.91</td>
</tr>
<tr>
<td></td>
<td>Drop Heights: (in.) 18, 24, 30, 36&quot;</td>
</tr>
<tr>
<td></td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>Estimated</td>
<td>Range of Optimum</td>
</tr>
<tr>
<td></td>
<td>Static Stress: (lb/in.²) 0.03 to 0.50</td>
</tr>
<tr>
<td>Wilson, L. T. (7)</td>
<td>Safe Low Temperature: (°F) -20</td>
</tr>
<tr>
<td>Sandia Labs</td>
<td>Parameters for VIBRATION DATA</td>
</tr>
<tr>
<td></td>
<td>Density: (lb/ft³) 2.91</td>
</tr>
<tr>
<td></td>
<td>Static Stress: (lb/in.²) .268</td>
</tr>
<tr>
<td></td>
<td>Thickness: (in.) 3.0</td>
</tr>
<tr>
<td></td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>Commercial Quote to SwRI</td>
<td>Material Cost: ($/ft³) 1.36</td>
</tr>
<tr>
<td>Estimated</td>
<td>Fabrication Cost: ($/min) 0.05</td>
</tr>
<tr>
<td>Estimated</td>
<td>Packing Cost: ($/min) 0.01</td>
</tr>
</tbody>
</table>

"Drop Height 36" was estimated.

'Compression of 16.7%.
# TABLE XX

**VINYL FOAM DATA**

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Vinyl Foam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>7</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft³)</td>
<td>7.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
<td>Density: (lb/ft³) 7.97</td>
</tr>
<tr>
<td>&quot;</td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>From Plots</td>
<td>Range of Optimum Static Stress: (lb/in.²) 0.02 to 0.20</td>
</tr>
<tr>
<td>Estimated</td>
<td>Safe Low Temperature: (°F) -20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wilson, L. T. (7) Sandia Labs</th>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density: (lb/ft³) * 7.93</td>
<td>Static Stress: (lb/in.²) .266</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thickness: (in.) 3.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>Estimated</td>
</tr>
</tbody>
</table>

*Compression of 16.1%.
### TABLE XXI
**FIBER GLASS DATA**

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Fiber Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>8</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft³)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-Hdbk. 304 (5)</td>
<td>Density: (lb/ft³) 1.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thicknesses: (in.) 2, 3, 4</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in²) 0.03 to 0.20</td>
</tr>
<tr>
<td>Estimated</td>
<td>Safe Low Temperature: (°F) -20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wilson, L. T. (7) Sandia Labs</th>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>Density: (lb/ft³) 2.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Static Stress: (lb/in²) 0.256</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thickness: (in.) 3.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Material Cost: ($/ft³) 1.00</td>
</tr>
<tr>
<td>Estimated Fabrication Cost: ($/min) 0.05</td>
</tr>
<tr>
<td>Estimated Packing Cost: ($/min) 0.01</td>
</tr>
</tbody>
</table>

*18, 24, 36 inch drop heights were estimated.

*Compression of 15.8%.
**TABLE XXII**

**RUBBER FOAM DATA**

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
<td>Density: ((\text{lb/ft}^3)) 11.9</td>
</tr>
<tr>
<td></td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td></td>
<td>Thicknesses: (in.) 2, 3, 4, 5</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>Mustin, SVM-2 (1)</td>
<td>Range of Optimum Static Stress: ((\text{lb/in.}^2)) 0.01 to 0.15</td>
</tr>
<tr>
<td>Wilson, L. T. (7)</td>
<td>Safe Low Temperature: (°F) -20</td>
</tr>
<tr>
<td>Sandia Labs</td>
<td>Parameters for VIBRATION DATA</td>
</tr>
<tr>
<td></td>
<td>Density: ((\text{lb/ft}^3)) 11.9</td>
</tr>
<tr>
<td></td>
<td>Static Stress: ((\text{lb/in.}^2)) 1.28</td>
</tr>
<tr>
<td></td>
<td>Thickness: (in.) 3.0</td>
</tr>
<tr>
<td></td>
<td>Temperature: (°F) 72</td>
</tr>
</tbody>
</table>

**COST DATA**

| Commercial Quote to SwRI | Material Cost: \((\$/ft^3)\) 4.20 |
| Estimated               | Fabrication Cost: \((\$/min)\) 0.05 |
| Estimated               | Packing Cost: \((\$/min)\) 0.01 |

° Compression of 3.0%.
### TABLE XXIII

**AIR CAP DATA**

<table>
<thead>
<tr>
<th>Material Description:</th>
<th>Air Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Code:</td>
<td>10</td>
</tr>
<tr>
<td>Density in Data File: (lb/ft³)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Reference Source</th>
<th>Parameters for SHOCK DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinetic Systems, Inc. (8)</td>
<td>Density: (lb/ft³) 1.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Drop Heights: (in.) 18, 24, 30, 36</td>
</tr>
<tr>
<td>&quot;</td>
<td>Thicknesses: (in.) 1, 2, 3</td>
</tr>
<tr>
<td>&quot;</td>
<td>Temperature: (°F) 72</td>
</tr>
<tr>
<td>From Data Plots</td>
<td>Range of Optimum Static Stress: (lb/in.²) 0.02 to 0.80</td>
</tr>
<tr>
<td>Estimated</td>
<td>Safe Low Temperature: (°F) -20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters for VIBRATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commercial Quote to SwRI</th>
<th>COST DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Cost: ($/ft³)</td>
<td>2.11</td>
</tr>
<tr>
<td>Estimated Fabrication Cost: ($/min)</td>
<td>0.05</td>
</tr>
<tr>
<td>Estimated Packing Cost: ($/min)</td>
<td>0.01</td>
</tr>
</tbody>
</table>
FIGURE 9. PEAK ACCELERATION VERSUS STATIC STRESS CURVES FOR POLYETHYLENE FOAM

[Mustin, G. S.](1)

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3. Materials Data

For each material listed in Table XIII, there is a coded file containing the following:

Data on Disk File for Each Package Cushioning Material

<table>
<thead>
<tr>
<th>Format</th>
<th>Record No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E7, 0, 512)</td>
<td>1</td>
<td>RHOM, DRPH, ICODE</td>
</tr>
<tr>
<td>E7, 0</td>
<td>RHOM - Specific weight of the material (PCF)</td>
<td></td>
</tr>
<tr>
<td>I2</td>
<td>DRPH - Drop height</td>
<td></td>
</tr>
<tr>
<td>I2</td>
<td>ICODE - Code used in updating files</td>
<td></td>
</tr>
<tr>
<td>(512)</td>
<td>2</td>
<td>NT, NTH, NS</td>
</tr>
<tr>
<td>I2</td>
<td>NT - Number of temperatures (Max. = 5)</td>
<td></td>
</tr>
<tr>
<td>I2</td>
<td>NTH - Number of thicknesses (Max. = 10)</td>
<td></td>
</tr>
<tr>
<td>I2</td>
<td>NS - Number of stresses (Max. = 10)</td>
<td></td>
</tr>
</tbody>
</table>
Format  Record No.  
(11E7.0)  3   (T(I), I = 1, NT)  
E7.0  T(I) - One of the temperatures at which data is recorded (degrees fahrenheit)  
(11E7.0)  4   (TH(I), I = 1, NTH)  
E7.0  TH(I) - One of the material thicknesses considered during data gathering  
(11E7.0)  5   (SIG(I), I = 1, NS)  
E7.0  SIG(I) - Static stress at a point:  
DO XX K = 1, NT  
DO XX I = 1, NTH  
(11E7.0)  6   XX READ (MS, F) (TAB1(I, J, K), J = 1, NS)  
through (NT) * (NTH)  
TAB1(I, J, K) = G = F(Thickness, Stress, Temperature)  
where (NT) * (NTH) = (5) * (4) = 20  
for the 18-inch drop height,  
The preceding type of information is also stored for the 24-inch drop height, 30-inch drop height, and 36-inch drop height, respectively.  
Next is the vibration environment which consists of the following:  
The first record number for the vibration data will be \( \ell rs + 1 \), since the last record of the shock data \( \ell rs \) will be  
\[
\ell rs = 4 \cdot 5 + (NT_{18}) \cdot (NTH_{18}) + (NT_{24}) \cdot (NTH_{24}) \\
+ (NT_{30}) \cdot (NTH_{30}) + (NT_{36}) \cdot (NTH_{36})
\]
where for \( NT_i \) and \( NTH_i \) the subscript \( i \) denotes the indicated drop height.
The complete shock and vibration data file printout is available from the cognizant project engineer at U.S. Army Natick Laboratories.

ii. Optimization Technique

The general concept of an optimization process involves the problem of minimizing a function of several variables, wherein the variables are subject to a set of constraints. The function to be minimized is generally referred to as a cost function and for the present problem it is exactly that, an expression of cost. The conditions of constraint for the
package problem involve numerous variables most of which deal with either the protection of the packaged item and thus the cushioning designs that meet the required fragility limits for a given shipping environment, or are of concern in the total weight and cube of the package for purposes of determining the cost of shipping.

Unfortunately, the constraint equations for this problem cannot be explicitly written out in functional form, such as in the form of inequalities, since most of the cushion design variables are in the form of various graphs which are stored as discrete variables; likewise, packaging exterior container designs and shipping costs are also in discrete form. Therefore, an optimization solution technique such as linear programming (8) does not conveniently lend itself to the present problem.

Thus, the optimization technique used in this computer-aided design procedure is to take the specified problem input values and use the input data in conjunction with the data stored for each material in an iterative process. The iterative process will finally produce only those materials which will meet all aspects of the shipping problem. The optimum material is finally selected on the basis of least cost.

After the input data are read by the computer, the three temperatures are set by using the specified high and low temperatures and a third temperature halfway between the two extremes.

Those materials that cannot provide protection throughout the specified temperature range are eliminated. If the static stress of the shipped item is outside of the optimum static stress range of a material, that material is eliminated from further consideration.

I. Package Cushioning CAD Program User Guide

To use the CAD Program, OPPACK, for the design of package cushioning, the user must be able to adequately understand, define, and describe his package cushioning problem. A very simple step-by-step tabulation of the required input data to the CAD Program, OPPACK, is shown in Table XXIV

Sample Problem No. 1

The problem is to optimumly ship a 12 in. x 12 in. x 24 in., 100-lb item in a cardboard container from Point A to Point B.

The package cushioning engineer completes the information in Table XXIV and codes the computer sheets for keypunching. The punched cards would appear as shown in Table XXV.

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**TABLE XXIV**

STEP-BY-STEP CAD PROGRAM, OPPACK, INPUT DATA REQUIREMENTS FROM USER

<table>
<thead>
<tr>
<th>Step 1. What is the shipping container material?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood - NIC =</td>
</tr>
<tr>
<td>etc.</td>
</tr>
</tbody>
</table>

**Step 2. Which type of vibration optimization is to be used?**

- MIL-STD-810B - IC = 1
- Multiple sine - IC = 2
- Random - IC = 3

**Step 3. What is the Item Number?**

Set IITM = 1

**Step 4. What are the maximum number of iterations needed for convergence of drop height calculations?**

MIC = __________

If the number of iterations are unknown, Set MIC = 20

**Step 5. Set MXI = 0**

**Step 6. What is the number of environmental frequencies which are going to be provided as input? (Up to a maximum of 11)**

MOMJ = __________

**Step 7. What is the cost of shipping?**

CS = __________ ($/lb)

**Step 8. What is the cost of the item?**

CI = __________ ($)

**Step 9. What is the thickness of the shipping container?**

TCON = __________ (in.)

**Step 10. What is the lowest environmental temperature (°F) to which the item will be exposed?**

TEML = __________ (°F)
Table XXIV (Contd.)

Step 11. What is the highest environmental temperature (°F) to which the item will be exposed?

\[
\text{TEMH} = \quad \frac{\text{°F}}{\text{°C}}
\]

**NOTE** If (TEMH - TEML) < 20 °F, make TEMH = TEML

---

**Input Data on Card Number Two**

**Step 12.** What are the environmental frequencies (radians/second) in ascending order up to a maximum of 11 (i.e., \(\text{MOMJ} \leq 11\)) from Step 6?

<table>
<thead>
<tr>
<th>Frequency (radians/second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.283, 62.83, 125.65, 314.159, 628.300, 1884.96, 3114.59, 4398.23, 5654.87, 5969.03, 6283.19</td>
</tr>
</tbody>
</table>

If the environmental frequencies are unknown, use

---

**Input Data on Card Number Three**

**Step 13.** What is the Power Spectral Density (PSD), \(g^2/\text{Hz}\) value at each of the corresponding environmental frequencies in Step 12?

<table>
<thead>
<tr>
<th>PSD Value ((g^2/\text{Hz}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000366, 0.000517, 0.000191, 0.000191, 0.000113, 4.09(\times)10(^{-7}), 5.83(\times)10(^{-6}), 5.09(\times)10(^{-7}), 5.09(\times)10(^{-7}), 5.09(\times)10(^{-7})</td>
</tr>
</tbody>
</table>

**Input Data on Card Number Four**

**Step 14.** What are the environmental acceleration levels, \(g\), which correspond to the environmental frequencies in Step 12?

<table>
<thead>
<tr>
<th>Acceleration Level ((g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5, 0.5, 1.0, 2.0, 3.0, 3.0, 3.0, 3.0, 3.0, 3.0</td>
</tr>
</tbody>
</table>
TABLE XXIV (Contd.)

**Input Data on Card Number Five**

**Step 15.** How many different types of containers are there to be considered?

> \[ NC = \underline{\text{_________}} \]

What is the Item Number?

> \[ MITEM = \underline{\text{_________}} \]

**MITEM** - is an arbitrary number assigned to the item being shipped. **MITEM must not be greater than two digits** (i.e., 99). The following must exist:

> \[ MITEM = \text{ITEM} = \text{ITEM} \]

What is the number of materials on disk file?

> \[ \text{MINMATS} = 10 \]

**MINMATS** (Columns 5-6) on Card Number Five should be the following (i.e., 10) until modified by Natick Laboratories. Check with cognizant engineer.

> \[ \underline{\text{_________}} \]

where **Number of Container types to be considered** - - - - - - - \( NC = 1 \)

(The input data for each type of container are as shown on Input Data Card Sixteen)

**Item Number** - - - - - - - \( MITEM = 1 \)

**Number of Materials on File** - \( \text{MINMATS} = 10 \)

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Step 16. Cards Numbers Six through Fifteen should be the following, until modified by Natick Laboratories. Check with cognizant engineer.

<table>
<thead>
<tr>
<th>Numbers</th>
<th>Operation</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.222</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>44444</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>55555</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>66666</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>77777</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>88888</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>99999</td>
<td></td>
<td>1.00</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
**Input Data on Card Number Sixteen through ....**

**Step 17.** Card Number Sixteen contains the specific weight (lb/in.$^3$) and cost ($$/in.$^3$) of the container material. The cost of container material is material volume, NOT container volume.

There should be one Card Number Sixteen type card for each container material specified in Data Card Number Five (i.e., NC). The data cards would appear as follows:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WI</th>
<th>XL</th>
<th>YL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE XXIV (Contd.)

**Step 22.** What is the $Z$-length (longest length) of the item?

$$ZL = \quad \quad \quad \text{(in.)}$$

where the lengths are:

![Diagram of lengths: ZL, YL, XL]

**Step 23.** How many different percent damage allowable cases are there? (Maximum = 10)

$$NPCNT = \quad \quad \quad$$

Input Data on Cards Numbers Fifteen + Number of Container Material Cards + 1 (i.e., Card Number Eighteen in Sample Problem), through... Last Card Containing Damage Allowable Data (i.e., Card Number Twenty-One in Sample Problem One).

**Step 24.** What is the fragility of the item in acceleration, $g$?

$$GMF(I) = \quad \quad \quad \text{(g)}$$

**Step 25.** What is the percent damage at the acceleration level in Step 24?

$$PCTD(I) = \quad \quad \quad \%$$

**Step 26.** What is the replacement cost for the percent damage in Step 25?

$$REPCI(I) = \quad \quad \quad \$/\text{item}$$

**Step 27.** Repeat Steps 24, 25, 26 for each different percent damage allowable case indicated in Step 23 on a separate input data card.
<table>
<thead>
<tr>
<th>Card No.</th>
<th>0112</th>
<th>1207</th>
<th>560.3</th>
<th>34001</th>
<th>250</th>
<th>2</th>
<th>12.0</th>
<th>12.0</th>
<th>720.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.03</td>
<td>95.6</td>
<td>314.1</td>
<td>1740.2</td>
<td>10.0</td>
<td>4</td>
<td>5439.0</td>
<td>235</td>
<td>45759.0</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
<td>6.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Input Data on Card Number One

Step 1. The shipping container is cardboard.
   NIC = 1

Step 2. The shipping environment is considered to have Multiple Sine Excitation.
   IC = 2

Step 3. The item number is No. 1
   IITM = 1
   IITM is an arbitrary number assigned to the item being shipped. IITM must not be greater than two digits (i.e., 99). The following must exist: IITM = MITEM = ITEM.

Step 4. The maximum number of iterations are desired for the drop height calculations.
   MIC = 20

Step 5. Set MXI = 0

Step 6. The eleven environmental frequencies are going to be provided.

Step 7. The shipping cost is $0.3359 per pound.
   CS = 0.3359 ($/lb)

Step 8. The item cost is $25.00.
   CI = 25.00 ($)

Step 9. The shipping container is 0.125-in. thick.
   TCON = 0.125 (in.)

Step 10. 55°F is the lowest environmental temperature.
   TEML = 55 (°F)

Step 11. 72°F is the highest environmental temperature.
   TEMH = 72 (°F)
   Since (TEMH - TEML) ≤ 20°F, make
   TEMH = TEML

Input Data Card Number One would look like the following:

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Input Data Card Number One

Step 12. The environmental frequencies (rad/sec) are UNKNOWN; therefore, the suggested frequencies are used.

Input Data Card Number Two would look like the following:

Step 12. The environmental frequencies (rad/sec) are UNKNOWN; therefore, the suggested frequencies are used.

Input Data Card Number Two would look like the following:
Input Data on Card Number Three

Step 13. Since the Multiple Sine Excitation (IC = 2) is being used, this card is blank.

Input Data Card Number Three would look like the following:

Input Data Card Number Four

Step 14. Since the suggested environmental frequencies are used (i.e., Step 12), the suggested acceleration levels are used.

Input Data Card Number Four would look like the following:
Step 15. Since there is only one type of container to be checked and the item number is "1", Input Data Card Number Five would look like the following:

Input Data on Cards Numbers Six through Fifteen

Step 16. Input Data Cards Numbers Six through Fifteen would look like the following:
Input Data on Card Number Sixteen

Step 17. Since the specific weight of the container is 0.0017 lb/in.\(^3\) and the container material cost is 0.00232 $/in.\(^3\). Input Data Card Number Sixteen would look like the following:

![Input Data Card Number Sixteen](image)

Input Data on Card Number Seventeen

Step 18. There is 1 item.

\[ \text{ITEM} = 1 \]

Step 19. The item weighs 100 lb.

\[ W_I = 100 \text{ (lb)} \]

Step 20. The second largest length is 12 inches.

\[ X_L = 12 \text{ (in.)} \]

Step 21. The shortest length is 12 inches.

\[ Y_L = 12 \text{ (in.)} \]

Step 22. The longest length is 24 inches.

\[ Z_L = 24 \text{ (in.)} \]

Step 23. There are 4 different percent damage allowable cases.

\[ \text{NPCUT} = 4 \]
Input Data Card Number Seventeen would look like the following:

<table>
<thead>
<tr>
<th>Fragility (g)</th>
<th>Percent Damage (%)</th>
<th>Repair Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>60.</td>
<td>5.</td>
<td>5.00</td>
</tr>
<tr>
<td>65.</td>
<td>20.</td>
<td>10.00</td>
</tr>
<tr>
<td>70.</td>
<td>80.</td>
<td>15.00</td>
</tr>
</tbody>
</table>

Input Data on Cards Numbers Eighteen through Twenty-One

Step 24 thru Step 26 The four different percent damage allowable cases are:

Input Data Cards Numbers Eighteen through Twenty-One would look like the following:
J. Source Program and Data File Change Procedures

The documentation for the basic procedures to change the computer resident object program for OPPACK or to change the computer resident data files is in:

NLABS U-1106 COMPUTER FACILITY
USERS GUIDE

Any modifications to any or all of the OPPACK subroutines should be made not only to the Source Program disk file (i.e., OPPACK., which contains OPPACK, MAIN, OPPACK, TEMPEV, OPPACK, DAMALW, OPPACK, CDPRO, OPPACK, DNGHT, OPPACK, COSTMT, OPPACK, MNCOS, OPPACK, SHOKE, OPPACK, VIBRTN, OPPACK, LAGINT, and OPPACK, FLAGR) but to the Source Program card file. After changes have been made to the Source Program disk file, the listing shown in Appendix J should be used to create the object program on the disk file.

Any modifications to the materials data file on disk can be made either by using SCALE and TDATAF programs or by using the disk file
edit procedures in the NLABS U-1166 COMPUTER FACILITIES USERS GUIDE. Since the programs SCALE and TDATAF were used to generate much of the estimated data information, it would be appropriate to use the file edit procedures in the USERS GUIDE to change the materials data as they become available.
III. SUMMARY

The initial development of a Computer Aided Design (CAD) program (designated as, OPPACK) for package cushioning has been done. The mathematical algorithms were computer-coded and the available materials data cataloged.

Since Natick Laboratories does not have fragility criteria data available, SwRI has set forth the assumptions and methods for describing the computer program fragility data input requirements. Also, SwRI constructed artificial shock, vibration, and temperature environments in statistical form. At some point, Natick Laboratories may be able to provide information about shock, vibration, and temperature environments.

The assumptions for the CAD program have been stated in this report. This report and the CAD program provide the basis and necessary starting point in a building-block approach to the refinement and enhancement of this CAD program for package cushioning.
REFERENCES


"Experimental Plastics Q-103.15 and Q-103.21 (Expanded Polystyrenes)," compiled by the Dow Chemical Company, Midland, Michigan, July 1954.


Hardigg, J., "Rubberized Curled Hair," - Chapter 6, Cushioning, Industrial Packaging, April 15, 1961, pp 31-33.


Kinetic Systems, Inc., Waltham, Mass., Test Results on Air Cap SD-240 Cushioning Material, manufactured by the Sealed Air Corp. Tests performed under Contract No. F33601-71-C-0802 (no date indicated), Department of the Air Force, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

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Properties of Rigid and Semi-Rigid Urethane Foams, an article published by DuPont, Bulletin No. HR-1, July 20, 1955.

Protective Packaging with Minicel Polyethylene Foams, a product information brochure prepared by Haskon, Inc., Foam Division, Wilmington, Delaware (no date shown).


"Scotchfoam Brand Expansible Compound Type A," Technical Data Sheet, January 20, 1956, 3M Company (Minnesota Mining & Manufacturing Co.), Adhesives and Coatings Division, Detroit, Michigan.


U. S. Army Rocket and Missile Container Guide (Section entitled "Static Compressive Force-Displacement Curves"), pp 7-48 through 7-53.


APPENDIX A

TEST, SUBROUTINE LAGINT, FUNCTION FLAGR
To debug and test the LAGINT subroutine and the FLAGR function, digital data were taken from the peak acceleration versus static stress curves shown in Figure A-1.

For a urethane foam, the tabulated input data are shown in Table A-I. The actual computer printout is shown in Table A-II. The tabulated interpolated and extrapolated output data are shown in Table A-III. As would be expected, the interpolated output data are very good and the extrapolated output data are less accurate, dependent upon how the data changes beyond the tabulated input data; the basis for this statement is a comparison of Peak Acceleration (g) data. (Table AIII) the peak Acceleration from Figure A-1. It is anticipated that the LAGINT subroutine will only be used for interpolation of tabulated data; however, it was desirable to design for the possibility of extrapolation, in case it is needed later.

Copies of the program (i.e., TEST), the subroutine LAGINT, and the function, FLAGR, are shown in Tables A-IV, A-V, and A-VI.

<table>
<thead>
<tr>
<th>Static Stress W/A (psi)</th>
<th>5 in. thick</th>
<th>4 in. thick</th>
<th>3 in. thick</th>
<th>2 in. thick</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GM₅ (g)</td>
<td>GM₄ (g)</td>
<td>GM₃ (g)</td>
<td>GM₂ (g)</td>
</tr>
<tr>
<td>0.04</td>
<td>62</td>
<td>70</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>0.05</td>
<td>54</td>
<td>60</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>0.07</td>
<td>43</td>
<td>48</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>0.09</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>0.14</td>
<td>26</td>
<td>29</td>
<td>34</td>
<td>54</td>
</tr>
<tr>
<td>0.16</td>
<td>24</td>
<td>25</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>0.18</td>
<td>22</td>
<td>24</td>
<td>29</td>
<td>50</td>
</tr>
<tr>
<td>0.20</td>
<td>20</td>
<td>22</td>
<td>28</td>
<td>50</td>
</tr>
<tr>
<td>0.50</td>
<td>19</td>
<td>25</td>
<td>42</td>
<td>78</td>
</tr>
<tr>
<td>0.80</td>
<td>30</td>
<td>48</td>
<td>79</td>
<td>124</td>
</tr>
</tbody>
</table>
FIGURE A-1. $G_m$-W/A Curves for Urethane Foam (Polyester Type, Large Celled, 4.0 pcf) for a 30-inch Drop Height.
\$NXYZ$

\$NX = 1\,\text{n},$

\$NY = 4,$

\$NZ = 1,$

\$XV = 0.11E+01,$

\$YV = 0.32E+01,$

\$ZV = 0.0,$

\$END$

**FUNCTION VALUE\_1** = 3.7802E+01

\$XV = 1.1000E+01 \quad YV = 3.2000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_2** = 6.1657E+01

\$XV = 1.0000E+01 \quad YV = 2.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_3** = 4.1343E+01

\$XV = 1.0000E+01 \quad YV = 3.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_4** = 3.7224E+01

\$XV = 1.0000E+01 \quad YV = 4.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_5** = 3.2343E+01

\$XV = 1.0000E+01 \quad YV = 5.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_6** = 2.9836E+01

\$XV = 1.0000E+01 \quad YV = 5.5000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_7** = 2.8000E+01

\$XV = 2.0000E+01 \quad YV = 3.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_8** = 4.2000E+01

\$XV = 5.0000E+01 \quad YV = 3.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_9** = 1.0500E+02

\$XV = 2.0000E+02 \quad YV = 3.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_10** = 9.8000E+01

\$XV = 2.0000E+02 \quad YV = 3.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_11** = 8.8000E+01

\$XV = 2.0000E+01 \quad YV = 1.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_12** = 9.6371E+01

\$XV = 1.0000E+01 \quad YV = 1.0000E+00 \quad ZV = 0.$

**FUNCTION VALUE\_13** = 9.6371E+01

\$XV = 1.0000E+01 \quad YV = 1.0000E+00 \quad ZV = 0.$

**TABLE A-II. OUTPUT DATA**
### TABLE A-III. - URETHANE FOAM OUTPUT DATA

<table>
<thead>
<tr>
<th>Static Stress W/A (psi)</th>
<th>Thickness (in.)</th>
<th>Peak Acceleration (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>3.2</td>
<td>37.8</td>
</tr>
<tr>
<td>0.10</td>
<td>2.0</td>
<td>61.7</td>
</tr>
<tr>
<td>0.10</td>
<td>3.0</td>
<td>41.9</td>
</tr>
<tr>
<td>0.10</td>
<td>4.0</td>
<td>37.2</td>
</tr>
<tr>
<td>0.10</td>
<td>5.0</td>
<td>32.3</td>
</tr>
<tr>
<td>0.10</td>
<td>5.5</td>
<td>29.8</td>
</tr>
<tr>
<td>0.20</td>
<td>3.0</td>
<td>28.0</td>
</tr>
<tr>
<td>0.50</td>
<td>3.0</td>
<td>42.0</td>
</tr>
<tr>
<td>0.02</td>
<td>3.0</td>
<td>105.0</td>
</tr>
<tr>
<td>0.02</td>
<td>4.0</td>
<td>98.0</td>
</tr>
<tr>
<td>0.20</td>
<td>1.0</td>
<td>88.0</td>
</tr>
<tr>
<td>0.10</td>
<td>1.0</td>
<td>96.4</td>
</tr>
</tbody>
</table>

Interpolated values indicated by 

Extrapolated values indicated by 

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PROGRAM TEST(INPUT, OUTPUT, TAPE1=INPUT, TAPE2=OUTPUT)

DIMENSION X(20), Y(20), Z(20), TAB(20, 20, 20), F(20)

COMMON /N/ NZ, N, NX, YV, XV, ZV

NAMELIST /NXYZ/ NX, N, NY, NZ, XV, YV, ZV

READ(1, NXYZ)

WRITE(2, NXYZ)

READ 1000, (X(I), I=1, NX)

IF(NY GT 1) READ 1000, (Y(I), I=1, NY)

IF(NZ GT 1) READ 1000, (Z(I), I=1, NZ)

READ 1000, ((TAB(I, J, K), I=1, NX), J=1, NY), K=1, NZ)

GO TO 20

10 CONTINUE

IF (EOF, 1) 9999, 15

15 CONTINUE

READ(1, NXYZ)

20 CONTINUE

CALL LAGINT(TAB, Z, Y, X, FV, F)

PRINT 2000, FV, XV, YV, ZV

1000 FORMAT(10F8.0)

2000 FORMAT(1H 2X,*FUNCTION VALUE= *E12.4,/, 1 3X,*XV**E12.4,2X,*YV**E12.4,2X,*ZV**E12.4,)

GO TO 10

9999 CONTINUE

STOP

END

TABLE A-IV. MAIN PROGRAM, TEST
SUBROUTINE LAGINT(A, ALF, BETA, GAM, F)
C NPTSG ---- NUMBER OF ROWS IN INPUT TABLE       VERTICAL
C NPTSB ---- NUMBER OF COLUMNS IN INPUT TABLE     HORIZONTAL
C NPTSA ---- NUMBER OF X-Y PLANES IN INPUT TABLE DEPTH
C XB ------ HOI RIZONTAL ARGUMENT
C YG ------ VERTICAL ARGUMENT
C ZA ------ DEPTH
C VAL------ INTERPOLATED VALUE
C ALF(NPTSA) ---- VECTOR OF INDEPENDENT VARIABLES
C BETA(NPTSB)---- VECTOR OF INDEPENDENT VARIABLES
C GAM(NPTSG) ---- VECTOR OF INDEPENDENT VARIABLES
C A(NPTSG,NPTSB, NPTSA) ---- INPUT TABLE
C IF NPTSA NOT EQ TO 1 INPUT TABLE IS 3-D
C IF NPTSB NE 1 AND NPTSA EQ 1 TABLE IS 2-D
C IF NPTSB EQ 1 AND NPTSA EQ 1 TABLE IS 1-D
UNO011    DIMENSION A(20,20,21),B(20,20),F(1),ALF(1),
           1 BETA(1),GAM(1)
000011    COMMON /N/ NPTSA, NPTSB,NPTSG,XB,YG,ZA
C CHECK FOR THREE DIMENSIONS
000012    IF(NPTSA.EQ.1)GO TO 100
C SOLVE THREE DIMENSIONAL CASE
000013    DO 10  I=1,NPTSG
000014    DO 10  J=1,NPTSB
000015    DO 5  K=1,NPTSA
000016      F(K) = A(I,J,K)
000017      5 (I,J) = FLAGR(NPTSA,ALF,F,ZA)
000018      10 CONTINUE
000019      GO TO 120
C CHECK FOR TWO DIMENSIONS
000020    100 CONTINUE
000021    IF(NPTSB.EQ.1)GO TO 200
000022    DO 110  I=1,NPTSG
000023    DO 110  J=1,NPTSB
000024      110 B(I,J)=A(I,J,1)
C SOLVE TWO DIMENSIONAL CASE
000025    120 CONTINUE
000026    DO 150  I=1,NPTSG
000027    DO 150  J=1,NPTSB
000028      140 F(J) = B(I,J)
000029      150 CONTINUE
000030      GO TO 220
C SOLVE ONE DIMENSIONAL CASE
000031    200 CONTINUE
000032    DO 210  I=1,NPTSG
000033    DO 210  J=1,NPTSB
000034      210 B(I,1) = A(I,1,1)
000035      220 CONTINUE
000036      VAL = FLAGR(NPTSG,GAM,B,YG)
000037      RETURN
000038    END

TABLE A-V. SUBROUTINE, LAGINT
```fortran
FUNCTION FLAGR(NPTS,XL,F,XK)
DIMENSION XL(1),F(1),W(3)
C LAGRANGE INTERPOLATING FUNCTION
DO 200 I=1,NPTS
IT=I
IF(XK.LE.XL(I))GO TO 210
200 CONTINUE
210 IF(XK.EQ.XL(I))GO TO 350
IC = 3
IF(IT.LE.2)GO TO 320
IF(IT.EQ.NPTS) GO TO 2
B=0.0
IF(IC.EQ.2) GO TO 350
C PARABOLA FROM THE RIGHT
DO 300 J=1,3
IARG = IT-2+J
WEIGHT = 1.0
DO 320 J=1,3
IF(J.EQ.I)GO TO 390
JARG = IT-2-J
WEIGHT = WEIGHT*(((XL-XL(JARG))/(XL(IARG)-XL(JARG)))
300 CONTINUE
W(I) = WEIGHT
320 CONTINUE
DO 350 K=1,3
IARG = IT-3+K
WEIGHT = 1.0
DO 390 J=1,3
JARG = IT-3-J
WEIGHT = WEIGHT*(((XL-XL(JARG))/(XL(IARG)-XL(JARG)))
350 CONTINUE
W(I) = WEIGHT
390 CONTINUE
DO 410 K=1,3
IARG = IT-3+K
WEIGHT = 0.5
DO 490 J=1,3
JARG = IT-3-J
WEIGHT = WEIGHT*(((XL-XL(JARG))/(XL(IARG)-XL(JARG)))
410 CONTINUE
B = B + W(K)*F(IARG)
490 CONTINUE
IF(B.EQ.0.5)GO TO 600
500 CONTINUE
B = B/0.5
600 CONTINUE
FLAGR = B
RETURN
END
```

**Table A-VI. FUNCTION, FLAGR**

200