

AD/A-006 645

DEVELOPMENT OF OPTIMIZATION PROCEDURE  
FOR DESIGN OF PACKAGE CUSHIONING

Tom D. Dunham, et al

Southwest Research Institute

Prepared for:

Army Natick Laboratories

January 1975

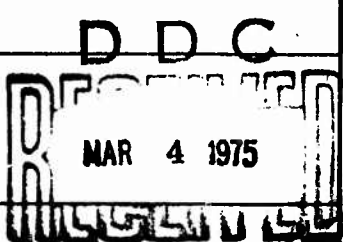
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 75-44-AMEL	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 1 A 006675
4. TITLE (and Subtitle)  Development of Optimization Procedure for Design of Package Cushioning		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report June 1973 - February 1974
		6. PERFORMING ORG. REPORT NUMBER 02-3692
7. AUTHOR(s)  Tom D. Dunham, Herbert G. Pennick, Daniel D. Kana, and Andrew (nmi) Nagy		6. CONTRACT OR GRANT NUMBER(s)  DAAG17-73-C-0239
9. PERFORMING ORGANIZATION NAME AND ADDRESS  Southwest Research Institute 8500 Culebra Road San Antonio, Texas 78284		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS  Tech. Work performed for others (Customer AMMRC)
11. CONTROLLING OFFICE NAME AND ADDRESS  Department of the Army U.S. Army Natick Laboratories Natick, Massachusetts 01760		12. REPORT DATE January 1975
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 202
		15. SECURITY CLASS. (of this report)  UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Distribution of this document is unlimited.		
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PACKAGING CUSHIONING PACKING MATERIALS CUSHIONING MATERIALS	DEVELOPMENT OPTIMIZATION DESIGN VIBRATION ISOLATION VIBRATION ISOLATORS	VIBRATION ISOLATION TECHNIQUES SHOCK ISOLATION SHOCK ABSORBERS TEMPERATURE TEMPERATURE EFFECTS
		COSTS INTERPOLATION EXTRAPOLATION
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
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)		

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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.

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## 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.

## I. 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.

## II. TECHNICAL DISCUSSION

### 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.

Theory and Practice of Cushion Design - SVM-2, by D. S. Moore<sup>(1)\*</sup> 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<sup>(2)</sup> provides information about both shock and vibration environments.

The MIL-STD-810B, Military Standard, Environmental Test Methods<sup>(3)</sup>, 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

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

TABLE I  
MATERIALS DATA CONTACTS

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

TABLE I (Contd.)  
MATERIALS DATA CONTACTS

Organization	Material Data Sought	Data Supplied
The Williamson Company	Polyvinyl Chloride	None
Union Carbide Corp.	Polyester, Polyether	None
B. F. Goodrich Chemical Co.	Polyurethane	None
Continental Felt Co.	Felt	None
Armstrong Cork Company	Cork	None
Chicago Curled Hair Co.	Curled Hair	None
Stearns and Foster Co.	Cellulose Wadding	None
Boeing Aerospace Co.	Polyurethane Foam	None (Classified)
Sheller-Globe Corp.	Polyurethane	None
GAF Corp.	Felt	Not useful
National Bureau of Standards	Anything available	None
Plastics Technical Evaluation Center, Picatinny Arsenal	Anything available	Numerous Reports
Janesville Cotton Mills	Curled Hair (Hairkore)	None
Blocksom & Co.	Rubberized Curled Hair	Very little data
Goodyear Aerospace Corp.	Fiberglass	None
Tenneco Chemicals, Inc. (Houston)	Polyurethane	None

to determine the best way to tabulate the voluminous shock data. An interpolation procedure was developed based upon "Digital Computer Program EMI 494 Aerodynamic Interpolation"<sup>(4)</sup>.

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<sup>(5)</sup>.

The report "Vibration Testing of Resilient Package Cushioning Materials"<sup>(6)</sup> 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/ft<sup>3</sup>)
- . Static Stress (lb/in.<sup>2</sup>)
- . 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"<sup>(7)</sup>. 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,  $E_T$ , 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"<sup>(8)</sup>. 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 physical 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.<sup>2</sup>)
- . Material thickness (in.)
- . Environmental Temperature (°F)
- . Material Density (lb/ft<sup>3</sup>)

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/ft<sup>3</sup>)
- . Static Stress (lb/in.<sup>2</sup>)
- . 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

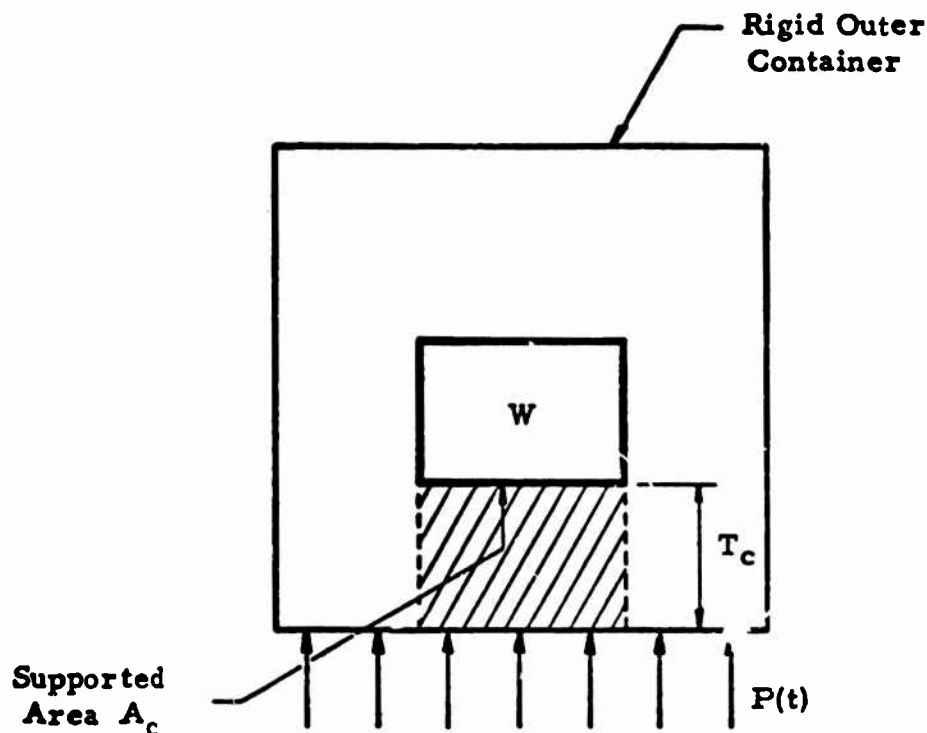


FIGURE 1. CONCEPT OF CUSHIONING PROBLEM

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<sup>(1)</sup> 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

$$E^* = E_r + i E_l = E_r (1 + i \tan \delta) \quad (1)$$

where  $E_r$  is the storage modulus,  $E_l$  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

$$\omega_n^2 = A_c E_{rn} g / T_c W \quad (2)$$

where  $A_c$  is the supported area,  $T_c$  is the cushioning material thickness,  $W$  is the weight,  $E_{rn}$  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

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

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

$$S_y(\omega) = |H(\omega)|^2 S_x(\omega) \quad (4)$$

Equation (4) is directly from Equation (3.137), page 99, Bendat and Piersol<sup>(10)</sup>. 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 (3.127)<sup>(10)</sup>] is obtained from the transformation of [i. e., Equation (3.134)<sup>(10)</sup>];

$$R_y(\tau) = \int_0^{\infty} \int_0^{\infty} h(\xi) h(\eta) R_x(\tau + \xi - \eta) d\xi d\eta \quad (5)$$

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  $E_r$  and  $E_{rn}$ , 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

$$\omega_j = \omega_{ni} \quad (6)$$

and

$$x_{oi} = |T_{oij}| x_j \quad (7)$$

also

$$T_{ci} = \frac{A_c E_{rni} g}{\omega_j^2 W} \quad (8)$$

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,  $\omega_j$ , are stored in a DATA statement in the subroutine VIBRTN as 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)

$$x_{oi} = \sum_j |T_{oij}| x_j \quad (9)$$

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  $S(\omega_j)$  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

$$\sigma_i^2 = \sum_j S(\omega_j) |T_{oij}(\omega_j)|^2 \quad (10)$$

and the RMS response is

$$\sigma_i = \sqrt{\sigma_i^2} \quad (11)$$

Assume for a Gaussian process that

$$x_{oi} = 2.5 \sigma_i \quad (13)$$

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.

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\* Discussed in Subsection F, Computer Software.

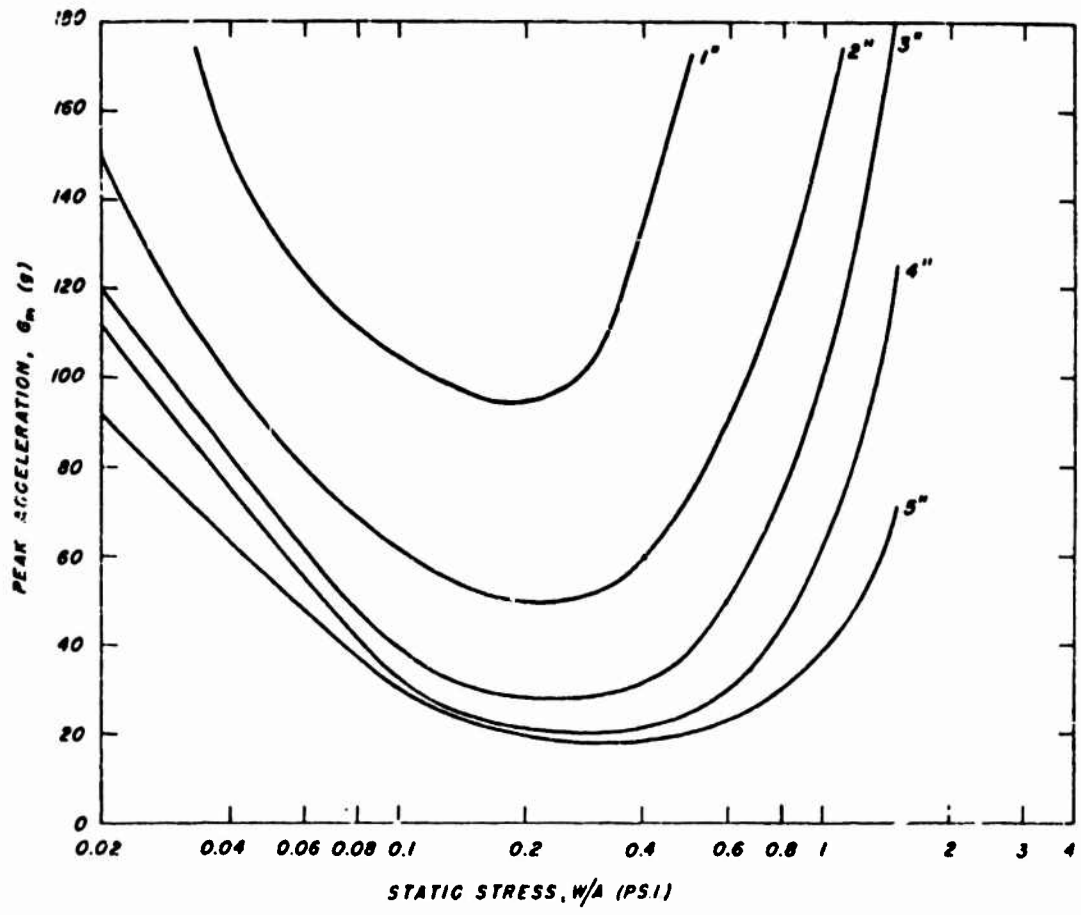


FIGURE 2. A TYPICAL SET OF PEAK ACCELERATION-  
 STATIC STRESS ( $G_m$ - $W/A$ ) CURVES FOR  
 FIXED DROP HEIGHT  $h$ .

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

$$\sigma_s = W/A \quad (13)$$

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

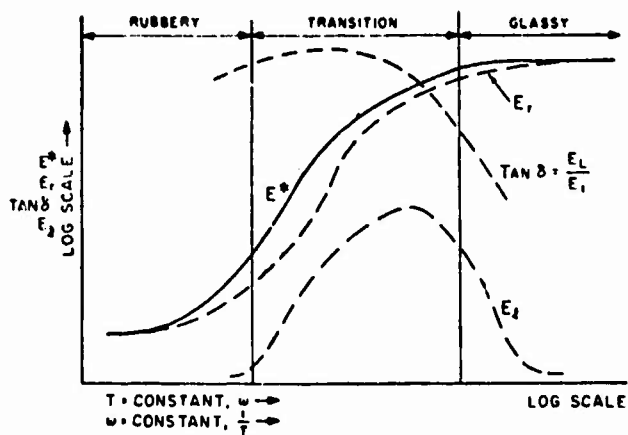


FIGURE 3a. FREQUENCY AND TEMPERATURE EFFECTS ON COMPLEX MODULI

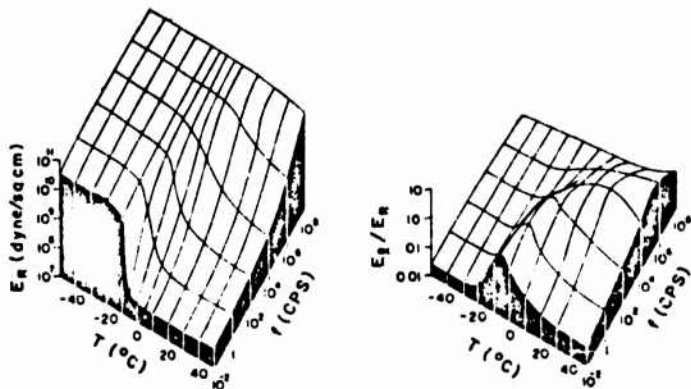


FIGURE 3b. APPROXIMATE BEHAVIOR OF  $E_T$  AND LOSS TANGENT OVER A WIDE RANGE OF FREQUENCY AND TEMPERATURE; SKETCHES ARE BASED ON EXPERIMENTAL DATA FOR A CARBON-FILLED BUNA-N. [Mustin, G. S.]<sup>(1)</sup>

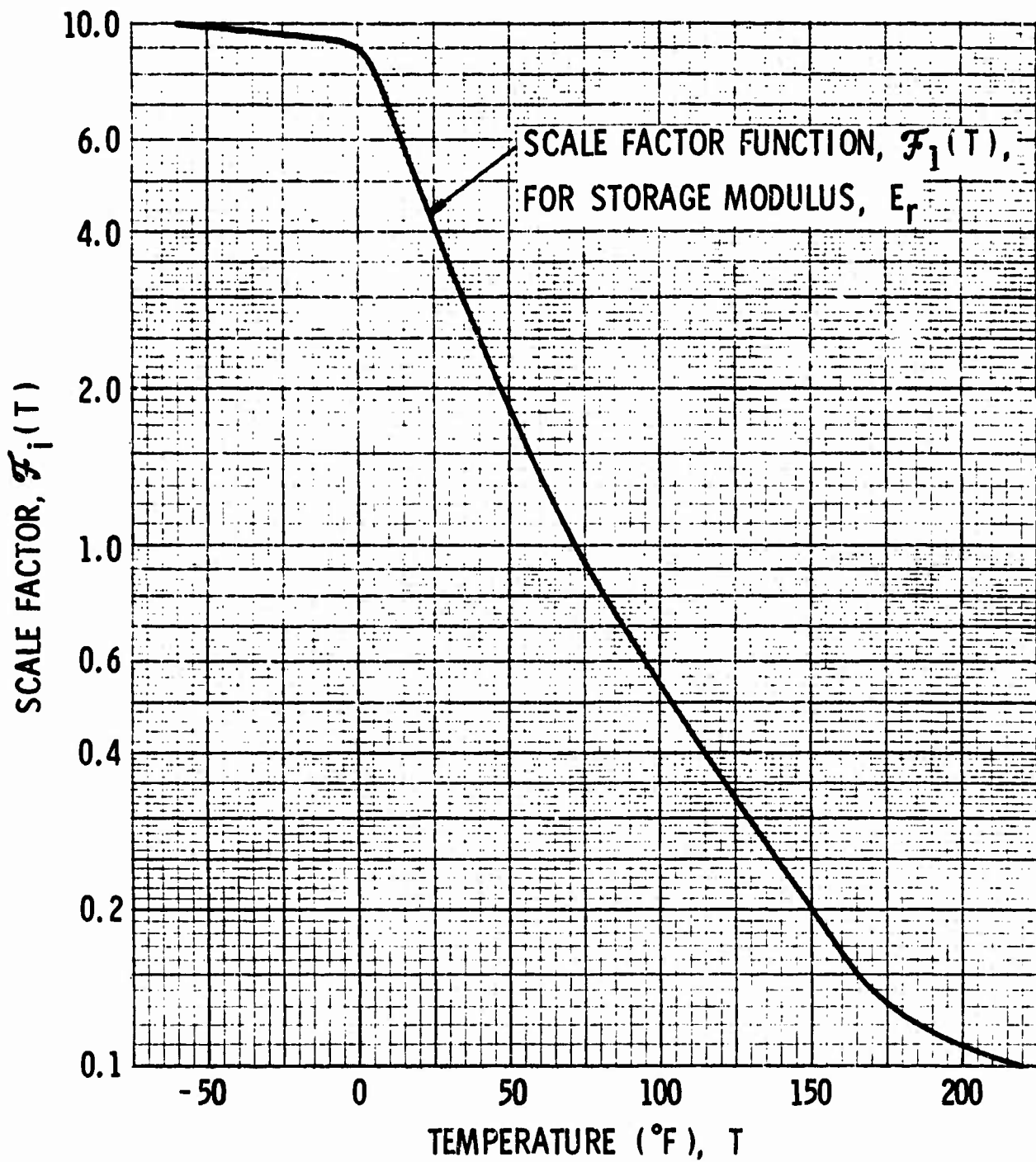


FIGURE 4. STORAGE MODULUS SCALE FACTOR AS A FUNCTION OF TEMPERATURE

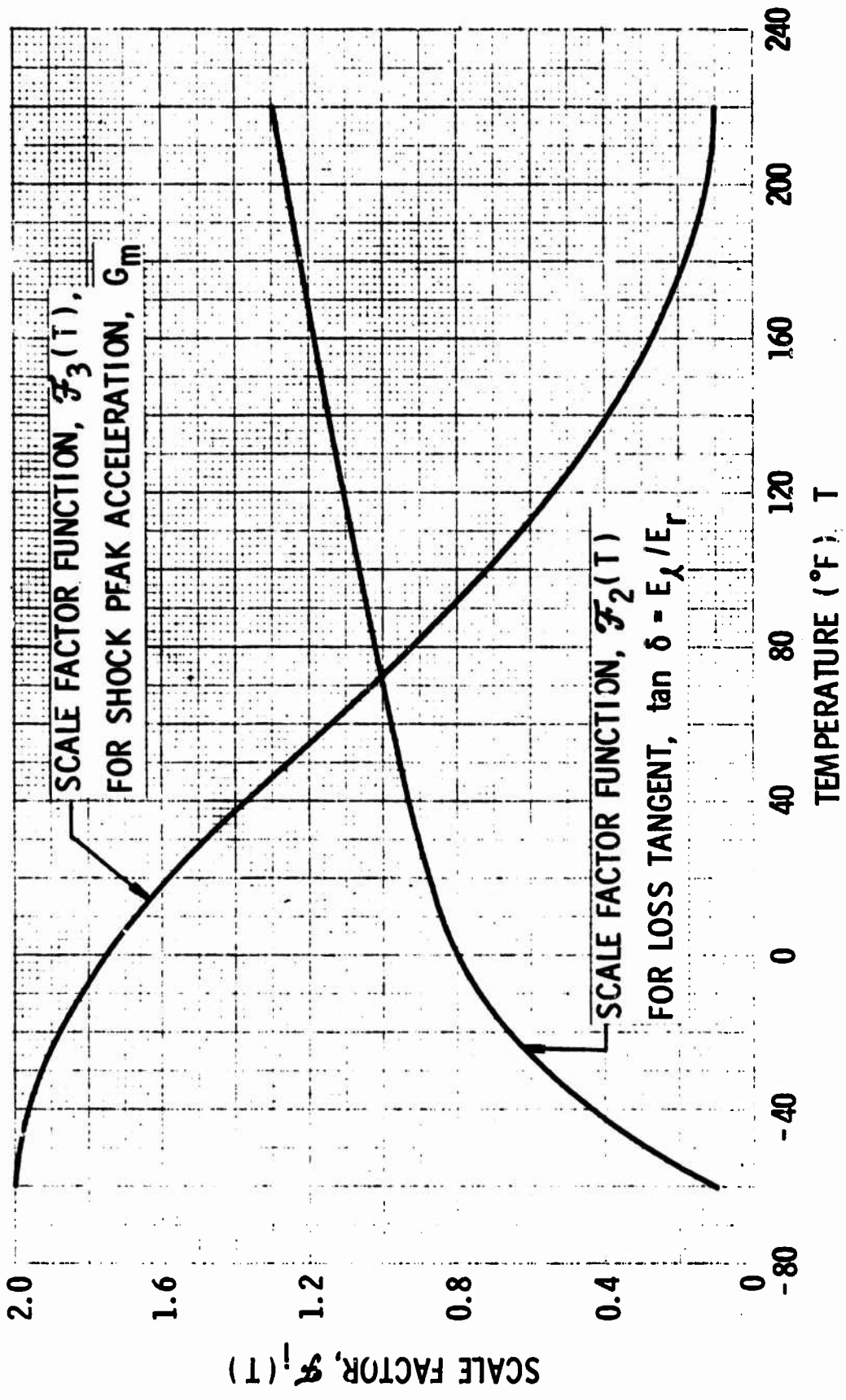


FIGURE 5. LOSS TANGENT AND SHOCK PEAK ACCELERATION SCALE FACTORS AS FUNCTIONS OF TEMPERATURE

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:

<u>Fragility Rating, g</u>	<u>Probable Percent Damaged, %</u>	<u>Repair Cost per Damaged Item, \$</u>
55	0	0.00
60	5	5.00
65	20	25.00
70	80	475.00

#### 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<sup>(2)</sup>. 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

$$p(g_x) = \frac{\sigma_g}{2\pi} e^{-[(g_x' - \mu_g)^2 / 2\sigma_g^2]} \quad (16)$$

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

$$g_{\max} = 3\sigma_g \quad (17)$$

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.

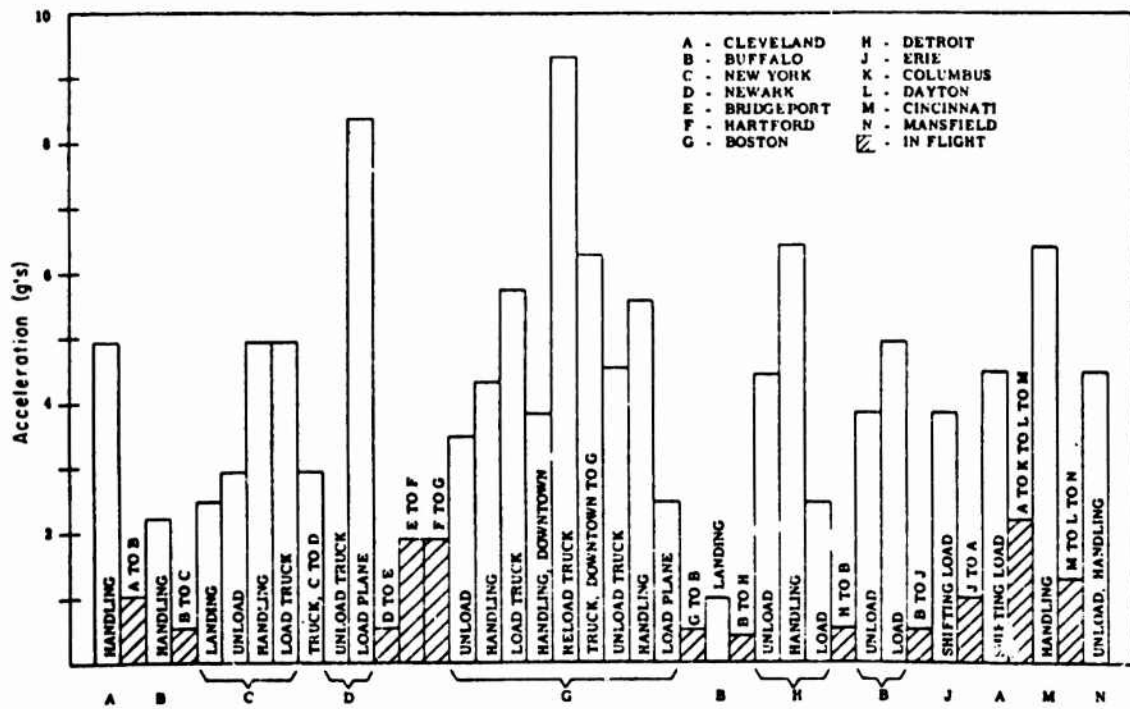


FIGURE 6a. MAXIMUM SHOCKS RECORDED DURING AIRLINE TEST SHIPMENT

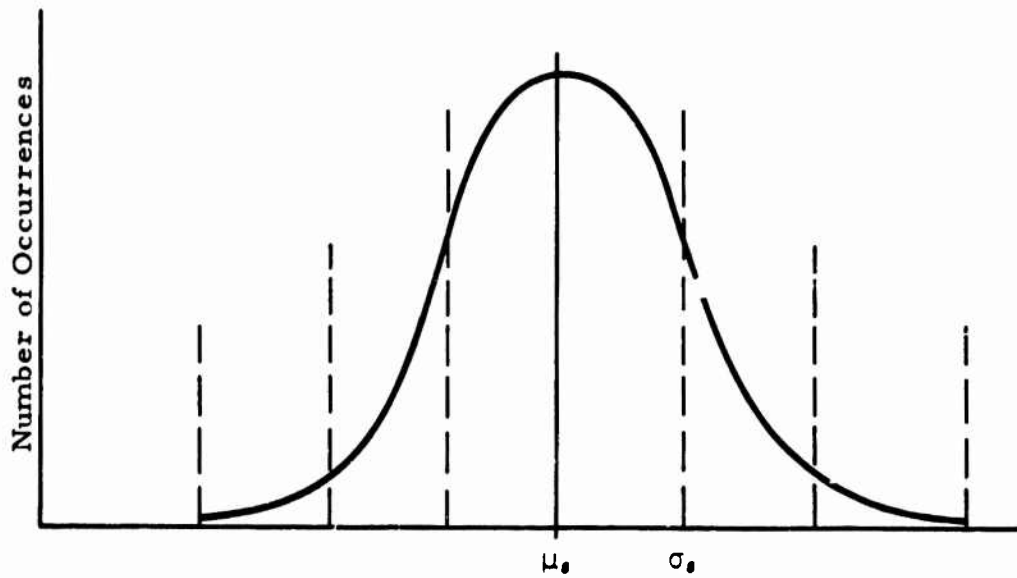


FIGURE 6b. SHOCK AMPLITUDE (gx)

TABLE II  
 TRANSIT DROP TEST HEIGHTS FROM  
 MIL-STD-810E, METHOD 516.1

Weight of test item and case	Largest dimensions (inches)	Notes	Height of drop (inches)
Under 100 pounds man-packed and man-portable	Under 36	A	48*
	36 and over	A	30
100 to 200 pounds, inclusive	Under 36	A	30
	36 and over	A	24
Over 200 to 1,000 Pounds, inclusive	Under 36	A	24
	36 to 60	B	36
	Over 60	B	24
Over 1,000 pounds	No limit	C	18
* 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<sup>(2)</sup> as shown by the example for truck transportation in Figure 7, or by a power spectrum<sup>(3)</sup> 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,

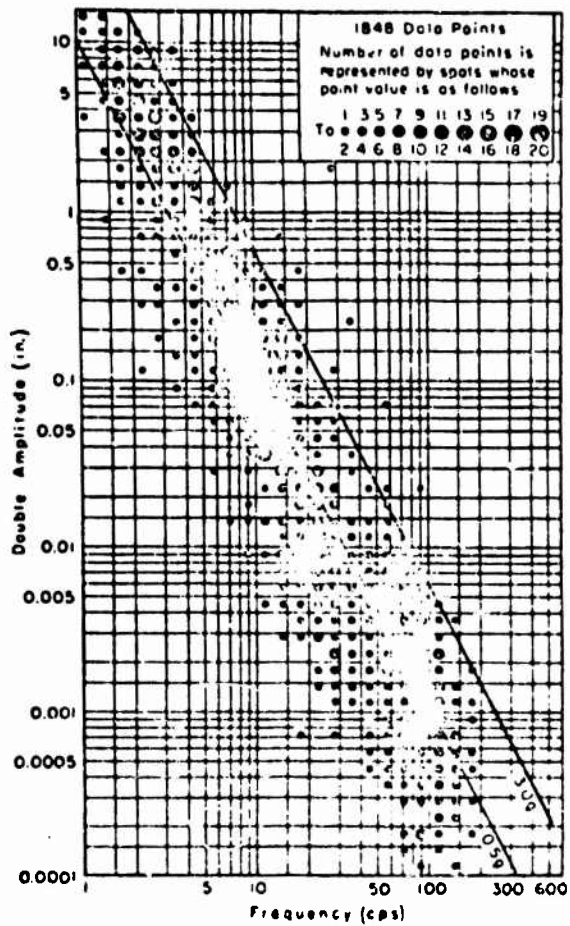
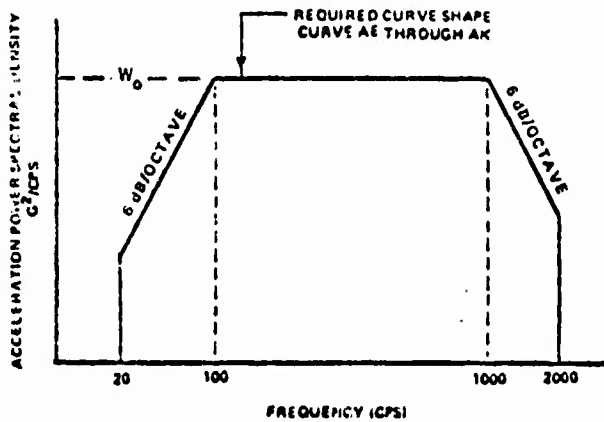


Figure 7. Truck Transportation Vibration Data (Ref. 2)

RANDOM VIBRATION CURVES

RANDOM VIBRATION ENVELOPE



RANDOM VIBRATION TEST LEVELS

TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY $W_0$ (G²/CPS)	COMPOSITE G-RMS MINIMUM
AE	0.02	5.4
AF	0.04	7.6
AG	0.06	9.3
AH	0.10	12.0
AJ	0.20	16.9
AK	0.30	20.7

NOTE COMPOSITE G-rms =  $\left[ \int_{f_1}^{f_2} W(f) df \right]^{1/2}$

WHERE  $f_1$  AND  $f_2$  ARE THE LOWER AND UPPER TEST FREQUENCY LIMITS, RESPECTIVELY.  $W(f)$  IS THE ACCELERATION POWER SPECTRAL DENSITY IN G²/CPS UNITS.

FIGURE 8. Vibration test curves for equipment installed in air launched missiles - equipment category (d)

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, 125.66, 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:

$3.66(10)^{-4}$ ,  $5.17(10)^{-4}$ ,  $1.91(10)^{-4}$ ,  $1.19(10)^{-4}$ ,  
 $1.13(10)^{-4}$ ,  $5.09(10)^{-7}$ ,  $5.83(10)^{-6}$ ,  $5.09(10)^{-7}$ ,  
 $5.09(10)^{-7}$ ,  $5.09(10)^{-7}$ ,  $5.09(10)^{-7}$ .

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:

$C_m \sim$  cost per unit volume of cushioning material,

$C_c \sim$  cost of the exterior container,

- $C_f$  ~ cost of fabrication of the cushioning material to the specified dimensions,  
 $C_p$  ~ cost of packaging of the item for shipment,  
 $C_s$  ~ cost of shipment,  
 $C_I$  ~ 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<sup>3</sup> and the container material cost is 0.00232 \$/in.<sup>3</sup>.

**CAUTION**  
\*\*\*\*\*

The cost of container, \$/in.<sup>3</sup>, 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

$$CF = n \left[ V_m C_m + C_c(W, V_c) + C_f(m, V_c) + C_p(W, V_c) + f_n C_I \right] + C_s(n, s, W, V_c) \quad (18)$$

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

$$V_m C_m = \sum_{i=1}^3 V_{m_i} C_{m_i} \quad (19)$$

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

$$C_s(n, s, W, V_c) = \sum_{S=1}^4 C_s(n, s, W, V_c). \quad (20)$$

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<sup>(4)</sup>. 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:

$$\Gamma(k) = \sum_{i=1}^M \gamma(k_i) \frac{(k-k_1) \cdots (k-k_{i-1})(k-k_{i+1}) \cdots (k-k_M)}{(k_i-k_1) \cdots (k_i-k_{i-1})(k_i-k_{i+1}) \cdots (k_i-k_M)} \quad (21)$$

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.

$\gamma_{i-1}$	$\gamma_i$	$\Gamma$	$\gamma_{i+1}$	$\gamma_{i+2}$
0	0	X	0	0
$k_{i-1}$	$k_i$	$k$	$k_{i+1}$	$k_{i+2}$

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

$$\begin{aligned} \Gamma(k)_L = & \gamma(k_{i-1}) \frac{(k-k_i)(k-k_{i+1})}{(k_{i-1}-k_i)(k_{i-1}-k_{i+1})} \\ & + \gamma(k_i) \frac{(k-k_{i-1})(k-k_{i+1})}{(k_i-k_{i-1})(k_i-k_{i+1})} \\ & + \gamma(k_{i+1}) \frac{(k-k_{i-1})(k-k_i)}{(k_{i+1}-k_{i-1})(k_{i+1}-k_i)} \end{aligned} \quad (22)$$

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

$$\begin{aligned} \Gamma(k)_R = & \gamma(k_i) \frac{(k-k_{i+1})(k-k_{i+2})}{(k_i-k_{i+1})(k_i-k_{i+2})} + \gamma(k_{i+1}) \frac{(k-k_i)(k-k_{i+2})}{(k_{i+1}-k_i)(k_{i+1}-k_{i+2})} \\ & + \gamma(k_{i+2}) \frac{(k-k_i)(k-k_{i+1})}{(k_{i+2}-k_i)(k_{i+2}-k_{i+1})} \end{aligned} \quad (23)$$

Thus, if the desired point lies between two adjacent points, we average the parabolas as

$$\Gamma(k) = \frac{1}{2} [\Gamma(k)_L + \Gamma(k)_R] . \quad (24)$$

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 OPACK

A	- - - - -	Support area of item (sq in.).
A (NPTSG, NPTSB, NPTSA)	-	Input table.
AL(I)	- - - - -	Array of longest dimensions for each face of package. (CDPRO subroutine).
AL(I)	- - - - -	Area of the perpendicular face of the package. (COSTMT subroutine).
ALF (NPTSA)	- - - - -	Vector of independent variables.
ALI(I)	- - - - -	Actual dimensions of package.
ALL	- - - - -	Item length + container and cushion thickness.
AT	- - - - -	Environmental temperature.
BETA (NPTSB)	- - - - -	Vector of independent variables.
C1	- - - - -	Cost of material on face one.
C2	- - - - -	Cost of material on face two.
C3	- - - - -	Cost of material on face three.
C12	- - - - -	Contains the minimum cost between the materials on face one and face two.
C13	- - - - -	Contains the minimum cost between the materials on face one and face three.
C23	- - - - -	Contains the minimum cost between the materials on face two and face three.
C123	- - - - -	Contains the lowest cost of the three materials.
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.

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

CAXIS (I, 1)	- - - - -	Cost of the packaging material for face one.
CAXIS (I, 2)	- - - - -	Cost of the packaging material for face two.
CAXIS (I, 3)	- - - - -	Cost of the packaging material for face three.
CAXIS (I, J)	- - - - -	Cost of packaging material for all three faces.
CD (I, J)	- - - - -	Container cost and property matrix. Contains specific weight of container and cost of container.
CF (I)	- - - - -	Array containing cost of fabrication to specific dimensions.
CFE	- - - - -	Cost of fabrication.
CI	- - - - -	Cost of item.
CM (I)	- - - - -	Array containing material cost.
COST	- - - - -	Total cost.
CP (I)	- - - - -	Array containing the cost of packaging.
CPP	- - - - -	Cost of packaging.
CS	- - - - -	Cost of shipment.
CSS	- - - - -	Cost of shipping the package.
CVC	- - - - -	Cost of material for corner.
DH	- - - - -	Calculated drop height.
DHH (I)	- - - - -	Drop height.
DHL (I)	- - - - -	Drop height longest length.

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

DHW (I)	- - - - -	Drop height upper weight limit.
DII	- - - - -	Array of drop heights.
DLH	- - - - -	Dummy parameter.
DL (I)	- - - - -	Change in package dimensions along each face.
DRPH	- - - - -	Actual drop height - stored on file.
DWB	- - - - -	Weight added by the addition of a bearing board.
ERI	- - - - -	Modulus at center frequency.
ERJ	- - - - -	Modulus at environmental frequency.
F (I)	- - - - -	Table of dependent variables.
F2 (I)	- - - - -	1-D array of interpolated accelerations.
FE (I)	- - - - -	Work - vector.
G	- - - - -	Interpolated acceleration.
GAM (NPTS)	- - - - -	Vector of independent variables.
GM	- - - - -	Maximum G-allowable (ft/sec/sec) (CDPRO subroutine)
GM	- - - - -	Fragility limit (acceleration). (SHOCKE subroutine)
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.

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

I3	- - - - -	Array subscript for material used on face three.
IC	- - - - -	Procedure code.
IC = 1	- - - - -	MIL-STD-810B excitation.
IC = 2	- - - - -	Multiple sine excitation.
IC = 3	- - - - -	Random excitation.
IGO	- - - - -	Code to determine type of interpolation.
II (I)	- - - - -	Contains array positions of optimum thickness for each of the three faces.
IITM	- - - - -	Item number.
IJE	- - - - -	Deletion code.
ITEM	- - - - -	Item number.
ITEMP	- - - - -	Number of temperatures considered.
MATOP (I, K)	- - - - -	Optimum material for each face. MATOP (I, K) = F (G-level, axis).
MATSC (I)	- - - - -	Material code.
MC (I)	- - - - -	Contains material code for each of the three faces.
MIC	- - - - -	Maximum iterations for drop height weight convergence.
MITEM	- - - - -	Item number.
MOMJ	- - - - -	Number of input environment frequencies.
MOMS	- - - - -	Number of frequencies stored on the vibration file. (CDPRO subroutine)

TABLE III ( Contd. )  
GLOSEARY OF VARIABLES FOR OPACK

MOMS	- - - - -	Number of frequencies stored on data files (VIBRTN Subroutine).
MTC	- - - - -	Material code.
MTS	- - - - -	Number of temperatures stored on the vibration file. (CDPRO subroutine)
MTS	- - - - -	Number of temperatures stored on data file. (VIBRTN subroutine)
MXI (I, J, K)	- - - - -	Array containing the number of thicknesses included in the dynamic thickness array.
MXIT (I, J, K)	- - - - -	Number of thicknesses stored for each axis and temperature.
NMATS	- - - - -	Number of materials to be considered.
NPCNT	- - - - -	Number of different percent damage allowed.
NPTS	- - - - -	Number of points in table.
NPTSA	- - - - -	Number of X-Y planes in input table.
NPTSB	- - - - -	Number of columns in input table.
NS	- - - - -	Number of static stresses. (CDPRO subroutine)
NS	- - - - -	Number of static stresses stored on file (SHOCKE subroutine)
NT	- - - - -	Number of temperatures. (CDPRO subroutine)
NT	- - - - -	Number of temperatures stored on file. (SHOCKE subroutine)
NTH	- - - - -	Number of thicknesses.

TABLE III (Contd.)

GLOSSARY OF VARIABLES FOR OPPACK

OB (I) - - - - -	Array of 1-Octave band center frequencies, Hz.
OCOST (I, K) - - - - -	Matrix of optimum cost for each allowed G-level. OCOST (I, K) = F (G-level, axis).
OM - - - - -	Environmental frequency.
OMJ (I) - - - - -	Environmental Frequencies (rad/sec)
OMS (I) - - - - -	Array of frequencies stored in ascending order. (CDPRO subroutine)
OMS (I) - - - - -	Frequency scale. (VIBRTN subroutine)
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.
RHOC - - - - -	Specific weight of container material under consideration.
RHOM - - - - -	Specific weight of material under consideration.
S (I) - - - - -	PSD (Power Spectral Density) input for random excitation. (DAMALW subroutine)
S (I) - - - - -	Array of 1-octave band power spectral densities. (VIBRTN subroutine)
SI - - - - -	Static stress (W/A). (CDPRO subroutine)

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

SI	- - - - -	Interpolating stress. (SHOCKE subroutine)
SIG (I)	- - - - -	Array of static stresses in ascending order. (CDPRO subroutine)
SIG (I)	- - - - -	1-D table of static stresses (W/A). (SHOCKE subroutine)
SIT (I)	. - - - -	Work array used for sorting.
SJ	- - - - -	Sum of output excitations for one center frequency.
SLT (I)	- - - - -	Safe low temperature.
T (I)	- - - - -	Array of temperatures in ascending order. (CDPRO subroutine)
T (I)	- - - - -	1-D table of temperatures. (SHOCKE subroutine)
T1	- - - - -	Material thickness for face one.
T2	- - - - -	Material thickness for face two.
T3	- - - - -	Material thickness for face three.
TAB1 (I, J, K)	- - - - -	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)
TAB1 (I, J, K)	- - - - -	3-D table of peak accelerations G = F (TH, SIG, T). (SHOCKE subroutine)
TAB1 (I, J, K)	- - - - -	Table containing behavior of storage modulus (ER) ER = F (frequency, temperature). (VIBRTN subroutine)

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

TAB2 (I, J, K)	- - - - -	Array which contains loss tangent = F (frequency, temperature). CDPRO subroutine)
TAB2 (I, J, K)	- - - - -	Table containing behavior of loss tangent EL/ER = F (Frequency, Temperature). (VIBRTN subroutine)
TCC	- - - - -	Total cost of container by volume.
TCC (I)	- - - - -	Calculated thicknesses.
TCMV	- - - - -	Total cost of material by volume.
TCON	- - - - -	Thickness of container (in.).
TF (I)	- - - - -	1-D array of guess thicknesses.
TF (WI, WJ, ERI, ERJ, DJ)	- -	Statement function to calculate transfer function.
THCK (A, ERI, WI, W)	- - -	Statement function to calculate thickness.
TH (I)	- - - - -	Array of thicknesses in ascending order. (CDPRO subroutine)
TH (I)	- - - - -	1-D table of thickness values. (SHOCKE subroutine)
THI	- - - - -	A trial thickness. (CDPRO subroutine)
THI	- - - - -	Guess thickness. (SHOCKE subroutine)
THIK (I, J)	- - - - -	Matrix of thicknesses generated during shock calculations.
THIKV (I, J)	- - - - -	Matrix of thicknesses generated during vibration calculations.
TI	- - - - -	An environmental temperature. (CDPRO subroutine)
TI	- - - - -	Interpolating temperature. (SHOCKE subroutine)

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

TIII	- - - - -	Environmental temperature.
TMX	- - - - -	Maximum allowed shock thickness.
TOP	- - - - -	Optimum thickness.
TOPP(I)	- - - - -	Array of acceptable thicknesses.
TS(I)	- - - - -	Array of temperatures stored in ascending order. (CDPRO subroutine)
TS(I)	- - - - -	Temperature scale. (VIBRTN subroutine).
TSK	- - - - -	Thickness predicted by shock environment.
TT(I)	- - - - -	A thickness work array.
TTHIK(I, J, K)	- - - - -	Dynamic array which contains the union of the thicknesses of all three temperature environments.
TTHIK(I, J, L)	- - - - -	Dynamic thickness array contains all acceptable vibration thicknesses for each material, axis, and temperature.
V1	- - - - -	Volume of packaging material needed for face one.
V2	- - - - -	Volume of packaging material needed for face two.
V3	- - - - -	Volume of packaging material needed for face three.
VAL	- - - - -	Interpolated value.
W	- - - - -	Weight of item.
WI	- - - - -	Weight of item (lb) (CDPRO subroutine)
WI	- - - - -	1-octave band center frequency. (VIBRTN subroutine)
WII	- - - - -	Weight of item.

TABLE III (Contd.)  
GLOSSARY OF VARIABLES FOR OPPACK

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

## 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-TAPE4,TAPE10)
C OPTIMIZATION PACKAGE MAIN PROGRAM
C ROUTINE READS CARD INPUT DATA
000003 COMMON /COSTM/ CA(10,7),CD(10,2),CS,CI,WII
000003 COMMON /VPASS/ NIC,IC,IITM,MIC,MXI,MOMJ,TCON,TEML,TEMH
000003 DIMENSION OMJ(11),S(11),XDJ(11)
000003 READ 1000,NIC,IC,IITM,MIC,MXI,MOMJ,CS,CI,TCON,TEML,TEMH
000035 READ 1020,(OMJ(I),I=1,MOMJ)
000050 READ 1020,(S(I),I=1,MOMJ)
000063 READ 1020,(XDJ(I),I=1,MOMJ)
000076 PRINT 1070
000102 PRINT 1030, NIC,IC,IITM,MIC,MXI,MOMJ,CS,CI,TCON,TEML,TEMH
000124 PRINT 1040, (OMJ(I), I=1, MOMJ )
000147 PRINT 1050, (S(I), I=1, MOMJ )
000162 PRINT 1060, (XDJ(I), I=1, MOMJ )
000175 CALL TEMPEV(OMJ,S,XDJ)
000200 1000 FORMAT(6I2,5E10.0)
000200 1010 FORMAT(40I2)
000200 1020 FORMAT(11E7.0)
000200 1030 FORMAT ( 1H0, I8 , 52H = NIC --- CODE NO. OF CONTAINER MATERIAL T
10 BE USED /1X,I8,25H = IC---OPTIMIZATION CODE /
1/I8 , 23H = IITM --- ITEM NUMBER
2/I8 , 56H = MIC --- MAXIMUM NO. OF ITERATIONS FOR DROP HT. CALC.
3/I8 , 55H = MXI --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE
4/I8 , 47H = MOMJ --- NUMBER OF ENVIRONMENTAL FREQUENCIES
5/E11.4, 33H ($/LB) = CS --- COST OF SHIPMENT
6/F8.2 , 29H ( $ ) = CI --- COST OF ITEM
7/F8.6, 42H (IN.) = TCON --- THICKNESS OF CONTAINER
9/F8.2, 50H ( F ) = TEML --- LOWEST ENVIRONMENT TEMPERATURE
1/F8.2, 51H ( F ) = TEMH --- HIGHEST ENVIRONMENT TEMPERATURE )
000200 1040 FORMAT ( 1H0,50H (RAD/SEC) = OMJ(I) ALL OF THE ENVIRONMENTAL FREQ.
1/ 11E11.5 )
000200 1050 FORMAT ( 1H0,34H PSD INPUT FOR RANDOM EXCITATION
1/ 11E11.5 )
000200 1060 FORMAT ( 1H0,92H (G'S) = XDJ(I) - ENVIRONMENTAL EXCITATIONS EACH
1 CORRESPONDING TO ONE OF THE ABOVE OMJ(I)'S/ 11E11.5)
000200 1070 FORMAT ( 1H1, // 30X, 65H*** OPTIMIZATION PROCEDURE FOR DESIGN OF
1PACKAGE CUSHIONING *** // )
000200 STOP
000202 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	-	000137C01	CS	-	000132C01
I	-	000471	IC	-	000001C02	IITM	-	000002C02	MIC	-	000003C02
MOMJ	-	000005C02	MXI	-	000004C02	NIC	-	000000C02	OMJ	-	000430
S	-	000443	TCON	-	000006C02	TEMM	-	000010C02	TEML	-	000007C02
XDJ	-	000456									

START OF CONSTANTS

000204

START OF TEMPORARIES

000420

START OF INDIRECTS

000430

UNUSED COMPILER SPACE

042400

### TEMPEV - Subroutine

Usage:

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

Subroutines called:

DAMALW

```

000006 SUBROUTINE TEMPEV(OMJ,S,XDJ)
000006 COMMON /VPASS/ NIC,IC,IITM,MIC,MXI,MOMJ,TCON,TEML,TEMH
000006 COMMON /COSTM/ CA(10,7),CD(10,2),CS,CI,WII
000006 COMMON /TEMPT/ TTHIK(10,3,11),IM,IAXS,ITEMP,IJE,TMX
000006 DIMENSION TI(3)
000006 DIMENSION OMJ(11),S(10),XDJ(11)
000006 TMX=12.
000007 ITEMP=3
000010 TI(1)= TEML
000012 TI(2)= 0.5*(TEMH+TEML)
000015 TI(3)= TEMH
000016 IF((TEMH-TEML).LT.20.)ITEMP=1
000022 CALL DAMALW(NIC,IC, IITM,TCON,TI,MIC,MXI,OMJ,MOMJ,S,XDJ)
000035 RETURN
000036 END

```

TEMPEV

SUBPROGRAM LENGTH  
000055

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS

VPASS - 000011    COSTM - 000135    TEMPT - 000517

VARIABLE ASSIGNMENTS

CD	-	000000C02	CD	-	000106C02	IC	-	000001C01	IITM	-	000002C01
ITEMP	-	000514C03	MIC	-	000003C01	MUJ	-	000005C01	MXI	-	000004C01
NIC	-	000000C01	TCON	-	000006C01	TEMH	-	000010C01	TEML	-	000007C01
	-	000052	TMX	-	000516C03	TTHIK	-	000000C03			

START OF CONSTANTS  
000040

START OF TEMPORARIES  
000044

START OF INDIRECTS  
000042

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.
- NP CNT - - - 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.

Glossary of Variables for DAMALW (Contd.)

- 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,      TIM,TCON,TI,MIC,MXI,OMJ,MOMJ,S,
1  XDJ)
C
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   CO(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 SUBSCRIP 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 (RAO/SEC)
C   OTHK(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 REAOS FRAGILITY DATA FOR DAMAGE ALLOWABLE
C   SUBROUTINE REAOS MATERIAL COST AND PROPERTY FILE
C   THEN 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
000016 DIMENSION TI(3)
000016 DIMENSION OPSS(10),OCOST(10,2),OTHK(10,3),MATOP(10,3)
000016 DIMENSION GMF(10),PCTD(10),REPCI(10),MATSC(10),OMJ(10),S(10),
1  XDJ(10)
000016 COMMON /OPT/ I1,I2,I3,T1,T2,T3
000016 COMMON /COSTM/ CA(10,7),CO(10,2),CS,CI,WII
C   READ COST FILE
000016 READ 500,NC,MITEM,MNMATS
000027 PRINT 4010, NC, MITEM, MNMATS
000041 READ 10, ((CA(I,J),J=1,7), I=1 ,MNMATS)
000060 READ 10, ((CO(I,J),J=1,2), I=1,NC)
000077 PRINT 4020, ((CA(I,J),J=1,7),I=1, MNMATS )
000116 PRINT 4030, ((CO(I,J),J=1,2), I=1, NC )
000135 RHOC=CO(NIC,1)
C   READ FRAGILITY DATA FOR DAMAGE ALLOWABLE
000143 20 CONTINUE
000143 READ 5, ITEM,WI,XL,YL,ZL,NPCNT
000163 PRINT 4040, ITEM, WI, XL, YL, ZL, NPCNT
C   USING THE RANGE OF OPTIMUM STRESSES DETERMINE THE MATERIALS TO BE
C   CONSIDERED
000203 X=XL
000205 Y=YL
000206 Z=ZL
000210 W=WII

```

```

C      CHANGE PCF TO PCI
C      CHANGE COST/CF TO COST/CI
000211 DO 25 I=1,MNMATS
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,MNMATS
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 MATSC(NMATS)=I
000301 28 CONTINUE
000304 IF(NMATS.EQ.0)PRINT 4000
000314 IF(NMATS.EQ.0)STOP
000317 PRINT 4060,(MATSC(I),I=1,NMATS)
000332 WII=WI
000334 IF(ITEM.NE.IITM)PRINT 3000
000350 READ 7, (GMF(I),PCTD(I),REPCI(I),I=1,NPCNT)
000367 PRINT 4050, (GMF(I), PCTD(I), REPCI(I),I=1, NPCNT)
000406 DO 40 IT=1,NPCNT
000413 GM=GMF(IT)
000415 CALL CDPRO(XL,YL,ZL,TCON,TI,WI,NMATS,RHOC,MIC,MXI,
1 COST,MATSC,GM,OMJ,MOMJ,S,XDJ,IC,NIC)
000442 IF(TI(1).EQ.1500.)GO TO 45
000450 OTHK(IT,1)=T1
000452 OTHK(IT,2)=T2
000453 OTHK(IT,3)=T3
000455 MATOP(IT,1)=MATSC(I1)
000457 MATOP(IT,2)=MATSC(I2)
000462 MATOP(IT,3)=MATSC(I3)
000464 OPSS(IT)=1./(1.0-0.01*PCTD(IT))
C      COST OF OVERSHIPPING
000471 OCOST(IT,1)=COST*OPSS(IT)
C      COST OF ALLOWING DAMAGE
000474 OCOST(IT,2)=COST+REPCI(IT)
000476 PRINT 1000, PCTD(IT),GM,COST,OPSS(IT),OCOST(IT,1),OCOST(IT,2)
000515 40 CONTINUE
000523 45 CONTINUE
000523 IF(TI(1).EQ.1500.)NPCNT=IT-1
000527 IF(NPCNT.EQ.0)PRINT 4070
000540 IF(NPCNT.EQ.0)RETURN
000542 II=1
000543 OSB=OCOST(1,1)
000545 DO 50 I=1,NPCNT
000546 IF(OSB.LE.OCOST(I,1)) GO TO 50
000551 OSB=OCOST(I,1)
000553 II=I
000554 50 CONTINUE
000557 PRINT 11000
000562 PRINT 1500, OSB,GMF(IT),PCTD(II),OPSS(II)

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000576      PRINT 2000,OTHK(II,1),MATOP(II,1),OTHK(II,2),MATOP(II,2),
1          OTHK(II,3),MATOP(II,3)
000616      II=1
000617      OVERS=OSB
000621      OSB=OCOST(1,2)
000622      OO 60 I=1,NPCNT
000627      IF(OSB.LE.OCOST(1,2)) GO TO 60
000632      OSB=OCOST(1,2)
000634      II=I
000635      60 CONTINUE
000640      PRINT 1600, OSB,GMF(II),PCTD(II),REPCI(II)
000653      PRINT 2000,OTHK(II,1),MATOP(II,1),OTHK(II,2),MATOP(II,2),
1          OTHK(II,3),MATOP(II,3)
000673      IF(OVERS.GT.OSB)GO TO 70
000702      PRINT 1800
000705      PRINT 12000
000711      RETURN
000712      70 CONTINUE
000712      PRINT 1900
000716      PRINT 12000
000722      RETURN
000723      5 FORMAT(I4,2X,4E10.0,2X,I2)
000723      7 FORMAT(3E10.0)
000723      10 FORMAT(E5.0,E6.0,E6.0,E6.0,3E15.5)
000723      500 FORMAT(40I2)
000723      1000 FORMAT(2X,3HFOR1X,F6.2,1X,22HPER-CENT DAMAGE AND A
1          17HFRAGILITY RATE OF F4.1,1X,3HG'S/
2          2X,11HTHE COST IS1X,F9.2,1X,15HOLLARS WITH A
3          25HMULTIPLICATION FACTOR OF 1X,F6.2,1X,9HTIMES ONE /
4          2X,20HWITH A FINAL COST OF1X,F9.2,1X,7HDOLLARS
5          17HFOR OVER SHIPPING /
6          2X,31HFOR ALLOWING DAMAGE THE COST IS 1X,F9.2,1X,
7          12HOLLARS/ITEM /)
000723      1500 FORMAT(2X,18HOVER SHIPPING DATA /
1          2X,19HTHE OPTIMUM COST IS1X,F9.2,1X,7HDOLLARS /
2          2X,21HTHE FRAGILITY RATE IS1X,F4.1,1X,3HG'S /
3          2X,22HTHE PER-CENT OAMAGE IS1X,F6.1 /
4          2X,28HTHE MULTIPLICATION FACTOR IS1X,F5.1/)
000723      1600 FORMAT(2X,21HOAMAGE ALLOWABLE DATA /
1          2X,19HTHE OPTIMUM COST IS1X,F9.2,1X,7HOLLARS /
2          2X,21HTHE FRAGILITY RATE IS1X,F4.1,1X,3HG'S /
3          2X,22HTHE PER-CENT OAMAGE IS1X,F6.1, /
4          2X,22HTHE REPAIR COST/ITEM =1X,F9.2,1X,7HOLLARS/)
000723      1800 FORMAT(32HOVERSHIPPING IS THE BEST POLICY/)
000723      1900 FORMAT(48H0THE ABOVE PER-CENTAGE DAMAGE IS THE BEST POLICY/)
000723      2000 FORMAT(2X,37HTHE OPTIMUM THICKNESS FOR FACE ONE IS1X,F7.3,1X,
1          6HINCHES1X,11HIF MATERIAL1X,I2,1X,7HIS USED/
2          2X,37HTHE OPTIMUM THICKNESS FOR FACE TWO IS1X,F7.3,1X,
3          6HINCHES1X,11HIF MATERIAL1X,I2,1X,7HIS USED/
4          2X,39HTHE OPTIMUM THICKNESS FOR FACE THREE IS1X,F7.3,1X,
5          6HINCHES1X,11HIF MATERIAL1X,I2,1X,7HIS USED//)
000723      3000 FORMAT(2X,45H*THE ITEM IDENTIFICATION NUMBER DOES NOT AGREE*
1          133H*WITH THAT OF THE FRAGILITY DATA*)
000723      4000 FORMAT(2X,52HNO MATERIAL IS IN THE RANGE OF OPTIMUM STRESS---STOP)
000723      4010 FORMAT (1H0,I8,30H = NC --- NUMBER OF CONTAINERS/
1          11X,I8,24H = MITEM --- ITEM NUMBER/
2          21X, I8,40H = MNMATS--- NUMBER OF MATERIALS ON FILE )
000723      4020 FORMAT (1H0,2X, 85H CST-MAT          CST-FAB          CST-PAK          SL-TEMP

```

```

1      LW-STRS      HI-STRS      GAMMA / (E11.4, 6E13.4)
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=WEIGHT OF ITEM WI
1( POUNDS ) /3X,E11.4,65H= DIMENSION PARALLEL TO X-AXIS 2ND LONGEST
2 DIMENSION XL (INCHES) /3X,E11.4,65H= DIMENSION PARALLEL TO Y-AXIS
3 3RD LONGEST DIMENSION YL (INCHES) /3X,E11.4,61H= DIMENSION PARALL
4EL TO Z-AXIS LONGEST DIMENSION ZL (INCHES) /,3X, 9HNUMBER = I8)
000723 4050 FORMAT ( 1H0,8X, 35H MAX-G      PCNT-DAM      REPLACE-CST /
1(3X,3E12.4) // 2(120(1H*)/ ) )
000723 4060 FORMAT(1HU2X,30HMATERIAL CODES CONSIDERED ARE 10(1X,I2,2H, ))
000723 4070 FORMAT(50H0 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

5	-	000735	7	-	000741	10	-	000743	20	-	000143
26	-	000224	28	-	000301	45	-	000523	50	-	000554
60	-	000635	70	-	000712	500	-	000747	1000	-	000751
1500	-	001032	1600	-	001072	1800	-	001133	1900	-	001140
2000	-	001147	3000	-	001216	4000	-	001231	4010	-	001241
4000	-	001264	4030	-	001301	4040	-	001310	4050	-	001352
4060	-	001365	4070	-	001374	11000	-	001404	12000	-	001407

BLOCK NAMES AND LENGTHS

DATA - 000006 COSTM - 000135

VARIABLE ASSIGNMENTS

CA	-	000000C02	CD	-	000106C02	COST	-	001702	GM	-	001701
GMF	-	001602	I	-	001655	II	-	001703	IT	-	001700
ITEM	-	001660	I1	-	000000C01	I2	-	000001C01	I3	-	000002C01
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	OSB	-	001704	OTHK	-	001506	OVERS	-	001705
PCTD	-	001614	REPCI	-	001626	RHOC	-	001657	S	-	000003
S1	-	001672	S11	-	001675	S2	-	001673	S22	-	001676
S3	-	001674	T1	-	000003C01	T2	-	000004C01	T3	-	000005C01
W	-	001671	WI	-	001661	WII	-	000134C02	X	-	001666
XDJ	-	000004	XL	-	001662	Y	-	001667	YL	-	001663
Z	-	001670	ZL	-	001664						

START OF CONSTANTS  
000725

START OF TEMPORARIES  
001414

START OF INDIRECTS  
001430

UNUSED COMPILER 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

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

Glossary of Variables for ODFRC (Contd.)

- 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 = 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,MXI,COST,
1 MATSC,GM,OMJ,MOMJ,S,XDJ,IC,NIC)
C CUSHION DESIGN PROCEEDURE
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)
000026 COMMON /MMM/ MXIT(10,3,3)
000026 COMMON /THK/ TSK,ITEM
000026 COMMON /TEMPT/ TTHIK(10,3,11),IM,IAXS,ITEMP,IJE,TMX
000026 COMMON /N/ NT,NS,NTH,SI,THI,TIII
000026 DIMENSION TI(3)
000026 DIMENSION TH(10),SIG(10),T(10),TAB1(10,10,10),MATSC(10),TS(10)
000026 DIMENSION OMS(10),THIK(10,3),DII(5),THIKV(10,3),TAB2(10,10,10)
000026 DIMENSION OMJ(11),XDJ(11),FE(10),S(10),AL(3),ALI(3),DL(3)
000026 EQUIVALENCE(TH,TS),(SIG,OMS),(T,FE)
000026 INTEGER DRPH
000026 INTEGER DH,DLH,DII
000026 DATA DII/ 18,24,30,36,48/
C STATEMENT FUNCTION TO CALCULATE WEIGHT CHANGES
000026 WF(T1,T2,T3,RC,RM)=2.*((RC*TCON+RM*T1)*(Z +2.*(TCON+T1))*
1 (Y +2.*(YCON+T1)) + (RC*TCON+RM*T2)*(X +2.*(TCON+T2))*
2 (Z +2.*(TCON+T2)) + (RC*TCON+RM*T3)*(Y +2.*(TCON+T3))*
3 (X +2.*(TCON+T3)))
C
000106 ITIME = 0
000107 DWH=0.0
000110 DO 130 ITEM=1,ITEMP
000111 TIII = TI(ITEM)
000113 XDDA=GM
000115 AL(1)=ZL
000116 AL(2)=ZL
000117 AL(3)=XL
000120 X=XL
000121 Y=YL
000122 Z=ZL
000123 PRINT 1100
000126 DO 50 IM=1,NMATS
000133 MS = MATSC(IM)
000136 REWIND MS
000140 DO 4 IAXS=1,3

```

```

000142      4 THIKV(IM,IAXS)=0.0
000150      5 CONTINUE
000150      THI=3.5
000152      THIK(IM,1)=THI
000154      THIK(IM,2)=THI
000155      THIK(IM,3)=THI
000156      DLH=0
000156      T1= THI
000157      T2= THI
000160      T3= THI
000161      TT1= T1
000162      TT2= T2
000164      TT3= T3
000165      DL(1)= 2.*(THI + TCON)
000170      DL(2)= 2.*(THI + TCON)
000173      DL(3)= 2.*(THI + TCON)
000176      READ(MS,12)RHOM,DRPH,ICODE
000207      RHOM=RHOM/12.**3
000211      DO 16 ICOUNT=1,MIC
000216      DO 15 IAXS=1,3
000217      THI=THIK(IM,IAXS)
000223      ALI(IAXS)=AL(IAXS)+DL(IAXS)
000226      IF(IAXS.EQ.1)A=Y*Z
000232      IF(IAXS.EQ.2)A=X*Z
000236      IF(IAXS.EQ.3)A=Y*X
000242      WW = WI + WF(TT1,TT2,TT3,RHOC,RHOM) + DWB
000255      DH= DHGHT(WW,ALI(IAXS))
000263      IJ=0
000264      11 CONTINUE
000264      IJ=IJ+1
000266      IF(IJ.GT.4)PRINT 10000
000303      READ(MS,20)NT,NTH,NS
000315      READ(MS,10)(T(I),I=1,NT)
000330      READ(MS,10)(TH(I),I=1,NTH)
000343      READ(MS,10)(SIG(I),I=1,NS)
000356      DO 1000 K=1,NT
000363      DO 1000 I=1,NTH
1000 READ(MS,10)(TAB1(I,J,K),J=1,NS)
000412      IF(DH.NE.DII(IJ))READ(MS,12)RHOM,DRPH,ICODE
000432      IF(DH.NE.DII(IJ))
1RHOM=RHOM/12.**3
000437      IF(DH.NE.DII(IJ))GO TO 11
000442      13 CONTINUE
000442      REWIND MS
000444      READ(MS,12)RHOM,DRPH,ICODE
000456      RHOM=RHOM/12.**3
000460      SI=WI/A
000466      THIK(IM,IAXS)= SHOCKE(TAB1,TH,SIG,T,GM,MXI)
000476      TT1 = THIK(IM,1)
000500      TT2 = THIK(IM,2)
000501      TT3 = THIK(IM,3)
000503      DL(1)=2.*(TT3+TCON)
000511      DL(2)=2.*(TT3+TCON)
000514      DL(3)=2.*(TT1+TCON)
C
000517      15 CONTINUE
000521      IF(ABS(T1-TT1).LE.1.E-1.AND.ABS(T2-TT2).LE.1.E-1.AND.ABS(T3-TT3).
1 LE.1.E-1) GO TO 45

```

```

000545      PRINT 7001,T1,T2,T3,TT1,TT2,TT3
000564      T1 = TT1
000566      T2 = TT2
000567      T3 = TT3
000571      16 CONTINUE
C          PRINT APPROPRIATE MESSAGE FOR NON-CONVERGENCE
000577      PRINT 7000,MATSC(IM)
000605      MATSC(IM)=0
000610      GO TO 50
000614      45 CONTINUE
000614      IF(TT3.LE.TMX)GO TO 50
000617      ITIME = ITIME+1
000620      IF(ITIME.NE.1)GO TO 50
000621      REWIND MS
000623      Y=YL+2.*T2
000626      PRINT 8000,XL,Y,ZL,I,IM
C          CALCULATE WEIGHT OF (1./4) INCH PLYWOOD FOR EACH AXIS
000644      DW8=0.0098*(Y*Z + Y*X)
000650      GO TO 5
000654      50 CONTINUE
C
000657      DO 56 IM=1,NMATS
000660      IF(MATSC(IM).EQ.0)GO TO 56
000662      MS=MATSC(IM)
C          READ TO BEGINNING OF VIBRATION FILES
000664      REWIND MS
000666      DO 55 IR=1,4
000670      READ(MS,12)RHOM,DRPH,ICODE
000701      READ(MS,20)NT,NTH,NS
000713      READ(MS,10)(T(I),I=1,NT)
000726      READ(MS,10)(TH(I),I=1,NTH)
000741      READ(MS,10)(SIG(I),I=1,NS)
000754      DO 55 K=1,NT
000761      DO 55 I=1,NTH
000762      55 READ(MS,10)(TAB1(I,J,K),J=1,NS)
001012      56 CONTINUE
C          CALCULATE THICKNESS FROM VIBRATION ENVIRONMENT
C
001015      DO 100 IM=1,NMATS
001016      MS=MATSC(IM)
001021      IF(MS.EQ.0)GO TO 100
001022      READ(MS,12)RHOM,MTS,MOMS
001033      READ(MS,14)(TS(I),I=1,MTS)
001046      READ(MS,14)(OMS(I),I=1,MOMS)
001061      DO 60 I=1,MOMS
001066      READ(MS,14)(TAB1(I,J,1),J=1,MTS)
001101      60 CONTINUE
001107      DO 65 I=1,MOMS
001111      READ(MS,14)(TAB2(I,J,1),J=1,MTS)
001124      65 CONTINUE
001132      DO 70 IAXS=1,3
001134      THIKV(IM,IAXS)=THIK(IM,IAXS)
001141      IF(IAXS.EQ.1)A=Y*Z
001145      IF(IAXS.EQ.2)A=X*Z
001151      IF(IAXS.EQ.3)A=Y*X
001155      WW=WI
001156      69 CONTINUE
001156      TSK=THIKV(IM,IAXS)

```

```

001162      CALL VIBRTN(TAB1,TAB2,TS,QMS,TOP,OMJ,FE,MOMJ,XDDA,A,WW,S,IC,XDJ)
001202      IF(IJE.EQ.0)GO TO 75
001207      THIKV(IM,IAXS)=TSK
001213      70 CONTINUE
001214      75 CONTINUE

C
001214      IF(IJE.EQ.0)MATSC(IM)=0
001220      100 CONTINUE
C
001223      PRINT THICKNESSES
C
001223      PRINT 5000,((THIKV(I,J),J=1,3),I=1,NMATS)
C
001242      ELIMINATE MATERIALS THAT DO NOT OVERLAP ALL TEMP REGIONS
      IK=0
C
001243      UP-DATE THICKNESS ARRAY
      DO 120 IM=1,NMATS
001250      IF(MATSC(IM).EQ.0) GO TO 120
001252      IX=IK+1
001254      DO 110 IA=1,3
001255      MXX=MXIT(IM,IA,ITEM)
001262      DO 110 IU=1,MXX
001264      TTHIK(IK,IA,IU)=TTHIK(IM,IA,IU)
001275      MXIT(IK,IA,ITEM)=MXX
001301      IF(ITEMP.EQ.1)GO TO 110
001303      MXIT(IK,IA,ITEM-1)=MXIT(IM,IA,ITEM-1)
001312      110 CONTINUE
001317      120 CONTINUE
C
001322      SORT OUT DELETIONS
      DO 125 I=1,NMATS
001323      DO 125 J=I,NMATS
001324      IF(MATSC(J).LT.MATSC(I))GO TO 125
001330      SAVE = MATSC(J)
001332      MATSC(J)=MATSC(I)
001335      MATSC(I)=SAVE
001340      125 CONTINUE
001345      NMATS = IK
001346      IF(NMATS.NE.0)GO TO 126
001347      PRINT 6000
001352      TI(1)=1500.
001357      RETURN
001360      126 CONTINUE
C
001360      SORT MATSC(I) BACK INTO ASCENDING ORDER
      DO 127 I=1,NMATS
001362      DO 127 J=I,NMATS
001363      IF(MATSC(J).GT.MATSC(I))GO TO 127
001370      SAVE=MATSC(J)
001372      MATSC(J)=MATSC(I)
001375      MATSC(I)=SAVE
001377      127 CONTINUE
001404      130 CONTINUE
      DO 135 I=1,NMATS
001406      DO 135 IA=1,3
001410      MXII=MXIT(I,IA,ITEMP)
001411      IF(ITEMP.EQ.1)MXII=1
001416      THIKV(I,IA)=TTHIK(I,IA,MXII)
001421      135 CONTINUE
001431      135 CONTINUE
001436      CALL COSTMT(THIKV,X ,Y ,Z ,TCON,THIK ,MATSC,NMATS,COST,NIC)
001451      RETURN
001452      10 FORMAT(11E7.0)
001452      12 FORMAT(E7.0,S12)

```

```

001452      14 FORMAT(11E11.4)
001452      20 FORMAT(5I2)
001452      5000 FORMAT(2X,39HMINIMUM THICKNESS FOR MATERIAL BY AXIS /
      1      10(2X,3E15.4/))
001452      6000 FORMAT(1X,58H ALL MATERIALS DELETED --- NO OVERLAP BETWEEN TEMPERA
      ITURES 29H-OPTIMIZE ON DATA ACCUMULATED )
001452      7000 FORMAT(55H CAN NOT DETERMINE THICKNESS FOR DROP HGT. CALCULATIONS
      1      2X,15HMATERIAL CODE =I3,2X,21HTHIS MATERIAL DELETED)
001452      7001 FORMAT(2X,3HT1=E11.4,2X,3HT2=E11.4,2X,3HT3=E11.4,
      1      2X,4HTT1=E11.4,2X,4HTT2=E11.4,2X,4HTT3=E11.4)
001452      8000 FORMAT(2X,30HPLYWOOD BEARING BOARD 1/4 INCH/
      13X,10HDIMENSIONS F5.2,3H X F5.2,2X,6H SIDE 3
      23X,10HDIMENSIONS F5.2,3H X F5.2,2X,6H SIDE 1 3X,15HMATERIAL NUMBER
      3 13)
001452      10000 FORMAT(1HD 25HCAN NOT FIND DROP HEIGHT      )
001452      11000 FORMAT (/ 120(1H*)/ )
001452      END

```

CDPRO

SUBPROGRAM LENGTH  
006032

FUNCTION ASSIGNMENTS  
WF - 000034

STATEMENT ASSIGNMENTS

4	-	000142	5	-	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	-	001500
6000	-	001511	7000	-	001525	7001	-	001542	8000	-	001554
10000	-	001603	11000	-	001610						

BLOCK NAMES AND LENGTHS

MMM - 000132 THK - 000002 TEMPT - 000517 N - 000006

VARIABLE ASSIGNMENTS

A	-	006012	AL	-	005756	ALI	-	005761	COST	-	000004
DH	-	005770	DII	-	003743	DL	-	005764	DLH	-	005771
DRPH	-	005767	DWB	-	005776	FE	-	001723	GM	-	000006
I	-	006015	IA	-	006025	IAXS	-	000513C03	IC	-	000013
ICODE	-	006010	ICOUNT	-	006011	IJ	-	006014	IJE	-	000515C03
IK	-	006024	IM	-	000512C03	IR	-	006020	ITEM	-	000001C02
ITEMP	-	000514C03	ITIME	-	005775	IU	-	006027	J	-	006017
K	-	006016	MATSC	-	006005	MIC	-	000002	MOMJ	-	000010
MOMS	-	006022	MS	-	006000	MTS	-	006021	MXI	-	000003
MXII	-	006031	MXIT	-	000000C01	MXX	-	006026	NIC	-	000014
NMATS	-	000000	NS	-	000001C04	NT	-	000000C04	NTH	-	000002C04
OMJ	-	000007	OMS	-	001711	RHOC	-	000001	RHOM	-	006007
S	-	000011	SAVE	-	006030	SI	-	000003C04	SIG	-	001711
T	-	001723	TAB1	-	001735	TAB2	-	004006	TH	-	001677
THI	-	000004C04	THIK	-	003705	THIKV	-	003750	TIII	-	000005C04
THX	-	000516C03	TOP	-	006023	TS	-	001677	TSK	-	000000C02
TTHIK	-	000000C03	TT1	-	006004	TT2	-	006005	TT3	-	006006
T1	-	006001	T2	-	006002	T3	-	006003	WW	-	006013
X	-	005774	XDDA	-	005777	XDJ	-	000012	Y	-	005773
Z	-	005772									

START OF CONSTANTS  
001454

START OF TEMPORARIES  
001613

START OF INDIRECTS  
001671

UNUSED COMPILER SPACE  
036300

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.

```

000005      FUNCTION DHGHT(WW,ALL)
              DIMENSION DHW(7),DHL(7),DHH(7)
C           ALL----- ITEM LENGTH + CONTAINER AND CUSHION THICKNESS
C           DHH----- DROP HEIGHT
C           DHL----- DROP HEIGHT MAXIMUM LENGTH
C           DHW----- DROP HEIGHT UPPER WEIGHT LIMIT
C           WW ----- ITEM WEIGHT + CONTAINER AND CUSHION WEIGHT
000005      DATA DHW/100.,100.,200.,200.,1000.,1000.,1000./
000005      DATA DHL/36.,500.,36.,500.,36.,60.,600./
C           DATA DHH/48.,30.,30.,24.,24.,36.,24./
000005      DATA DHH/36.,30.,30.,24.,24.,36.,24./
C           THIS FUNCTION PICKS THE APPROPRIATE DROP HEIGHT
              DH= 18.
000006      IF(WW.GT.1000.)GO TO 20
000011      DO 10 I=1,7
000012      II=I
000013      7 CONTINUE
000013      IF(WW.GT.DHW(II))GO TO 10
000017      IF(ALL.LT.DHL(II))GO TO 18
000021      IF(DHW(II).LT.DHW(II+1))GO TO 18
000023      II=II+1
000025      GO TO 7
000025      10 CONTINUE
000027      18 DH=DHH(II)
000031      20 DHGHT=DH+.1
000033      RETURN
000034      END

```

DHGHT

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 - 000067 DHL - 000060  
DKW - 000071 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 COSTMP

AL(I)	- - - - -	Area of the perpendicular face of the package.
C1	- - - - -	Cost of material on face one.
C2	- - - - -	Cost of material on face two.
C3	- - - - -	Cost of material on face three.
C12	- - - - -	Contains the minimum cost between the materials on face one and face two.
C13	- - - - -	Contains the minimum cost between the materials on face one and face three.
C23	- - - - -	Contains the minimum cost between the materials on face two and face three.
C123	- - - - -	Contains the lowest cost of the three materials.
CAXIS(I, 1)	- - -	Cost of the packaging material for face one.
CAXIS(I, 2)	- - -	Cost of the packaging material for face two.
CAXIS(I, 3)	- - -	Cost of the packaging material for face three.
CF(I)	- - - - -	Array containing cost of fabrication to specific dimensions.
CFF	- - - - -	Cost of fabrication.
CM(I)	- - - - -	Array containing material cost.
COST	- - - - -	Total cost.
CP(I)	- - - - -	Array containing the cost of packaging.
CPP	- - - - -	Cost of packaging.
CSS	- - - - -	Cost of shipping the package.
CVC	- - - - -	Cost of material for corners.
II(I)	- - - - -	Contains array positions of optimum thickness for each of the three faces.

Glossary of Variables for COSTMT ( Contd. )

- MC (I) - - - - - Contains material code for each of the three faces.  
MTC - - - - - Material code.  
SLT (I) - - - - - Safe low temperature.  
T1 - - - - - Optimum thickness for face one.  
T2 - - - - - Optimum thickness for face two.  
T3 - - - - - Optimum thickness for face three.  
TCC - - - - - Total cost of container by volume.  
TCMV - - - - - Total cost of material by volume.  
V1 - - - - - Volume of packaging material needed for face one.  
V2 - - - - - Volume of packaging material needed for face two.  
V3 - - - - - Volume of packaging material needed for face three.

```

SUBROUTINE COST MT(THIKV,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 ---- COST 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 /COSIM/ CA(10,?),CD(10,2),CS,CI,WII
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),CC(10),THIKV(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)
000015 AL(1) =ZL*YL
000015 AL(2)=ZL*XL
000015 AL(3)=XL*YL
000015 DO 20 I=1,NMATS
000015 MTC=MATSC(I)
000015 V1=AL(1)*THIKV(I,1)
000015 V2=AL(2)*THIKV(I,2)
000015 V3=AL(3)*THIKV(I,3)
000015 CAXIS(I,1)=V1*CM(MTC)
000015 CAXIS(I,2)=V2*CM(MTC)
000015 CAXIS(I,3)=V3*CM(MTC)
000015 20 CONTINUE
000015 CALL MINCOS(II,CAXIS,NMATS)
000015 C   DETERMINE COST OF PACKING MATERIAL
000015 DO 30 I=1,3
000015 C   II(I) CONTAINS ARRAY POSITIONS
000015 IL=II(I)
000015 C   MC(I) CONTAINS MAT. CODE
000015 MC(I)=MATSC(IL)
000015 30 CONTINUE
000015 C   I,J,K CONTAINS MAT. CODE
000015 I=MC(1)
000015 J=MC(2)
000015 K=MC(3)
000015 C   CALCULATE MIN. COST FOR CORNER AND EDGE CUSHIONING
000015 C123=AMIN1(CM(I),CM(J),CM(K))
000015 C12=AMIN1(CM(I),CM(J))
000015 C13=AMIN1(CM(I),CM(K))
000015 C23=AMIN1(CM(J),CM(K))
000015 I1=II(1)
000015 I2=II(2)
000015 I3=II(3)
000015 T1=THIKV(I1,1)

```

```

000132      T2=THIKV(I2,2)
000133      T3=THIKV(I3,3)
000137      CSS=(ZL*YL*T1*CA(I1,7)+ZL*XL*T2*CA(I2,7)+XL*YL*T3*CA(I3,7))*CS
1          + CS*WII
000154      PRINT 2000,MC(1),THIKV(I1,1),MC(2),THIKV(I2,2),MC(3),THIKV(I3,3)
000221      C1=ZL*THIKV(I1,1)*THIKV(I2,2)*C12
000232      C2 =XL*THIKV(I2,2)*THIKV(I3,3)*C23
000237      C3=YL*THIKV(I3,3)*THIKV(I1,1)*C13
000244      CVC=THIKV(I1,1)*THIKV(I2,2)*THIKV(I3,3)*C123
C          TOTAL COST OF MATERIAL BY VOLUME
000252      TCMV=2.*(CAXIS(I1,1)+CAXIS(I2,2)+CAXIS(I3,3))
1          +8.*CVC+4.*(C1+C2+C3)
C          TOTAL COST OF CONTAINER BY VOLUME
000252      TCC=CC(IC)*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
C          THAT IT TAKES 1/2 AS MUCH TIME TO CUT THE EDGE FILLER AS TO CUT
C          THE SURFACE.
000315      CFF=2.*(CF(I)*(ZL+YL)+CF(J)*(XL+ZL)+CF(K)*(XL+YL))
C          TOTAL COST
000332      CPP=6.*(CP(I)*(ZL+YL)+CP(J)*(XL+ZL)+CP(K)*(XL+YL))
000346      COST=TCMV+TCC+CFF+CSS+CI+CPP
C          TO BE CONTINUED LATER      *****
000354      PRINT 1000, COST, (MATSC(IA), (CAXIS(IA,JA), JA=1,3), IA=1,NMATS)
000411      RETURN
000412      1000 FORMAT(2X,16HTOTAL COST/ITEM=F8.2/,2X,12HMINCOS=INPUT /
1          2X,46MCOST MATRIX=MATERIAL VERTICAL,AXIS HORIZONTAL /
2          10(2X,I2,2X,F8.2,2X,F8.2,2X,F8.2/))
000412      2000 FORMAT(2X,15HMATERIAL CODE = I4,2X,24MTHICKNESS FOR FACE ONE =F8.3
1          ,1X,6HINCHES/
2          2X,15HMATERIAL CODE = I4,2X,24MTHICKNESS FOR FACE TWO =F8.3
3          ,1X,6HINCHES/
4          2X,15HMATERIAL CODE = I4,2X,25MTHICKNESS FOR FACE THREE=
5          F8.3,1X,6HINCHES/)
000412      END

```

COSTMT

SUBPROGRAM LENGTH  
000701

FUNCTION ASSIGNMENT:

STATEMENT ASSIGNMENTS

1000 - 000422      2000 - 000444

BLOCK NAMES AND LENGTHS

COSTM - 000135      OPT - 000006

VARIABLE ASSIGNMENTS

AL	-	000644	CA	-	000000C01	CC	-	000120C01	CD	-	000106C01
CF	-	000012C01	CFF	-	000675	CI	-	000133C01	CM	-	000000C01
COST	-	000002	CP	-	000024C01	CPP	-	000676	CS	-	000132C01
CSS	-	000666	CVC	-	000672	C1	-	000667	C12	-	000663
C123	-	000662	C13	-	000664	C2	-	000670	C23	-	000665
C3	-	000671	GAMAC	-	000106C01	I	-	000652	IA	-	000677
IC	-	000003	II	-	000647	IL	-	000657	I1	-	000000C02
I2	-	000001C02	I3	-	000002C02	J	-	000660	JA	-	000700
K	-	000661	MATSC	-	000000	MC	-	000644	MTC	-	000653
NMATS	-	000001	ROS1	-	000050C01	ROS2	-	000062C01	SLT	-	000036C01
TCC	-	000674	TCMV	-	000673	T1	-	000003C02	T2	-	000004C02
T3	-	000005C02	V1	-	000654	V2	-	000655	V3	-	000656
WII	-	000134C01									

START OF CONSTANTS

000414

START OF TEMPORARIES

000510

START OF INDIRECTS

000574

UNUSED COMPILER SPACE

041000

MINCOS - Subroutine

Usage:

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

Subroutines called:

None

Glossary of Variables for MINCOS

- CAXIS (I, 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 MINCUS(II,CAXIS,NMATS)
C   MIN COST
C   SUBROUTINE PICKS THE MATERIAL FOR EACH AXIS-WHICH
C   HAS THE MINIMUM COST
000006   DIMENSION II(1),CAXIS(10,3),SIT(10)
000006   DO 50 IAXIS=1,3
000007   DO 30 I=1,NMATS
000010   30 SIT(1)=CAXIS(I,IAXIS)
000020   II(IAXIS)=I
000022   DO 40 IM=1,NMATS
000024   IF(SIT(1).LT.SIT(IM)) GO TO 40
000027   II(IAXIS)=IM
000031   SAVE=SIT(1)
000032   SIT(1)=SIT(IM)
000033   SIT(IM)=SAVE
000034   40 CONTINUE
000037   50 CONTINUE
000041   RETURN
000041   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 - 000067  
SIT - 000052

START OF CONSTANTS  
000043

START OF TEMPORARIES  
000044

START OF INDIRECTS  
000046

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  $\text{thickness} = F(G)$ .
- (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,TH,SIG,T,GM,MXI)
000011 COMMON /N/ NT,NS,NTH,SI,THI,TI
000011 DIMENSION TAB1(10,10,10),TH(10),SIG(10),T(10),F(10)
000011 DIMENSION TF(5),F2(5)
C      GM -- FRAGILITY LIMIT (ACCELERATION)
C      NS -- NUMBER OF STRESSES MUST BE AT LEAST 3 UNLESS EXTRAPOLATING
C           THEN 2 ARE NEEDED
C      NT -- NUMBER OF TEMPERATURES MUST BE AT LEAST 1
C      NTH -- NUMBER OF THICKNESS VALUES MUST BE AT LEAST 3
C      T -- 1-D TABLE OF TEMPERATURES (FAHRENHEIT)
C      TAB1--3-D TABLE OF PEAK ACCELERATIONS G=F(TH,SIG,T)
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
000011 110 CONTINUE
000011 DO 120 I=1,5
000013 THI=FLOAT(I)
000014 TF(I)=FLOAT(I)
000016 CALL LAGINT(TAB1,T,SIG,TH,G,F)
000021 F2(I)=G
000023 IF(ABS(G-GM).LT.0.1)GO TO 15
000033 120 CONTINUE
000035 SHOCKE=FLAGR(5,F2,TF,GM)
000044 RETURN
000045 15 CONTINUE
000045 SHOCKE=THI
000047 RETURN
000047 END

```

SHOCKE

SUBPROGRAM LENGTH  
000112

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS  
15 - 000045 110 - 000011

BLOCK NAMES AND LENGTHS  
N - 000006

VARIABLE ASSIGNMENTS  
F - 000064 F2 - 000103 G - 000111 I - 000110  
SHOCKE - 000063 TF - 000076 THI - 000004C01

START OF CONSTANTS  
000051

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 VIBRTN

A	- - - - -	Support area of item (sq in.).
AT	- - - - -	Environmental temperature.
ERI	- - - - -	Modulus at center frequency.
ERJ	- - - - -	Modulus at environmental frequency.
FE(I)	- - - - -	Force - 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).

Glossary of Variables for VIBRTN ( Contd. )

- 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 - - - - - Optimurn 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,TAB2,TS,OMS,TOP,OMJ,FE,MOMJ,XDDA,A,W,S,
1IC,XDJ)
C SUBROUTINE CALCULATES THE OPTIMUM THICKNESS FOR THE VIBRATION
C ENVIRONMENT
000021 DIMENSION (AB1(10,10,10),TAB2(10,10,10),OB(11),TS(1),OMS(1),
1OMJ(1),S(1),FE(1),XDD(11),TCC(11),XOJ(1),TOPP(11),TT(22)
000021 COMMON /MMM/ MXI (10,3,3)
000021 COMMON /TEMPT/ TTHIK(10,3,11),IM,IAX,ITEMP,IJ,TMX
000021 COMMON /THK/ TSK,ITEM
000021 COMMON /N/ M,MTS,MOMS,AT,OM,ZA
000021 DATA OB/1.,2.,4.,8.,16.,31.5,63.,125.,250.,500.,1000./
*****
C FE ----- WORK - VECTOR
C MOMJ ----- NUMBER OF INPUT ENVIRONMENT FREQ.
C OMJ ----- ENVIRONMENTAL FREQUENCIES - VECTOR
C OMS ----- FREQUENCY SCALE (PTS. AT WHICH INFO. IS RECORDED) - VECTOR
C TAB1 ----- TWO - O TABLE (CURVES) CONTAINING BEHAVIOR OF STORAGE
C MODULUS(ER) ER = F(TEMP,FREQ)
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 W ----- WEIGHT OF ITEM *****
C S ----- P S O - IN 1-OCTAVE BANDS *** INPUT IF IC = 3 *** - VECTOR
C XDJ ----- ENVIRONMENTAL G-LEVELS - VECTOR *****
C IC ----- PROCEEDURE CODE VALUE=1,2,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 OM ----- ENVIRONMENTAL FREQ OMJ(J)
C MOMS ----- NUMBER OF VALUES ALONG FREQ. SCALE (OMS)
C MTS-----NUMBER OF TEMPERATURES STORED ON FILE
**
C TAB1 AND TAB2 ARE ASSUMED TO USE THE SAME TS AND OMS VECTORS
*****
000021 TF(WI,WJ,ERI,ERJ,OJ)= SQRT((1.+DJ**2)/((1.-(WJ/WI)**2*ERI/ERJ)**2
1 + DJ**2))
000047 THCK(A,ERI,WI,W) = 386.40*A*ERI/(W*WI**2)
000061 M=1
000062 ZA=0.0
000063 DO 50 I=1,11
000065 SJ = 0.0
000066 WI=6.2831853*OB(I)
000070 OM = WI
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,WI,W)
000115 GO TO (10,20,30), IC
000124 10 CONTINUE
C MIL STD 810 - B EXCITATION
000124 CALL LAGINT(TAB2,DUMY,TS,OMS,DJ,FE)
000130 SJ = TF(WI,OM,ERI,ERI,DJ)*XDJ (I)

```

```

000147      GO TO 45
000147      20 CONTINUE
C          MULTIPLE SINE EXCITATION
000147      00 25 J=1,MOMJ
000151      OM = OMJ(J)
000153      IF(OM.LT.OMS(1).OR.OM.GT.OMS(MOMS))GO TO 25
000164      CALL LAGINT(TAB1,OUMY,TS,OMS,ERJ,FE)
000167      CALL LAGINT(TAB2,OUMY,TS,OMS,OJ, FE)
000176      SJ = SJ + TF(WI,OM,ERI,ERJ,OJ )* XDJ(J)
000217      25 CONTINUE
000222      GO TO 45
000222      30 CONTINUE
C          RANOOM EXCITATION (PSO INPUT )
000222      00 35 J=1,MOMJ
000224      OM = OMJ(J)
000226      CALL LAGINT(TAB1,OUMY,TS,OMS,ERJ,FE)
000231      CALL LAGINT(TAB2,OUMY,TS,OMS,OJ ,FE)
000240      SJ = SJ + 3(J)*TF(WI,OM,ERI,ERJ,OJ )**2
000261      35 CONTINUE
000264      SJ = 2.5* SQRT(SJ)
000267      45 CONTINUE
000267      XDD(I) = SJ
000271      50 CONTINUE
000277      II=0
000300      CT=1.
000301      00 60 I =1,11
000303      IF(XDD(I).EQ.1.E10)GO TO 60
000306      IF(XDD(I).GT.X00A)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 ASCENDOING OROER
000330      00 65 I=1,II
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
000356      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

```

```

000415      75 TSK=TOPP(III)
000417      80 CONTINUE
C          C CHECK OPTIMUM THICKNESS AGAINST MAX ALLOWABLE OPTIMUM
000417      IF(TSK.GT.TMX)IJ=0
000426      IF(TSK.GT.TMX)PRINT 3000,IM
000442      IF(TSK.GT.TMX)PRINT 5000,TSK,TMX
000460      IF(TSK.GT.TMX)RETURN
C          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 I=III,II
000475      I4=III+(I-III)
000477      IF(TTHIK(IM,IAX,I).GE.TOPP(I4))GO TO 85
000505      IJ=IJ+1
000507      TT(IJ)=TOPP(I4)
000512      85 CONTINUE
000515      IF(IJ.EQ.0)
1PRINT 3000,IM
000527      IF(IJ.EQ.0)
1PRINT 4000
000540      IF(IJ.EQ.0)RETURN
000542      IK=0
000543      DO 90 I=1,MXII
000545      IF(TTHIK(IM,IAX,I).GE.TT(IJ))GO TO 90
000551      IK = IK + 1
000556      TT(IJ+IK)=TTHIK(IM,IAX,I)
000564      90 CONTINUE
000567      IJK = IJ + IK
000571      DO 95 I=1,IJK
000572      DO 95 J=I,IJK
000573      IF(TT(J).GT.TT(I))GO TO 95
000600      SAVE = TT(J)
000601      TT(J)= TT(I)
000604      TT(I)= SAVE
000605      95 CONTINUE
000612      IF(IJK.GT.11)IJK=11
000615      DO 100 I=1,IJK
000617      TTHIK(IM,IAX,I) = TT(I)
000627      100 CONTINUE
000631      MXI(IM,IAX,ITEM)=IJK
000636      RETURN
000636      105 CONTINUE
000636      IT = II-III +1
000641      DO 110 I=1,IT
000642      II=III+I-1
000645      TTHIK(IM,IAX,I) = TOPP(I)
000653      110 CONTINUE
000655      MXI(IM,IAX,1)=IT
000660      IJ=1
000661      RETURN
000661      500 FORMAT(2X,6E15.6)
000661      1000 FORMAT(51H SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS)
000661      2000 FORMAT(2X,16HSHOCK THICKNESS= E15.4,2X,28HOPTIMUM VIBRATION THICK
NESS= E15.4)
000661      3000 FORMAT(9HUMATERIAL 13,17H IS BEING DELETED )
000661      4000 FORMAT(23H NO TEMPERATURE OVERLAP )
000661      5000 FORMAT(20H OPTIMUM THICKNESS = E15.5,2X,

```

000661

1 33HMAX ALLOWABLE OPTIMUM THICKNESS = E15.5,/)   
 END

VI8RTN

SUBPROGRAM LENGTH  
001133

FUNCTION ASSIGNMENTS

TF - 000027 THCK - 000053

STATEMENT ASSIGNMENTS

10	-	000124	20	-	000147	25	-	000217	30	-	000222
45	-	000267	50	-	000271	60	-	000326	62	-	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
5000	-	000727									

BLOCK NAMES AND LENGTHS

MMH - 000132 TEMPT - 000517 THK - 000002 N - 000006

VARIABLE ASSIGNMENTS

A	-	000003	CT	-	001123	OJ	-	001117	DUMY	-	001115
ERI	-	001116	ERJ	-	001121	FE	-	000000	I	-	001112
IAX	-	000513C02	IC	-	000006	II	-	001122	III	-	001125
IJ	-	000515C02	IJK	-	001131	IK	-	001130	IM	-	000512C02
IT	-	001132	ITEM	-	000001C03	I4	-	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	-	001064	TTHIK	-	000000C02
W	-	000004	WI	-	001114	XDD	-	001023	XODA	-	000002
XOJ	-	000007	ZA	-	000005C04						

START OF CONSTANTS

000663

START OF TEMPORARIES

000743

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 - 0
C   IF NPTSB EQ 1 AND NPTSA EQ 1 TABLE IS 1 - 0
C   IF NPTSB NE 1 AND NPTSA EQ 1 TABLE IS 2 - 0
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
000011 DIMENSION A(10,10,10),B(10,10),F(1),ALF(1),
1 BETA(1),GAM(1)
000011 COMMON /N/ NPTSA, NPTSB,NPTSG,XB,YG,ZA
C   CHECK FOR THREE DIMENSIONS
000011 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 5 F(K) = A(I,J,K)
000031 B(I,J) = FLAGR(NPTSA,ALF,F,7A)
000043 10 CONTINUE
000047 GO TO 120
C   CHECK FOR TWO DIMENSIONS
000050 100 CONTINUE
000050 IF(NPTSB.EQ.1)GO TO 200
000052 DO 110 I=1,NPTSG
000054 DO 110 J=1,NPTSB
000055 110 B(I,J)=A(I,J,1)
C   SOLVE TWO DIMENSIONAL CASE
000071 120 CONTINUE
000071 DO 150 I=1,NPTSG
000073 DO 140 J=1,NPTSB
000074 140 F(J) = B(I,J)
000105 B(I,1)=FLAGR(NPTSB,BETA,F,XB)
000115 150 CONTINUE
000117 GO TO 220
C   SOLVE ONE DIMENSIONAL CASE
000120 200 CONTINUE
000120 DO 210 I=1,NPTSG
000122 210 B(I,1) = A(I,1,1)
000131 220 CONTINUE
000131 VAL = FLAGR(NPTSG,GAM,B,YG)
000140 RETURN
000141 END

```

LAGINT

SUBPROGRAM LENGTH  
000322

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

S	=	000016	100	=	000050	110	=	000055	120	=	000071
140	=	000074	200	=	000120	210	=	000122	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

043000

## 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,XIK,F,XK)
DIMENSION XIK(1),F(1),W(3)
LAGRANGE INTERPOLATING FUNCTION
DO 200 I=1,NPTS
IT=I
IF(XK.LE.XIK(I))GO TO 210
200 CONTINUE
FLAGR=F(NPTS)+(XK-XIK(NPTS))*(F(NPTS)-F(NPTS-1))
1 / (XIK(NPTS)-XIK(NPTS-1))
RETURN
205 CONTINUE
FLAGR=F(1)+(XK-XIK(1))*(F(1)-F(2))
1 / (XIK(1)-XIK(2))
RETURN
210 IF(XK.EQ.XIK(I))GO TO 500
IGO = 3
IF(IT.LE.2)IGO=1
IF(IT.EQ.NPTS) IGO = 2
B=0.0
IF(IGO.EQ.2) GO TO 350
C PARABOLA FROM THE RIGHT
IF(IT.EQ.1)GO TO 205
DO 300 I=1,3
IARG = IT-2+I
WEIGHT = 1.
DO 290 J=1,3
IF(J.EQ.I)GO TO 290
JARG = IT - 2 + J
WEIGHT = WEIGHT*((XK-XIK(JARG))/(XIK(IARG)-XIK(JARG)))
290 CONTINUE
W(I) = WEIGHT
300 CONTINUE
DO 310 K=1,3
IARG = IT - 2 + K
B = B + W(K)*F(IARG)
310 CONTINUE
IF(IGO.EQ.1)GO TO 600
C PARABOLA FROM THE LEFT
350 CONTINUE
DO 400 I=1,3
IARG = IT - 3 + I
WEIGHT = 1.0
DO 390 J=1,3
IF(J.EQ.I)GO TO 390
JARG = IT - 3 + J
WEIGHT = WEIGHT*((XK-XIK(JARG))/(XIK(IARG)-XIK(JARG)))
390 CONTINUE
W(I)= WEIGHT
400 CONTINUE
DO 410 K=1,3
IARG = IT - 3 + K
B = B + W(K)*F(IARG)
410 CONTINUE
IF(IGO.EQ.2)GO TO 600
B = B * 0.5
GO TO 600
500 CONTINUE

```

```
000166      B = F(IT)
000170      600 CONTINUE
000170      FLAGR = 3
000172      RETURN
000172      END
```

FLAGR

SUBPROGRAM LENGTH  
000231

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

205	-	000030	210	-	000040	290	-	000077	350	-	000121
390	-	000142	500	-	000166	600	-	000170			

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS

B	-	000223	FLAGR	-	000214	I	-	000220	IARG	-	000224
L	-	000222	IT	-	000221	J	-	000226	JARG	-	000227
K	-	000230	W	-	000215	WEIGHT	-	000225			

START OF CONSTANTS  
000174

START OF TEMPORARIES  
000177

START OF INDIRECTS  
000207

UNUSED COMPILER SPACE  
043000

FWA OF THE LOAD 101  
 LWA+1 OF THE LOAD 530??  
 TRANSFER ADDRESS -- OPACK 250  
 NO. TABLE MOVES 38

625318 WORDS WERE REQUIRED FOR LOADING

## PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	PREFIX TABLE CONTENTS
/COSTM/	101	135		
/VPASS/	236	11		
OPACK	247	31022	BINPAK	
/TEMP/	31271	517		
TEMPV	32010	55	BINPAK	
/OPT/	32065	6		
DAMALM	32073	1706	BINPAK	
/MM/	34001	132		
/THK/	34133	2		
/N/	34135	6		
COPRO	34143	6032	BINPAK	
OMGHT	42175	101	BINPAK	
COSTMT	42276	701	BINPAK	
MINCOR	43177	70	BINPAK	
SHOCKE	43267	112	BINPAK	
VIHRTN	43401	1133	BINPAK	
LAGINT	44534	322	BINPAK	
FLAGR	45056	231	BINPAK	
SYSTEM	45307	1125	SL-NUCLEUS	05/24/73
ACGOER	46434	12	SL-LIB33	OP
GETRA	46446	17	SL-LIB33	OP
CHEKIT	46465	32	SL-LIB33	OP
SURT	46517	45	SL-LIB33	OP
INPUTC	46564	104	SL-LIB33	OP
CUTPTC	46670	104	SL-LIB33	OP
REXIMM	46774	115	SL-LIB33	OP
KRAKER	47111	1041	SL-LIB33	OP
KUDER	50152	1254	SL-LIB33	05/17/73
SIO8	51426	1451	SL-SYSIO	10/30/73 14.49.36. SCOPE 3.4 COMPASS 3.73247

1.149 CP SECONDS LOAD TIME

### 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 1000 FORMAT  
(612, 5E 10.0)

#### Columns

- |       |  |
|-------|--|
| 1 - 2 | NIC - Code number of container material to be used.  |
| 3- 4  | IC - Code denoting type of optimization to be used;<br>IC = 1, MIL-STD-810B excitation<br>IC = 2, Multiple sine excitation<br>IC = 3, Random excitation.                                       |
| 5- 6  | IITM - Item number which is an arbitrary number assigned to the item being shipped. IITM <u>must not be greater than two digits</u> (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  | MXI* - 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 ( $^{\circ}$ F).
- 53-62 TEMH\* - High environmental temperature ( $^{\circ}$ 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).  $g^2/Hz$  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  $20^{\circ}$ 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<sup>3</sup>).

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

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

18-23 Safe low temperature (°F).

24-38 Low stress<sup>(1)</sup> (lb/in.<sup>2</sup>).

39-53 High stress<sup>(1)</sup> (lb/in.<sup>2</sup>).

54-68 Gamma (lb/ft<sup>3</sup>).

Card Number Sixteen \*\* is read according to statement 10 FORMAT  
(E5.0, 3E6.0, 3E15.5).  
Only input data type specifications E5.0 and the  
first of 3E6.0 are used to read the data from this  
card type. Statement 10 FORMAT is also used for  
other data card input.

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.<sup>3</sup>).

---

\* 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.<sup>3</sup>). 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).

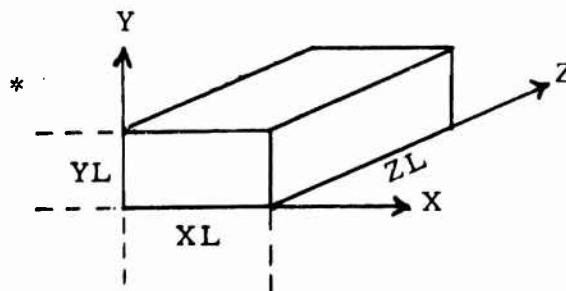
Columns

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).



### Input Data - Disk Files

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 scrutinization of that 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 USE 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

<u>Format</u>	
(E7.0, 5I2)	RHOM, DRPH, ICODE
E7.0	RHOM - Specific weight of the material (PCF)
I2	DRPH - Drop height
I2	ICODE - Code used in updating files
(5I2)	NT, NTH, NS
I2	NT - Number of temperatures (Max. = 5)
I2	NTH - Number of thicknesses (Max. = 10)
I2	NS - Number of stresses (Max. = 10)
(11E7.0)	(T(I), I = 1, NT)
E7.0	T(I) - One of the temperatures at which data is recorded (degrees fahrenheit)
(11E7.0)	(TH(I), I = 1, NTH)
E7.0	TH(I) - One of the material thicknesses considered during data gathering.

(11E7.0) (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) 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, 5I2) 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.)

#### 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  $T_1$ ,  $T_2$ , and  $T_3$  are compared to the corresponding newly calculated thicknesses  $TT_1$ ,  $TT_2$ , and  $TT_3$ , 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 OPACK Program output for each of the nine sample problems.



1.0

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

SAMPLE PROBLEM #1 (MULTIPLE SINE EXCITATION) CONSTANT TEMPERATURE

1 = IITH --- ITEM NUMBER  
 20 = MIC --- MAXIMUM NO. OF ITERATIONS FOR DROP HT. CALC.  
 75 = M2I --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE  
 11 = MCMJ --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
 3.3590E-01 (\$/LB) = CS --- COST OF SHIPMENT  
 25.00 (\$ ) = CI --- COST OF ITEM  
 .125000 (IN.) = TCON --- THICKNESS OF CONTAINER  
 -90.00 ( F ) = TEMPL --- LOWEST ENVIRONMENT TEMPERATURE  
 120.00 ( F ) = TEMH --- HIGHEST ENVIRONMENT TEMPERATURE

(RAD/SEC) = OMJ(1) ALL OF THE ENVIRONMENTAL FREQ.  
 .28300E+006, 28300E+011, 25660E+023, 159E+026, 28300E+021, 88496E+033, 14159E+034, 3981E+035, 65487E+035, 96903E+036, 28319E+03

PSD INPUT FOR RANDOM EXCITATION  
 . . . . .

(G'S) = IDJ(1) - ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE OMJ, I's  
 .00000E+015, .00000E+011, .00000E+002, .00000E+003, .00000E+003, .00000E+003, .00000E+003, .00000E+003, .00000E+003, .00000E+003, .00000E+003, .00000E+003

1 = NC --- NUMBER OF CONTAINERS  
 1 = NITEM --- ITEM NUMBER  
 10 = MNMATS --- NUMBER OF MATERIALS ON FILE

CST-MAT	CST-FAM	CST-PAK	SL-TEMP	LH-STRS	MI-STRS	GAMMA
1.4200E+00	5.0000E-02	1.0000E-02	-2.2000E+01	1.0000E-01	1.0000E+00	1.5000E+00
5.4000E+00	5.0000E-02	1.0000E-02	-6.0000E+01	1.0000E-01	1.5000E+00	2.0000E+00
2.1600E+00	5.0000E-02	1.0000E-02	-3.4000E+01	3.0000E-02	3.0000E-01	2.4000E+00
1.4400E+00	5.0000E-02	1.0000E-02	-6.0000E+01	2.0000E-01	1.5000E+00	8.0000E-01
1.5800E+00	5.0000E-02	1.0000E-02	-4.0000E+01	3.0000E-02	3.0000E-01	1.5000E+00
1.3600E+00	5.0000E-02	1.0000E-02	-2.0000E+01	3.0000E-02	5.0000E-01	3.0000E+00
1.0000E+00	5.0000E-02	1.0000E-02	-2.0000E+01	2.0000E-02	2.0000E-01	7.9000E+00
1.0000E+00	5.0000E-02	1.0000E-02	-2.0000E+01	3.0000E-02	2.3000E-01	1.1000E+00
4.2000E+00	5.0000E-02	1.0000E-02	-2.0000E+01	1.0000E-02	1.5000E-01	1.1900E+01
2.1100E+00	5.0000E-02	1.0000E-02	-2.0000E+01	2.0000E-02	8.0000E-01	1.1100E+01

GAMMA CST-CONTAINER  
 1.7700E-03 2.3200E-03

1 = ITEM NUMBER  
 1.0000E+02 = HEIGHT OF ITEM HI ( POUNDS )  
 1.2000E+01 = DIMENSION PARALLEL TO X-AXIS 2ND LONGEST DIMENSION XL (INCHES)  
 1.2000E+01 = DIMENSION PARALLEL TO Y-AXIS 3RD LONGEST DIMENSION YL (INCHES)  
 2.4000E+01 = DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)  
 NUMBER = 4

MATERIAL CODES CONSIDERED ARE 2, 4,

MAX-G	PCNT-DAM	REPLACE-CST
5.5000E+01	0.	0.
6.0000E+01	5.0000E+00	5.0000E+00
6.5000E+01	2.0000E+01	1.0000E+01
7.0000E+01	8.0000E+01	1.5000E+01

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5505E+00 TT2= 2.5505E+00 TT3= 3.0306E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2311E+00 TT2= 2.2311E+00 TT3= 2.2050E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1569E+00 TT2= 2.1569E+00 TT3= 2.0991E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1511E+00 TT2= 2.1511E+00 TT3= 2.6241E+00  
 SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS  
 SHOCK THICKNESS= 2.6241E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E+02

(2.2) MATERIAL 4 IS BEING DELETED  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1085E+00 3.1085E+00 3.4565E+00  
 3.5987E+00 3.5987E+00 3.4550E+00  
 3.0097E+00 3.0098E+00 2.9943E+00  
 2.9322E+00 2.9322E+00 2.6241E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 2.994 INCHES

(2.4) TOTAL COST/ITEM= 81.01  
 MINCOS-INPUT  
 COST MATRIX-MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 .99 .99 .59  
 2 3.24 3.24 1.55  
 4 .72 .72 .36

(2.5) FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY 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 OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 81.01 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9497E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.9053E+00 TT2= 1.9053E+00 TT3= 2.0002E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.0818E+00 TT2= 2.0818E+00 TT3= 2.0506E+00

MATERIAL 3 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.32901E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.20000E+01

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.7316E+00 4.7316E+00 3.4839E+00  
 7.4540E+00 7.4540E+00 3.7270E+00  
 2.0918E+00 0. 0.

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.732 INCHES  
 MATERIAL CODE = 1 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 .64  
 2 4.71 4.71 1.64

FOR 5.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 88.50 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE  
 WITH A FINAL COST OF 93.15 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 93.50 DOLLARS/ITEM

```

*****
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2650E+00 TT2= 2.2650E+00 TT3= 2.8687E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.5796E+00 TT2= 1.5796E+00 TT3= 1.7876E+00
MINIMUM THICKNESS FOR MATERIAL BY AXIS
      4.5755E+00      4.5755E+00      3.9839E+00
      1.9587E+00      1.9587E+00      1.9272E+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= 87.98
MINCOS=INPUT
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL
  1      1.46      1.46      .64
  2      1.76      1.76      .87

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S
THE COST IS 87.98 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 97.98 DOLLARS/ITEM

```

```

*****
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1222E+00 TT2= 2.1222E+00 TT3= 2.7877E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.2538E+00 TT2= 1.2538E+00 TT3= 1.5790E+00
MINIMUM THICKNESS FOR MATERIAL BY AXIS
      4.5755E+00      4.5755E+00      3.9839E+00
      1.9587E+00      1.9587E+00      1.9272E+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= 87.98
MINCOS=INPUT
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL
  1      1.46      1.46      .64
  2      1.76      1.76      .87

FOR 20.00 PER-CENT 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 439.90 DOLLARS FOR OVER SHIPPING
FOR ALLOWING DAMAGE THE COST IS 102.98 DOLLARS/ITEM

```

- ```

*****
(3.1) 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

(3.2) 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

```

3.3

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

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

\*\*\*\*\*





\*\*\*\*\*  
 (2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.9766E+00 TT2= 3.9766E+00 TT3= 3.3233E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5589E+00 TT2= 2.5589E+00 TT3= 2.3593E+00

MATERIAL 2 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.3290E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.2000E+03

(2.2) MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 7.4540E+00 7.4540E+00 3.7270E+00  
 2.5589E+00 0. 0.

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.1217E+00 TT2= 3.1217E+00 TT3= 2.7756E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.8544E+00 3.8544E+00 3.7283E+00

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1=-8.8229E+00 TT2=-8.8229E+00 TT3=-9.6140E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 1.9587E+00 1.9587E+00 9.7936E-01

(2.3) MATERIAL CODE = 2 THICKNESS FOR FACE ONE = 20.592 INCHES  
 MATERIAL CODE = 2 THICKNESS FOR FACE TWO = 20.592 INCHES  
 MATERIAL CODE = 2 THICKNESS FOR FACE THREE = 10.296 INCHES

(2.4) TOTAL COST/ITEM= 465.60  
 MINCUS=INPUT  
 COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
 2 16.53 18.53 4.63

(2.5) FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 55.0 G'S  
 THE COST IS 465.60 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
 WITH A FINAL COST OF 465.60 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 465.60 DOLLARS/ITEM

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8096E+00 TT2= 3.8096E+00 TT3= 3.2163E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.8544E+00 3.8544E+00 3.7283E+00

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.8769E+00 TT2= 2.8769E+00 TT3= 2.6188E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.8544E+00 3.8544E+00 3.7283E+00

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1=-1.0693E+01 TT2=-1.0693E+01 TT3=-1.1334E+01  
 T1=-1.0693E+01 T2=-1.0693E+01 T3=-1.1334E+01 TT1=-6.7993E+00 TT2=-6.7993E+00 TT3= 1.0726E+00  
 T1=-6.7993E+00 T2=-6.7993E+00 T3= 1.0726E+00 TT1=-1.0693E+01 TT2=-1.0693E+01 TT3=-1.1334E+01  
 T1=-1.0693E+01 T2=-1.0693E+01 T3=-1.1334E+01 TT1=-6.7993E+00 TT2=-6.7993E+00 TT3= 1.0726E+00  
 T1=-6.7993E+00 T2=-6.7993E+00 T3= 1.0726E+00 TT1=-1.0693E+01 TT2=-1.0693E+01 TT3=-1.1334E+01





1.0 I = NIO --- CODE NO. OF CONTAINER MATERIAL TO BE USED  
 I = IO --- OPTIMIZATION CODE

SAMPLE PROBLEM #3 (MIL-STD 810B  
 EXCITATION) CONSTANT TEMPERATURE

I = IIM --- ITEM NUMBER  
 NM = MII --- MAXIMUM NO. OF ITERATIONS FOR DYNAMIC CALC.  
 IN = MII --- MAXIMUM NO. OF ITERATIONS FOR D-CONVERGENCE  
 II = MII --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
 3.35E+01 (3) = C1 --- COST OF SHIPMENT  
 25.00 (3) = C2 --- COST OF ITEM  
 1.25E+01 (1) = T1 --- THICKNESS OF CONTAINER  
 72.00 (3) = TEM1 --- LOWEST ENVIRONMENT TEMPERATURE  
 74.00 (3) = TEM2 --- HIGHEST ENVIRONMENT TEMPERATURE

DATA SET 1 (001) ALL OF THE ENVIRONMENTAL FREQ.  
 1.2000E+03, 2.0000E+03, 2.5000E+03, 3.1500E+03, 3.9800E+03, 4.9800E+03, 6.3000E+03, 7.9400E+03, 1.0000E+04, 1.2500E+04, 1.5700E+04, 2.0000E+04

INPUT FOR HAZARD EXCITATION

DATA SET 2 (002) ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE OMJ(I)S  
 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01, 1.0000E+01

I = NIO --- NUMBER OF CONTAINERS  
 I = IIM --- ITEM NUMBER  
 IO = NMATS --- NUMBER OF MATERIALS ON FILE

| ST-MAT     | CST-MAT    | CST-MAT    | SL-TEMP     | LR-STRS    | MI-STRS    | GAMMA      |
|------------|------------|------------|-------------|------------|------------|------------|
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+01 | 1.0000E+01 | 1.0000E+00 | 1.5000E+00 |
| 5.0000E+00 | 5.0000E+02 | 1.0000E+02 | -6.0000E+01 | 1.0000E+01 | 1.5000E+00 | 2.0000E+00 |
| 2.0000E+01 | 5.0000E+02 | 1.0000E+02 | -3.0000E+01 | 3.0000E+02 | 3.0000E+01 | 2.0000E+00 |
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -4.0000E+01 | 2.0000E+01 | 1.5000E+00 | 4.0000E+01 |
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -4.0000E+01 | 3.0000E+02 | 3.0000E+01 | 1.5000E+00 |
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+02 | 3.0000E+02 | 5.0000E+01 | 3.0000E+00 |
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+01 | 2.0000E+02 | 2.0000E+01 | 2.0000E+00 |
| 1.0000E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+01 | 3.0000E+02 | 2.0000E+01 | 1.1000E+00 |
| 2.0000E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+01 | 1.0000E+02 | 1.5000E+01 | 1.1000E+01 |
| 2.1100E+01 | 5.0000E+02 | 1.0000E+02 | -2.0000E+01 | 2.0000E+02 | 8.0000E+01 | 1.1100E+01 |

GAMMA CST-CONTAINER  
 1.2000E+03 2.3500E+03

I = ITEM NUMBER  
 1.0000E+02 = HEIGHT OF ITEM (IN INCHES)  
 1.2000E+01 = DIMENSION PARALLEL TO X-AXIS AND LONGEST DIMENSION XL (INCHES)  
 1.2000E+01 = DIMENSION PARALLEL TO Y-AXIS AND LONGEST DIMENSION YL (INCHES)  
 2.0000E+01 = DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)

MATERIAL CODES CONSIDERED ARE 1, 2, 4, 10,

| MAT-G      | PENT-MAT   | REPLACE-CST |
|------------|------------|-------------|
| 1.0000E+01 | .          | .           |
| 5.0000E+01 | 5.0000E+00 | 1.0000E+00  |
| 5.0000E+01 | 2.0000E+01 | 4.0000E+00  |
| 2.0000E+01 | 4.0000E+01 | 1.5000E+01  |

\*\*\*\*\*  
 (2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8356E+00 TT2= 3.4356E+00 TT3= 3.7544E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 5.1629E+00 TT2= 5.1629E+00 TT3= 4.0832E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.8322E+00 TT2= 2.8322E+00 TT3= 2.5361E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4109E+00 TT2= 2.4109E+00 TT3= 2.9096E+00

MATERIAL 2 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.86532E+01 MAX ALLOWABLE OPTIMUM THICKNESS = 1.20000E+01

MATERIAL 3 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.86532E+01 MAX ALLOWABLE OPTIMUM THICKNESS = 1.20000E+01

SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS  
 SHOCK THICKNESS= 2.9096E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E-02

(2.2) MATERIAL 4 IS BEING DELETED  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 5.6061E+00 5.6061E+00 4.3535E+00  
 5.1629E+00 0. 0.  
 2.8322E+00 0. 0.  
 2.9096E+00 2.9096E+00 2.9096E+00

(2.3) MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 5.606 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 5.606 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE THREE = 4.354 INCHES

(2.4) TOTAL COST/ITEM= 92.01  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 1.29 1.29 .70

(2.5) FOR 0.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 10.0 G'S  
 THE COST IS 92.01 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
 WITH A FINAL COST OF 92.01 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 92.01 DOLLARS/ITEM

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9497E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.5755E+00 4.5755E+00 3.9839E+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= 87.98  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 1.46 1.46 .64

FOR 5.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 87.98 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE  
 WITH A FINAL COST OF 92.43 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 88.98 DOLLARS/ITEM

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2650E+00 TT2= 2.2650E+00 TT3= 2.8687E+00  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 3.9839E+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# 87.98  
MINUSS-INPUT  
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
1 1.46 1.46 .64

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S  
THE COST IS 87.98 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 91.98 DOLLARS/ITEM

\*\*\*\*\*  
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1222E+00 TT2= 2.1222E+00 TT3= 2.7877E+00  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 3.9839E+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# 87.98  
MINUSS-INPUT  
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
1 1.46 1.46 .64

FOR 80.00 PER-CENT 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 439.90 DOLLARS FOR OVER SHIPPING  
FOR ALLOWING DAMAGE THE COST IS 102.98 DOLLARS/ITEM

\*\*\*\*\*

- (3.1) OVER SHIPPING DATA  
THE OPTIMUM COST IS 92.01 DOLLARS  
THE FRAGILITY RATE IS 10.0 G'S  
THE PER-CENT DAMAGE IS 0.0  
THE MULTIPLICATION FACTOR IS 1.0
- (3.2) THE OPTIMUM THICKNESS FOR FACE ONE IS 5.606 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE TWO IS 5.606 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE THREE IS 4.354 INCHES IF MATERIAL 1 IS USED
- (3.3) DAMAGE ALLOWABLE DATA  
THE OPTIMUM COST IS 88.98 DOLLARS  
THE FRAGILITY RATE IS 60.0 G'S  
THE PER-CENT DAMAGE IS 5.0  
THE REPAIR COST/ITEM # 1.00 DOLLARS
- (3.4) 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 3.984 INCHES IF MATERIAL 1 IS USED

③.5 THE ABOVE PER-CENTAGE DAMAGE IS THE BEST POLICY

\*\*\*\*\*



1.0

1 = NSIC --- TOTAL WT. OF CONTAINER MATERIAL TO BE USED  
 3 = IC --- OPTIMIZATION CODE

SAMPLE PROBLEM #4 (RANDOM EXCITATION) CONSTANT TEMPERATURE

1 = ITEM --- ITEM NUMBER  
 2 = MIC --- MAXIMUM NO. OF ITERATIONS FOR DYNAMIC CALC.  
 3 = MCI --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE  
 4 = MFI --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
 5.344E+01 (53.44) = CS --- COST OF SHIPMENT  
 2E+01 (20) = CI --- COST OF ITEM  
 1E+01 (10) = TIN --- THICKNESS OF CONTAINER  
 2E+00 (2) = TMIN --- LOWEST ENVIRONMENT TEMPERATURE  
 2E+00 (2) = TMAX --- HIGHEST ENVIRONMENT TEMPERATURE

(HARD/SEC) = CMJ(I) ALL OF THE ENVIRONMENTAL FREQ.  
 1.9278E+001, 8.899E+013, 7.6891E+017, 5.4982E+011, 5.0796E+023, 0.1593E+026, 0.3106E+021, 2.0637E+032, 5.1274E+034, 8.2549E+033

PSD INPUT FOR RANDOM EXCITATION  
 1.6677E+005, 1.707E+014, 9.1000E+011, 1.9000E+011, 1.1300E+005, 3.9900E+075, 8.3000E+065, 0.9000E+075, 0.9000E+075, 0.9000E+075

(G)S = (I)S --- ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE CMJ(I)S  
 . . . . .

1 = NC --- NUMBER OF CONTAINERS  
 4 = NITEM --- ITEM NUMBER  
 10 = NNMATS --- NUMBER OF MATERIALS ON FILE

| CST-MAT     | CST-FAB   | CST-PAR   | SL-TEMP    | LW-STRS   | HI-STRS   | GAMMA     |
|-------------|-----------|-----------|------------|-----------|-----------|-----------|
| 1.42E+01    | 5.000E+02 | 1.000E+02 | +2.200E+01 | 1.000E+01 | 1.000E+00 | 1.500E+00 |
| 5.4E+01E+00 | 5.000E+02 | 1.000E+02 | +4.000E+01 | 1.000E+01 | 1.500E+00 | 2.000E+00 |
| 2.1E+01E+01 | 5.000E+02 | 1.000E+02 | +4.000E+01 | 2.000E+02 | 3.000E+01 | 2.000E+00 |
| 1.4E+01E+00 | 5.000E+02 | 1.000E+02 | +6.000E+01 | 2.000E+01 | 1.500E+00 | 8.000E+01 |
| 1.5E+01E+01 | 5.000E+02 | 1.000E+02 | +9.000E+01 | 3.000E+02 | 3.000E+01 | 1.500E+00 |
| 1.3E+01E+00 | 5.000E+02 | 1.000E+02 | +7.000E+01 | 3.000E+02 | 5.000E+01 | 3.000E+00 |
| 1.000E+00   | 5.000E+02 | 1.000E+02 | +2.000E+01 | 2.000E+02 | 2.000E+01 | 7.000E+00 |
| 1.000E+00   | 5.000E+02 | 1.000E+02 | +2.000E+01 | 3.000E+02 | 2.000E+01 | 1.100E+00 |
| 9.200E+00   | 5.000E+02 | 1.000E+02 | +2.000E+01 | 1.000E+02 | 1.500E+01 | 1.100E+01 |
| 2.110E+00   | 5.000E+02 | 1.000E+02 | +2.100E+01 | 2.000E+02 | 8.000E+01 | 1.110E+01 |

GAMMA CST-CONTAINER  
 1.700E+03 2.320E+01

1=ITEM NUMBER  
 1.000E+02=HEIGHT OF ITEM WIC (POUNDS)  
 1.200E+01= DIMENSION PARALLEL TO X-AXIS AND LONGEST DIMENSION XL (INCHES)  
 1.200E+01= DIMENSION PARALLEL TO Y-AXIS AND LONGEST DIMENSION YL (INCHES)  
 2.000E+01= DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)  
 NUMBER 8

MATERIAL CODES CONSIDERED ARE 1, 2, 4, 10,

| MAT=0     | PENL-DAM  | REPLACE=CST |
|-----------|-----------|-------------|
| 1.500E+01 | 0.        | 0.          |
| 8.000E+01 | 5.000E+00 | 5.000E+00   |
| 8.000E+01 | 2.000E+01 | 1.000E+01   |
| 7.000E+01 | 8.000E+01 | 1.500E+01   |

.....

(2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.6928E+00 TT2= 3.6928E+00 TT3= 3.6784E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 4.8371E+00 TT2= 4.8371E+00 TT3= 3.8745E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.7572E+00 TT2= 2.7572E+00 TT3= 2.4875E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3820E+00 TT2= 2.3820E+00 TT3= 2.9779E+00

SMOOR THICKNESS IS LARGER THAN VIBRATION THICKNESS  
 SMOOR THICKNESS= 2.8779E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E-02

MATERIAL 4 IS BEING DELETED

(2.2) MINIMUM THICKNESS FOR MATERIAL BY AXIS

|            |            |            |
|------------|------------|------------|
| 5.6861E+00 | 5.6861E+00 | 4.3535E+00 |
| 6.4101E+00 | 6.4101E+00 | 6.2941E+00 |
| 3.0044E+00 | 3.0044E+00 | 2.9943E+00 |
| 2.4322E+00 | 2.9322E+00 | 2.8779E+00 |

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 2.994 INCHES

TOTAL COST/ITEM= 81.01  
 MING S-INPUT

COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL

|   |      |      |      |
|---|------|------|------|
| 1 | 1.79 | 1.79 | .70  |
| 2 | 6.22 | 6.22 | 2.83 |
| 4 | .72  | .72  | .35  |

(2.5) FOR 10.0 PER-CENT DAMAGE AND A FRAGILITY RATE OF 15.0 G'S  
 THE COST IS 81.01 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
 WITH A FINAL COST OF 41.01 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 81.01 DOLLARS/ITEM

.....

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9497E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.4053E+00 TT2= 1.4053E+00 TT3= 2.0000E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.0818E+00 TT2= 2.0818E+00 TT3= 2.0506E+00

MATERIAL 3 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.3290E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.2000E+01

MINIMUM THICKNESS FOR MATERIAL BY AXIS

|            |            |            |
|------------|------------|------------|
| 4.7316E+00 | 4.7316E+00 | 3.9839E+00 |
| 2.4540E+00 | 2.4540E+00 | 3.7270E+00 |
| 2.0548E+00 | 0.         | 0.         |

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.732 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 4.732 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE THREE = 3.984 INCHES

TOTAL COST/ITEM= 49.50  
 MING S-INPUT

COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL

|   |      |      |      |
|---|------|------|------|
| 1 | 1.51 | 1.51 | .69  |
| 2 | 6.71 | 6.71 | 1.68 |

FOR 5.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 49.50 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE  
 WITH A FINAL COST OF 43.16 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 49.50 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2650E+00 TT2= 2.2650E+00 TT3= 2.8687E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.5796E+00 TT2= 1.5796E+00 TT3= 1.7876E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.5755E+00 4.5755E+00 3.9839E+00  
 1.4587E+00 1.4587E+00 1.9272E+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= 87.98  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL  
 1 1.45 1.45 .64  
 2 1.76 1.76 .47

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S  
 THE COST IS 87.98 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 97.98 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1222E+00 TT2= 2.1222E+00 TT3= 2.7877E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.2538E+00 TT2= 1.2538E+00 TT3= 1.5796E+00  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.5755E+00 4.5755E+00 3.9839E+00  
 1.4587E+00 1.4587E+00 1.9272E+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= 87.98  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL  
 1 1.45 1.45 .64  
 2 1.76 1.76 .87

FOR 40.00 PER-CENT 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 439.90 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 102.98 DOLLARS/ITEM

\*\*\*\*\*

3.1 OVER SHIPPING DATA  
 THE OPTIMUM COST IS 81.01 DOLLARS  
 THE FRAGILITY RATE IS 15.0 G'S  
 THE PER-CENT DAMAGE IS 0.0  
 THE MULTIPLICATION FACTOR IS 1.0

3.2 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

(3.3) DAMAGE ALLOWABLE DATA  
THE OPTIMUM COST IS \$1.01 DOLLARS  
THE FRAGILITY RATE IS 15.0 G'S  
THE PER-CENT 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

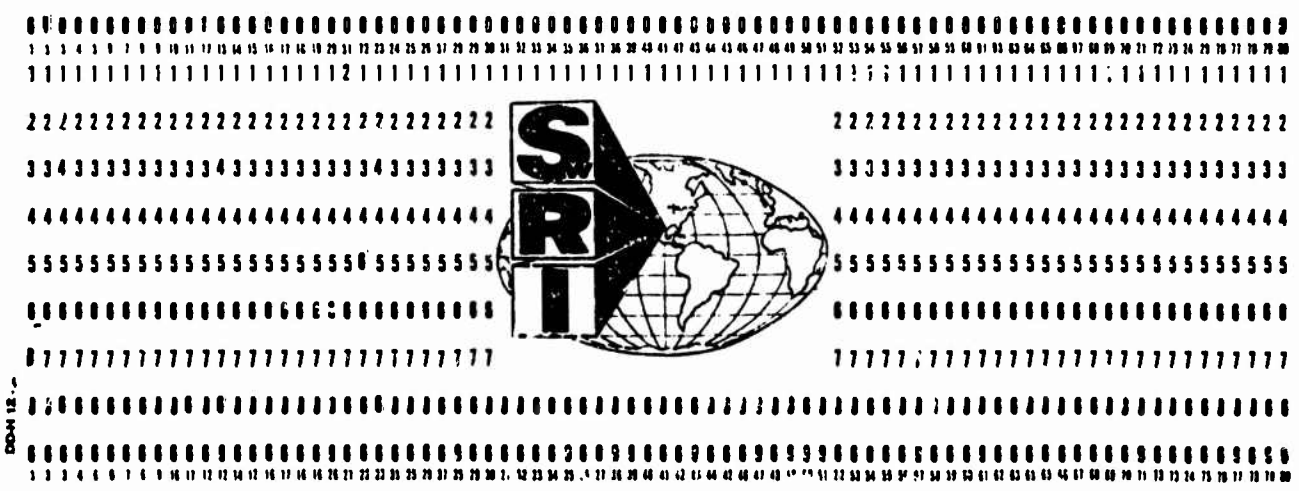
(3.5) OVERSHIPPING IS THE BEST POLICY

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TABLE VIII  
 SAMPLE PROBLEM NUMBER FIVE  
 INPUT DATA CARDS

Reproduced from  
 best available copy.

| Card No. | 1      | 2        | 3         | 4     | 5       | 6    | 7     | 8     | 9      | 10    | 11    | 12       | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|----------|--------|----------|-----------|-------|---------|------|-------|-------|--------|-------|-------|----------|----|----|----|----|----|----|----|----|----|
| 1        | 0102   | 12075110 | 0.3359000 | 25.00 | 0.12    | 0.00 | 72.00 | 0     | 72.00  | 0     |       |          |    |    |    |    |    |    |    |    |    |
| 2        | 6.283  | 64.83    | 125.6     | 14.1  | 19028.2 | 1.84 | 76317 | 1.594 | 298.23 | 654.8 | 576.0 | 36283.14 |    |    |    |    |    |    |    |    |    |
| 3        |        |          |           |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 4        | 0.5    | 0.5      | 0.5       | 2.0   | 3.0     | 3.0  | 4.0   | 3.0   | 3.0    | 3.0   | 3.0   | 3.0      |    |    |    |    |    |    |    |    |    |
| 5        | 010110 |          |           |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 6        | 1.92   | 0.15     | 0.1       | -22.0 | 0.10    |      | 1.00  |       |        |       |       | 1.5      |    |    |    |    |    |    |    |    | 1  |
| 7        | 5.40   | 0.15     | 0.1       | -60.0 | 0.14    |      | 1.50  |       |        |       |       | 2.0      |    |    |    |    |    |    |    |    | 2  |
| 8        | 2.16   | 0.15     | 0.1       | -34.0 | 0.03    |      | 0.30  |       |        |       |       | 2.4      |    |    |    |    |    |    |    |    | 3  |
| 9        | 1.44   | 0.15     | 0.1       | -60.0 | 0.20    |      | 1.50  |       |        |       |       | 0.8      |    |    |    |    |    |    |    |    | 4  |
| 10       | 1.53   | 0.15     | 0.1       | -40.0 | 0.03    |      | 0.30  |       |        |       |       | 1.5      |    |    |    |    |    |    |    |    | 5  |
| 11       | 1.36   | 0.15     | 0.1       | -20.0 | 0.03    |      | 0.50  |       |        |       |       | 3.0      |    |    |    |    |    |    |    |    | 6  |
| 12       | 1.00   | 0.15     | 0.1       | -20.0 | 0.02    |      | 0.20  |       |        |       |       | 7.9      |    |    |    |    |    |    |    |    | 7  |
| 13       | 1.00   | 0.15     | 0.1       | -20.0 | 0.03    |      | 0.20  |       |        |       |       | 1.1      |    |    |    |    |    |    |    |    | 8  |
| 14       | 4.20   | 0.15     | 0.1       | -20.0 | 0.01    |      | 0.15  |       |        |       |       | 11.9     |    |    |    |    |    |    |    |    | 9  |
| 15       | 2.11   | 0.15     | 0.1       | -20.0 | 0.02    |      | 0.80  |       |        |       |       | 11.1     |    |    |    |    |    |    |    |    | 10 |
| 16       | 0.017  | 0.0023   |           |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 17       | 1      | 0.5      | 12.0      | 12.0  | 12.0    | 12.0 | 4     |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 18       | 20.0   | 0.0      | 0.0       |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 19       | 60.0   | 5.0      | 5.0       |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 20       | 65.0   | 20.0     | 10.0      |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |
| 21       | 70.0   | 80.0     | 15.0      |       |         |      |       |       |        |       |       |          |    |    |    |    |    |    |    |    |    |



(1.0)

1 = NIC --- CODE NO. OF CONTAINER MATERIAL TO BE USED  
2 = II --- OPTIMIZATION CODE

SAMPLE PROBLEM #5 (MULTIPLE SINE EXCITATION) CONSTANT TEMPERATURE

1 = IITH --- ITEM NUMBER  
20 = MIO --- MAXIMUM NO. OF ITERATIONS FOR DROP HT. CALC.  
24 = MVI --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE  
11 = NOMB --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
3.3440E+01 (\$/LB) = CS --- COST OF SHIPMENT  
25.00 ( \$ ) = CI --- COST OF ITEM  
.125000 (IN.) = TCIN --- THICKNESS OF CONTAINER  
72.00 ( F ) = TEMPL --- LOWEST ENVIRONMENT TEMPERATURE  
72.00 ( F ) = TEMH --- HIGHEST ENVIRONMENT TEMPERATURE

1.44745E01 = DMJ(I) ALL OF THE ENVIRONMENTAL FREQ.  
.28710E+01 2.8300E+01 1.25460E+02 3.14159E+02 2.8300E+02 1.88496E+03 3.14159E+03 3.9823E+03 6.5487E+03 9.6903E+03 2.8319E+03

INPUT FOR RANDOM EXCITATION

DMJ(I) = DMJ(I) - ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE DMJ(I)S  
.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

1 = NC --- NUMBER OF CONTAINERS  
1 = NITEM --- ITEM NUMBER  
10 = MNMATS --- NUMBER OF MATERIALS ON FILE

| CO-MAT     | CST-FAM    | CST-PAK    | SL-TEMP     | LW-STRS    | MI-STRS    | GAMMA      |
|------------|------------|------------|-------------|------------|------------|------------|
| 1.4400E+00 | 5.0000E-02 | 1.0000E-02 | -2.2000E+01 | 1.0000E-01 | 1.0000E+00 | 1.5000E+00 |
| 5.4000E+00 | 5.0000E-02 | 1.0000E-02 | -6.0000E+01 | 1.4000E-01 | 1.5000E+00 | 2.0000E+00 |
| 2.1600E+00 | 5.0000E-02 | 1.0000E-02 | -3.4000E+01 | 3.0000E-02 | 3.0000E-01 | 2.4000E+00 |
| 1.4400E+00 | 5.0000E-02 | 1.0000E-02 | -6.0000E+01 | 2.0000E-01 | 1.5000E+00 | 8.0000E-01 |
| 1.4400E+00 | 5.0000E-02 | 1.0000E-02 | -4.0000E+01 | 3.0000E-02 | 3.0000E-01 | 1.5000E+00 |
| 1.3600E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 3.0000E-02 | 5.0000E-01 | 3.0000E+00 |
| 1.0000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 2.0000E-02 | 2.0000E-01 | 7.0000E+00 |
| 1.0000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 3.0000E-02 | 2.0000E-01 | 1.1000E+00 |
| 4.2000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 1.0000E-02 | 1.5000E-01 | 1.1400E+01 |
| 2.1100E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 2.0000E-02 | 8.0000E-01 | 1.1100E+01 |

GAMMA CST=CONTAINER  
1.7000E+03 2.3200E+03

1=ITEM NUMBER  
5.0000E+01=HEIGHT OF ITEM W/ ( POUNDS )  
1.2000E+01= DIMENSION PARALLEL TO X-AXIS 2ND LONGEST DIMENSION XL (INCHES)  
1.2000E+01= DIMENSION PARALLEL TO Y-AXIS 3RD LONGEST DIMENSION YL (INCHES)  
1.2000E+01= DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)  
NUMBER :

MATERIAL CODES CONSIDERED ARE 1, 2, 4, 6, 10,

| MAX-G      | PCIT-DAM   | WEPLACE-CST |
|------------|------------|-------------|
| 2.0000E+01 | 1.         | 0.          |
| 6.0000E+01 | 5.0000E+00 | 5.0000E+00  |
| 6.0000E+01 | 2.7000E+01 | 1.0000E+01  |
| 7.0000E+01 | 8.0000E+01 | 1.5000E+01  |

\*\*\*\*\*

(2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.6079E+00 TT2= 3.6079E+00 TT3= 3.6079E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 4.5007E+00 TT2= 4.5007E+00 TT3= 4.5007E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.1777E+00 TT2= 3.1777E+00 TT3= 3.1777E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 4.2808E+00 TT2= 4.2808E+00 TT3= 4.2808E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.7021E+00 TT2= 2.7021E+00 TT3= 2.7021E+00

(2.2) MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 5.6276E+00 5.6276E+00 5.6276E+00  
 6.9366E+00 6.9366E+00 6.9366E+00  
 6.0115E+00 6.0115E+00 6.0115E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

(2.3) MATERIAL CODE = 10 THICKNESS FOR FACE ONE = 2.943 INCHES  
 MATERIAL CODE = 10 THICKNESS FOR FACE TWO = 2.943 INCHES  
 MATERIAL CODE = 10 THICKNESS FOR FACE THREE = 2.943 INCHES

(2.4) TOTAL COST/ITEM= 59.12  
 MINCOS=INPUT  
 COST MATRIX-MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 .90 .90 .90  
 2 3.12 3.12 3.12  
 4 .72 .72 .72  
 6 .70 .70 .70  
 10 .52 .52 .52

(2.5) FOR 0.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 20.0 G'S  
 THE COST IS 59.12 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
 WITH A FINAL COST OF 59.12 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 59.12 DOLLARS/ITEM

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T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.6616E+00 TT2= 2.6616E+00 TT3= 2.6616E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4155E+00 TT2= 2.4155E+00 TT3= 2.4155E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3442E+00 TT2= 2.3442E+00 TT3= 2.3442E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8600E+00 TT2= 3.8600E+00 TT3= 3.8600E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3853E+00 TT2= 2.3853E+00 TT3= 2.3853E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94  
 MINCOS=INPUT  
 COST MATRIX-MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 .50 .50 .50  
 2 1.63 1.63 1.63  
 4 .36 .36 .36  
 6 .70 .70 .70  
 10 .52 .52 .52

FOR 5.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE

WITH A FINAL COST OF 60.94 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 62.94 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5433E+00 TT2= 2.5433E+00 TT3= 2.5433E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1548E+00 TT2= 2.1548E+00 TT3= 2.1548E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2400E+00 TT2= 2.2400E+00 TT3= 2.2400E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8074E+00 TT2= 3.8074E+00 TT3= 3.8074E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3457E+00 TT2= 2.3457E+00 TT3= 2.3457E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94

MINGOS-INPUT

COST MATRIX-MATERIAL VERTICAL AXIS HORIZONTAL

|    |      |      |      |
|----|------|------|------|
| 1  | .50  | .50  | .50  |
| 2  | 1.63 | 1.63 | 1.63 |
| 4  | .36  | .36  | .36  |
| 6  | .70  | .70  | .70  |
| 10 | .52  | .52  | .52  |

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S  
 THE COST IS 57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.25 TIMES ONE  
 WITH A FINAL COST OF 72.43 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 67.94 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4250E+00 TT2= 2.4250E+00 TT3= 2.4250E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.8942E+00 TT2= 1.8942E+00 TT3= 1.8942E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1358E+00 TT2= 2.1358E+00 TT3= 2.1358E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.7547E+00 TT2= 3.7547E+00 TT3= 3.7547E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3061E+00 TT2= 2.3061E+00 TT3= 2.3061E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94

MINGOS-INPUT

COST MATRIX-MATERIAL VERTICAL AXIS HORIZONTAL

|   |      |      |      |
|---|------|------|------|
| 1 | .50  | .50  | .50  |
| 2 | 1.63 | 1.63 | 1.63 |
| 4 | .36  | .36  | .36  |
| 6 | .70  | .70  | .70  |

10 .52 .52 .52

FOR 80.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 70.0 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 SHIPPING  
FOR ALLOWING DAMAGE THE COST IS 72.94 DOLLARS/ITEM

\*\*\*\*\*

3.1 OVER SHIPPING 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

3.2 THE OPTIMUM THICKNESS FOR FACE ONE IS 2.943 INCHES IF MATERIAL 10 IS USED  
THE OPTIMUM THICKNESS FOR FACE TWO IS 2.943 INCHES IF MATERIAL 10 IS USED  
THE OPTIMUM THICKNESS FOR FACE THREE IS 2.943 INCHES IF MATERIAL 10 IS USED

3.3 DAMAGE ALLOWABLE DATA  
THE OPTIMUM COST IS 59.12 DOLLARS  
THE FRAGILITY RATE IS 20.0 G'S  
THE PER-CENT DAMAGE IS 0.0  
THE REPAIR COST/ITEM = 0.00 DOLLARS

3.4 THE OPTIMUM THICKNESS FOR FACE ONE IS 2.943 INCHES IF MATERIAL 10 IS USED  
THE OPTIMUM THICKNESS FOR FACE TWO IS 2.943 INCHES IF MATERIAL 10 IS USED  
THE OPTIMUM THICKNESS FOR FACE THREE IS 2.943 INCHES IF MATERIAL 10 IS USED

3.5 OVERSHIPPING IS THE BEST POLICY

\*\*\*\*\*



(1.0)

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

SAMPLE PROBLEM #6 (MULTIPLE SINE  
 EXCITATION) VARYING TEMPERATURE

1 = IITM --- ITEM NUMBER  
 20 = MIC --- MAXIMUM NO. OF ITERATIONS FOR DROP MT. CALC.  
 25 = MII --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE  
 11 = MOMJ --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
 3.3590E-01 (\$/LB) = CS --- COST OF SHIPMENT  
 25.00 ( \$ ) = CI --- COST OF ITEM  
 .125000 (IN.) = TCCN --- THICKNESS OF CONTAINER  
 72.00 ( F ) = TCEL --- LOWEST ENVIRONMENT TEMPERATURE  
 100.00 ( F ) = TCEH --- HIGHEST ENVIRONMENT TEMPERATURE

(RAD/SEC) = OMJ(1) ALL OF THE ENVIRONMENTAL FREQ.  
 .20300E+006.20300E+011.25660E+021.14159E+024.20300E+021.80496E+033.14159E+034.34023E+035.65407E+035.96903E+036.20319E+03

PSD INPUT FOR RANDOM EXCITATION

(G'S) = RDJ(1) - ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE OMJ(I)'S  
 .00000E-015.00000E-011.00000E+002.00000E+003.00000E+003.00000E+003.00000E+003.00000E+003.00000E+003.00000E+003.00000E+00

1 = NC --- NUMBER OF CONTAINERS  
 1 = NITEM --- ITEM NUMBER  
 10 = NMMITS--- NUMBER OF MATERIALS ON FILE

| CST-MAT    | CST-FAB    | CST-PAK    | SL-TEMP     | LW-STRS    | MI-STRS    | GAMMA      |
|------------|------------|------------|-------------|------------|------------|------------|
| 1.4200E+00 | 5.0000E-02 | 1.0000E-02 | -2.2000E+01 | 1.0000E-01 | 1.0000E+00 | 1.5000E+00 |
| 5.4000E+00 | 5.0000E-02 | 1.0000E-02 | -6.0000E+01 | 1.0000E-01 | 1.5000E+00 | 2.0000E+00 |
| 2.1600E+00 | 5.0000E-02 | 1.0000E-02 | -3.0000E+01 | 3.0000E-02 | 3.0000E-01 | 2.0000E+00 |
| 1.4400E+00 | 5.0000E-02 | 1.0000E-02 | -6.0000E+01 | 2.0000E-01 | 1.5000E+00 | 0.0000E+01 |
| 1.4800E+00 | 5.0000E-02 | 1.0000E-02 | -9.0000E+01 | 3.0000E-02 | 3.0000E-01 | 1.5000E+00 |
| 1.3600E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 3.0000E-02 | 5.0000E-01 | 3.0000E+00 |
| 1.0000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 2.0000E-02 | 2.0000E-01 | 7.0000E+00 |
| 1.0000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 3.0000E-02 | 2.0000E-01 | 1.1000E+00 |
| 4.2000E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 1.0000E-02 | 1.5000E-01 | 1.1400E+01 |
| 2.1100E+00 | 5.0000E-02 | 1.0000E-02 | -2.0000E+01 | 2.0000E-02 | 0.0000E-01 | 1.1100E+01 |

GAMMA CST-CONTAINER  
 1.1000E-03 2.3200E-03

I=ITEM NUMBER  
 1.0000E+02=HEIGHT OF ITEM MIC (POUNDS)  
 1.2000E+01= DIMENSION PARALLEL TO X-AXIS 2ND LONGEST DIMENSION XL (INCHES)  
 1.2000E+01= DIMENSION PARALLEL TO Y-AXIS 3RD LONGEST DIMENSION YL (INCHES)  
 2.0000E+01= DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)  
 NUMBER =

MATERIAL CODES CONSIDERED ARE 1, 2, 4, 10.

| MAX-G      | PCNT-OAM   | REPLACE-CST |
|------------|------------|-------------|
| 5.5000E+01 | 0.         | 0.          |
| 6.0000E+01 | 5.0000E+00 | 5.0000E+00  |
| 6.5000E+01 | 2.0000E+01 | 1.0000E+01  |
| 7.0000E+01 | 0.0000E+01 | 1.5000E+01  |

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.....
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5505E+00 TT2= 2.5505E+00 TT3= 3.0306E+00
(2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2311E+00 TT2= 2.2311E+00 TT3= 2.2050E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1569E+00 TT2= 2.1569E+00 TT3= 2.0991E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1511E+00 TT2= 2.1511E+00 TT3= 2.6241E+00
SMOOR THICKNESS IS LARGER THAN VIBRATION THICKNESS
SMOOR THICKNESS= 2.6241E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E-02

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.....
(2.2) MATERIAL 4 IS BEING DELETED
MINIMUM THICKNESS FOR MATERIAL BY AXIS
3.1085E+00 3.1085E+00 3.6565E+00
3.5987E+00 3.5987E+00 3.4550E+00
3.0098E+00 3.0098E+00 2.4943E+00
2.9322E+00 2.9322E+00 2.6241E+00

```

```

.....
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3060E+00 TT2= 2.3060E+00 TT3= 2.8920E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.6730E+00 TT2= 1.6730E+00 TT3= 1.8477E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.0284E+00 TT2= 2.0284E+00 TT3= 2.0160E+00

```

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.....
MATERIAL 3 IS BEING DELETED
OPTIMUM THICKNESS = 1.32901E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.20000E+01

```

```

.....
MINIMUM THICKNESS FOR MATERIAL BY AXIS
4.7316E+00 4.7316E+00 3.9839E+00
7.4540E+00 7.4540E+00 1.7270E+00
2.0284E+00 0. 0.

```

```

.....
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.9914E+00 TT2= 1.9914E+00 TT3= 2.7136E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1= 1.6556E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1= 1.6556E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2= 1.6556E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2= 1.6556E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 2.0497E+00
T1=-4.0578E+00 T2=-4.0578E+00 T3= 2.0497E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2= 2.0497E+00 T3= 1.3880E+00 TT1= 1.6556E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1= 1.6556E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2= 1.6556E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2= 1.6556E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 2.0497E+00
T1=-4.0578E+00 T2=-4.0578E+00 T3= 2.0497E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1= 1.6556E+00 T2=-4.0578E+00 T3= 2.0497E+00 TT1=-4.0578E+00 TT2= 1.6556E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2= 2.0497E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2= 1.6556E+00 TT3= 1.3880E+00
T1= 1.6556E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 2.0497E+00
T1=-4.0578E+00 T2= 1.6556E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2=-4.0578E+00 T3= 2.0497E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 1.3880E+00
T1= 1.6556E+00 T2=-4.0578E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2= 1.6556E+00 TT3= 1.3880E+00
T1=-4.0578E+00 T2= 2.0497E+00 T3= 1.3880E+00 TT1=-4.0578E+00 TT2=-4.0578E+00 TT3= 2.0497E+00
CAN NOT DETERMINE THICKNESS FOR DRCP HGT. CALCULATIONS MATERIAL CODE = 2 THIS MATERIAL DELETED

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.....
MINIMUM THICKNESS FOR MATERIAL BY AXIS
4.5753E+00 4.5755E+00 3.9839E+00
0. 0. 0.

```

```

(2.3) MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 7.968 INCHES
MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 7.964 INCHES

```

MATERIAL COEF = 1 THICKNESS FOR FACE THREE = 3.984 INCHES

2.4 TOTAL COST/ITEM = 100.82  
MINUS-INPUT  
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
1 2.55 2.55 .64

2.5 FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 55.0 G'S  
THE COST IS 100.82 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
WITH A FINAL COST OF 100.82 DOLLARS FOR OVER SHIPPING  
FOR ALLOWING DAMAGE THE COST IS 100.82 DOLLARS/ITEM

\*\*\*\*\*  
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9997E+00  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 3.9839E+00

\*\*\*\*\*  
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1410E+00 TT2= 2.1410E+00 TT3= 2.7984E+00

MATERIAL 1 IS BEING DELETED  
NO TEMPERATURE OVERLAP  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 2.7984E+00

ALL MATERIALS DELETED --- NO OVERLAP BETWEEN TEMPERATURES-OPTIMIZE ON DATA ACCUMULATED  
\*\*\*\*\*

3.1 OVER SHIPPING DATA  
THE OPTIMUM COST IS 100.82 DOLLARS  
THE FRAGILITY RATE IS 55.0 G'S  
THE PER-CENT DAMAGE IS 0.0  
THE MULTIPLICATION FACTOR IS 1.0

3.2 THE OPTIMUM THICKNESS FOR FACE ONE IS 2.968 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE TWO IS 2.968 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.984 INCHES IF MATERIAL 1 IS USED

3.3 DAMAGE ALLOWABLE DATA  
THE OPTIMUM COST IS 100.82 DOLLARS  
THE FRAGILITY RATE IS 55.0 G'S  
THE PER-CENT DAMAGE IS 0.0  
THE REPAIR COST/ITEM = 0.00 DOLLARS

3.4 THE OPTIMUM THICKNESS FOR FACE ONE IS 2.968 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE TWO IS 2.968 INCHES IF MATERIAL 1 IS USED  
THE OPTIMUM THICKNESS FOR FACE THREE IS 3.984 INCHES IF MATERIAL 1 IS USED

3.5 OVERSHIPPING IS THE BEST POLICY





.....

(2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5505E+00 TT2= 2.5505E+00 TT3= 3.0306E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2311E+00 TT2= 2.2311E+00 TT3= 2.2050E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1569E+00 TT2= 2.1569E+00 TT3= 2.0991E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1511E+00 TT2= 2.1511E+00 TT3= 2.6241E+00  
 SHOCK THICKNESS IS LARGER THAN VIBRATION THICKNESS  
 SHOCK THICKNESS= 2.6241E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E-02

(2.2) MATERIAL 4 IS BEING DELETED  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1085E+00 3.1085E+00 3.6565E+00  
 3.5942E+00 3.5942E+00 3.4550E+00  
 3.0048E+00 3.0048E+00 2.9943E+00  
 2.4322E+00 2.4322E+00 2.6241E+00

(2.3) MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 2.994 INCHES

TOTAL COST/ITEM= 81.01  
 MINORS=INPUT  
 COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL  
 1 .49 .49 .59  
 2 3.24 3.24 1.55  
 4 .72 .72 .36

(2.4) FOR 3.00 PERCENT DAMAGE AND A FRAGILITY 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 OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 81.01 DOLLARS/ITEM

.....

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9497E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.9053E+00 TT2= 1.9053E+00 TT3= 2.0000E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.0816E+00 TT2= 2.0816E+00 TT3= 2.0504E+00

MATERIAL 3 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.3290E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.2000E+01

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.7916E+00 4.7916E+00 3.9839E+00  
 2.7540E+00 2.7540E+00 3.7270E+00  
 2.6718E+00 0. 0.

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.792 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE TWO = 4.792 INCHES  
 MATERIAL CODE = 1 THICKNESS FOR FACE THREE = 3.984 INCHES

TOTAL COST/ITEM= 44.51  
 MINORS=INPUT  
 COST MATRIX=MATERIAL VERTICAL AXIS HORIZONTAL  
 1 1.51 1.51 .64  
 2 5.71 5.71 1.64

FOR 5.00 PERCENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 44.51 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE  
 WITH A FINAL COST OF 44.16 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 44.51 DOLLARS/ITEM

```

*****
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2650E+00 TT2= 2.2650E+00 TT3= 2.8677E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.5796E+00 TT2= 1.5796E+00 TT3= 1.7876E+00
MINIMUM THICKNESS FOR MATERIAL BY AXIS
  4.5755E+00  4.5755E+00  3.9839E+00
  1.9587E+00  1.9587E+00  1.9272E+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= 87.98
MINCOS=INPUT
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL
  1  1.46  1.46  .64
  2  1.76  1.76  .87

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S
THE COST IS 87.98 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 97.98 DOLLARS/ITEM

```

```

*****
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1222E+00 TT2= 2.1222E+00 TT3= 2.7877E+00
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.2538E+00 TT2= 1.2538E+00 TT3= 1.5790E+00
MINIMUM THICKNESS FOR MATERIAL BY AXIS
  4.5755E+00  4.5755E+00  3.9839E+00
  1.9587E+00  1.9587E+00  1.9272E+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= 87.98
MINCOS=INPUT
COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL
  1  1.46  1.46  .64
  2  1.76  1.76  .87

FOR 80.00 PER-CENT 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 439.90 DOLLARS FOR OVER SHIPPING
FOR ALLOWING DAMAGE THE COST IS 102.98 DOLLARS/ITEM

```

- ```

*****
3.1 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

3.2 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

```

3.3 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

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

\*\*\*\*\*



1.0

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

SAMPLE PROBLEM #8 (RANDOM EXCITATION) CONSTANT TEMPERATURE

1 = IITM --- ITEM NUMBER  
 20 = MIC --- MAXIMUM NO. OF ITERATIONS FOR DROP WT. CALC.  
 75 = MXI --- MAXIMUM NO. OF ITERATIONS FOR G-CONVERGENCE  
 10 = MOMJ --- NUMBER OF ENVIRONMENTAL FREQUENCIES  
 3.3590E-01 (\$/LB) = CS --- COST OF SHIPMENT  
 25.00 ( \$ ) = CI --- COST OF ITEM  
 .125000 (IN.) = ICUN --- THICKNESS OF CONTAINER  
 72.00 ( F ) = TEMPL --- LOWEST ENVIRONMENT TEMPERATURE  
 73.00 ( F ) = TEMH --- HIGHEST ENVIRONMENT TEMPERATURE

(RAD/SEC) = OMJ(I) ALL OF THE ENVIRONMENTAL FREQ.  
 .42478E+001.88496E+013.76991E+017.53492E+011.50796E+023.01593E+026.03186E+021.20637E+032.41274E+034.82544E+03

NO INPUT FOR RANDOM EXCITATION  
 .6000E-04 .1700E-041.4100E-041.1400E-041.1300E-045.0900E-075.8300E-065.0900E-075.0900E-075.0900E-07

(G'S) = KDJ(I) - ENVIRONMENTAL EXCITATIONS EACH CORRESPONDING TO ONE OF THE ABOVE OMJ(I)'S  
 \* \* \* \* \*

1 = NC --- NUMBER OF CONTAINERS  
 1 = MITEM --- ITEM NUMBER  
 10 = MNMATS --- NUMBER OF MATERIALS ON FILE

CST-MAT	CST-FAB	CST-PAN	SL-TEMP	LW-STRS	HI-STRS	GAMMA
1.9280E+00	5.0000E-02	1.0000E-02	-2.2000E+01	1.0000E-01	1.0000E+00	1.5000E+00
5.4000E+00	5.0000E-02	1.0000E-02	-6.0000E+01	1.4000E-01	1.5000E+00	2.0000E+00
2.1600E+00	5.0000E-02	1.0000E-02	-3.4000E+01	3.0000E-02	3.0000E-01	2.4000E+00
1.4400E+00	5.0000E-02	1.0000E-02	-6.0000E+01	2.0000E-01	1.5000E+00	8.0000E-01
1.5800E+00	5.0000E-02	1.0000E-02	-4.0000E+01	3.0000E-02	3.0000E-01	1.5000E+00
1.3600E+00	5.0000E-02	1.0000E-02	-2.0000E+01	3.0000E-02	5.0000E-01	3.0000E+00
1.0000E+00	5.0000E-02	1.0000E-02	-2.0000E+01	2.0000E-02	2.0000E-01	7.4000E+00
1.0700E+00	5.0000E-02	1.0000E-02	-2.0000E+01	3.0000E-02	2.0000E-01	1.1000E+00
7.2000E+00	5.0000E-02	1.0000E-02	-2.0000E+01	1.0000E-02	1.5000E-01	1.1900E+01
2.1100E+00	5.0000E-02	1.0000E-02	-2.0000E+01	2.0000E-02	8.0000E-01	1.1100E+01

GAMMA CST-CONTAINER  
 1.7000E-03 2.3200E-03

1=ITEM NUMBER  
 1.0000E+02=WEIGHT OF ITEM MIC ( POUNDS )  
 1.2000E+01= DIMENSION PARALLEL TO X-AXIS 2ND LONGEST DIMENSION XL (INCHES)  
 1.2000E+01= DIMENSION PARALLEL TO Y-AXIS 3RD LONGEST DIMENSION YL (INCHES)  
 2.4000E+01= DIMENSION PARALLEL TO Z-AXIS LONGEST DIMENSION ZL (INCHES)  
 NUMBER \*

MATERIAL CODES CONSIDERED ARE 1, 2, 4, 10,

MAX-G	PCNT-DAM	REPLAC-CST
5.4000E+01	0.	0.
6.0000E+01	5.0000E+00	5.0000E+00
6.5000E+01	2.0000E+01	1.0000E+01
7.0000E+01	8.0000E+01	1.5000E+01

\*\*\*\*\*

(2.1) T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5505E+00 TT2= 2.5505E+00 TT3= 3.0306E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2311E+00 TT2= 2.2311E+00 TT3= 2.2050E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1569E+00 TT2= 2.1569E+00 TT3= 2.0991E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1511E+00 TT2= 2.1511E+00 TT3= 2.6241E+00  
 SMUCK THICKNESS IS LARGER THAN VIBRATION THICKNESS  
 SHOCK THICKNESS= 2.6241E+00 OPTIMUM VIBRATION THICKNESS= 3.2187E-02

(2.2) MATERIAL 4 IS BEING DELETED  
 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1085E+00 3.1085E+00 3.6565E+00  
 3.5987E+00 3.5987E+00 3.4550E+00  
 3.0098E+00 3.0098E+00 2.9943E+00  
 2.9322E+00 2.9322E+00 2.6241E+00

(2.3) MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.010 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 2.994 INCHES

(2.4) TOTAL COST/ITEM= 81.01  
 MINCOS-INPUT  
 COST MATRIX-MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 .99 .99 .59  
 2 3.24 3.24 1.55  
 4 .72 .72 .36

(2.5) FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY 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 OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 81.01 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4078E+00 TT2= 2.4078E+00 TT3= 2.9497E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.9053E+00 TT2= 1.9053E+00 TT3= 2.0000E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.0818E+00 TT2= 2.0818E+00 TT3= 2.0506E+00

MATERIAL 3 IS BEING DELETED  
 OPTIMUM THICKNESS = 1.32901E+02 MAX ALLOWABLE OPTIMUM THICKNESS = 1.20000E+01

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 4.7316E+00 4.7316E+00 3.9839E+00  
 7.4540E+00 7.4540E+00 3.7270E+00  
 2.0818E+00 0. 0.

MATERIAL CODE = 1 THICKNESS FOR FACE ONE = 4.732 INCHES  
 MATERIAL CODE = 1 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 .64  
 2 6.71 6.71 1.68

FOR 5.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 88.50 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE  
 WITH A FINAL COST OF 93.16 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 93.50 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2650E+00 TT2= 2.2650E+00 TT3= 2.8687E+00  
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.5796E+00 TT2= 1.5796E+00 TT3= 1.7876E+00  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 3.9839E+00  
1.9587E+00 1.9587E+00 1.9272E+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= 87.98

MINCOS=INPUT

COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL

1 1.46 1.46 .64  
2 1.76 1.76 .87

FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 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  
FOR ALLOWING DAMAGE THE COST IS 97.98 DOLLARS/ITEM

\*\*\*\*\*

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1222E+00 TT2= 2.1222E+00 TT3= 2.7877E+00  
T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.2538E+00 TT2= 1.2538E+00 TT3= 1.5790E+00  
MINIMUM THICKNESS FOR MATERIAL BY AXIS  
4.5755E+00 4.5755E+00 3.9839E+00  
1.9587E+00 1.9587E+00 1.9272E+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= 87.98

MINCOS=INPUT

COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL

1 1.46 1.46 .64  
2 1.76 1.76 .87

FOR 80.00 PER-CENT 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 439.90 DOLLARS FOR OVER SHIPPING  
FOR ALLOWING DAMAGE THE COST IS 102.98 DOLLARS/ITEM

\*\*\*\*\*

- 3.1 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

- 3.2 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

3.3 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

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

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2.1 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.7799E+00 TT2= 2.7799E+00 TT3= 2.7799E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.6761E+00 TT2= 2.6761E+00 TT3= 2.6761E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4483E+00 TT2= 2.4483E+00 TT3= 2.4483E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.9126E+00 TT2= 3.9126E+00 TT3= 3.9126E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4249E+00 TT2= 2.4249E+00 TT3= 2.4249E+00

2.2 MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

2.3 MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

2.4 TOTAL COST/ITEM= 57.94  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
 . .50 .50 .50  
 2 1.63 1.63 1.63  
 4 .36 .36 .36  
 6 .70 .70 .70  
 10 .52 .52 .52

2.5 FOR 0.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 55.0 G'S  
 THE COST IS 57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.00 TIMES ONE  
 WITH A FINAL COST OF 57.94 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 57.94 DOLLARS/ITEM

.....

T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.6616E+00 TT2= 2.6616E+00 TT3= 2.6616E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4155E+00 TT2= 2.4155E+00 TT3= 2.4155E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3442E+00 TT2= 2.3442E+00 TT3= 2.3442E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8600E+00 TT2= 3.8600E+00 TT3= 3.8600E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3853E+00 TT2= 2.3853E+00 TT3= 2.3853E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94  
 MINCOS=INPUT  
 COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL  
 1 .50 .50 .50  
 2 1.63 1.63 1.63  
 4 .36 .36 .36  
 6 .70 .70 .70  
 10 .52 .52 .52

FOR 5.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 60.0 G'S  
 THE COST IS 57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.05 TIMES ONE

WITH A FINAL COST OF 60.99 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 58.94 DOLLARS/ITEM

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.5433E+00 TT2= 2.5433E+00 TT3= 2.5433E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1548E+00 TT2= 2.1548E+00 TT3= 2.1548E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.2400E+00 TT2= 2.2400E+00 TT3= 2.2400E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.8074E+00 TT2= 3.8074E+00 TT3= 3.8074E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3457E+00 TT2= 2.3457E+00 TT3= 2.3457E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94

MINCOS=INPUT

COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL

1	.50	.50	.50
2	1.63	1.63	1.63
4	.36	.36	.36
6	.70	.70	.70
10	.52	.52	.52

FOR 20.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 65.0 G'S  
 THE COST IS 57.94 DOLLARS WITH A MULTIPLICATION FACTOR OF 1.25 TIMES ONE  
 WITH A FINAL COST OF 72.43 DOLLARS FOR OVER SHIPPING  
 FOR ALLOWING DAMAGE THE COST IS 61.94 DOLLARS/ITEM

\*\*\*\*\*  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.4250E+00 TT2= 2.4250E+00 TT3= 2.4250E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 1.8942E+00 TT2= 1.8942E+00 TT3= 1.8942E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.1358E+00 TT2= 2.1358E+00 TT3= 2.1358E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 3.7547E+00 TT2= 3.7547E+00 TT3= 3.7547E+00  
 T1= 3.5000E+00 T2= 3.5000E+00 T3= 3.5000E+00 TT1= 2.3061E+00 TT2= 2.3061E+00 TT3= 2.3061E+00

MINIMUM THICKNESS FOR MATERIAL BY AXIS  
 3.1204E+00 3.1204E+00 3.1204E+00  
 3.6125E+00 3.6125E+00 3.6125E+00  
 3.0213E+00 3.0213E+00 3.0213E+00  
 6.1683E+00 6.1683E+00 6.1683E+00  
 2.9435E+00 2.9435E+00 2.9435E+00

MATERIAL CODE = 4 THICKNESS FOR FACE ONE = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE TWO = 3.021 INCHES  
 MATERIAL CODE = 4 THICKNESS FOR FACE THREE = 3.021 INCHES

TOTAL COST/ITEM= 57.94

MINCOS=INPUT

COST MATRIX=MATERIAL VERTICAL, AXIS HORIZONTAL

1	.50	.50	.50
2	1.63	1.63	1.63
4	.36	.36	.36
6	.70	.70	.70

10 .52 .52 .52

FOR 80.00 PER-CENT DAMAGE AND A FRAGILITY RATE OF 70.0 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 SHIPPING  
FOR ALLOWING DAMAGE THE COST IS 72.94 DOLLARS/ITEM

\*\*\*\*\*

3.1 OVER SHIPPING DATA  
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

3.3 DAMAGE ALLOWABLE DATA  
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

3.4 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 OVERSHIPPING IS THE BEST POLICY

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## 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<sup>3</sup>. 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<sup>3</sup>, 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

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

range of Optimum Static Stress of 0.10 to 1.00 lb/in.<sup>2</sup>, 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<sup>(4)</sup>. 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

Material Description:	Urethane Foam (Ether Type)	
Material Code:	1	
Density in Data File: (lb/ft <sup>3</sup> )	2.0	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk. 304 (5)	Density: (lb/ft <sup>3</sup> )	2.0
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.10 to 1.00
Mustin, SVM-2 (!)	Safe Low Temperature: (°F)	-22
	<u>Parameters for VIBRATION DATA</u>	
PB 167 372, Zell(6)	Density: (lb/ft <sup>3</sup> )	2.0
"	Static Stress: (lb/in. <sup>2</sup> )	0.16
"	Thickness: (in.)	2.9
"	Temperature: (°F)	72.0
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	1.92
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

TABLE XV  
POLYETHYLENE DATA

Material Description:	Polyethylene Foam	
Material Code:	2	
Density in Data File (lb/ft <sup>3</sup> )	2.0	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk. 304 (5)	Density: (lb/ft <sup>3</sup> )	2.0
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.14 to 1.50
Estimated	Safe Low Temperature: (°F)	-60
	<u>Parameters for VIBRATION DATA</u>	
Estimated	Density: (lb/ft <sup>3</sup> )	2.1
Estimated	Static Stress: (lb/in. <sup>2</sup> )	1.0
Estimated	Thickness: (in.)	2.0
Estimated	Temperature: (°F)	72
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	5.40
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

TABLE XVI  
FELT DATA

Material Description:	Wood Fiber Felt	
Material Code:	3	
Density in Data File: (lb/ft <sup>3</sup> )	2.4	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk 304 (5)	Density: (lb/ft <sup>3</sup> )	2.4
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.03 to 0.30
Mustin, SVM-2 (1)	Safe Low Temperature: (°F)	-34
	<u>Parameters for VIBRATION DATA</u>	
Estimated	Density: (lb/ft <sup>3</sup> )	1.8
Estimated	Static Stress: (lb/in. <sup>2</sup> )	0.08
Estimated	Thickness: (in.)	4.0
Estimated	Temperature: (°F)	72
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	2.16
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

TABLE XVII  
POLYSTYRENE DATA

Material Description:	Polystyrene (Expanded Resilient)	
Material Code:	4	
Density in Data File: (lb/ft <sup>3</sup> )	0.8	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk. 304 (5)	Density: (lb/ft <sup>3</sup> )	0.4 to 1.5
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	1,* 1.5, 2, 3, 4, 6
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.20 to 1.50
Mustin, SVM-2 (1)	Safe Low Temperature: (°F)	-60
	<u>Parameters for VIBRATION DATA</u>	
PB 167 372, Zell(6)	Density: (lb/ft <sup>3</sup> )	0.8
"	Static Stress: (lb/in. <sup>2</sup> )	1.46
"	Thickness: (in.)	5.0
"	Temperature: (°F)	72
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	1.44
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

\*1 inch only for 18, 24, 36 inch drops.

TABLE XVIII  
RUBBER HAIR DATA

Material Description:	Rubberized Hair	
Material Code:	5	
Density in Data File: (lb/ft <sup>3</sup> )	1.5	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk. 304 (5)	Density: (lb/ft <sup>3</sup> )	1.5
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.03 to 0.30
Mustin, SVM-2 (1)	Safe Low Temperature: (°F)	-40
	<u>Parameters for VIBRATION DATA</u>	
Estimated	Density: (lb/ft <sup>3</sup> )	1.48
Estimated	Static Stress: (lb/in. <sup>2</sup> )	.256
Estimated	Thickness: (in.)	3.0
Estimated	Temperature: (°F)	72
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	1.58
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

TABLE XIX  
CELLULOSE DATA

Material Description:	Cellulose Wadding, Asphalt Treated	
Material Code:	6	
Density in Data File: (lb/ft <sup>3</sup> )	3.0 (Estimated)	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk, 304 (5)	Density: (lb/ft <sup>3</sup> )	2.91
"	Drop Heights: (in.)	18, 24, 30, 36*
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.03 to 0.50
Estimated	Safe Low Temperature: (°F)	-20
<u>Parameters for VIBRATION DATA</u>		
Wilson, L. T. (7) Sandia Labs	Density: (lb/ft <sup>3</sup> )**	2.91
"	Static Stress: (lb/in. <sup>2</sup> )	.268
"	Thickness: (in.)	3.0
"	Temperature: (°F)	72
<u>COST DATA</u>		
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	1.36
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

\* Drop Height 36" was estimated.

\*\* Compression of 16.7%.

TABLE XX  
VINYL FOAM DATA

Material Description:	Vinyl Foam	
Material Code:	7	
Density in Data File: (lb/ft <sup>3</sup> )	7.9	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
Estimated	Density: (lb/ft <sup>3</sup> )	7.97
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.02 to 0.20
Estimated	Safe Low Temperature: (°F)	-20
	<u>Parameters for VIBRATION DATA</u>	
Wilson, L. T. (7) Sandia Labs	Density: (lb/ft <sup>3</sup> )*	7.93
"	Static Stress: (lb/in. <sup>2</sup> )	.266
"	Thickness: (in.)	3.0
"	Temperature: (°F)	72
	<u>COST DATA</u>	
Estimated	Material Cost: (\$/ft <sup>3</sup> )	1.00
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

\*Compression of 16.1%.

TABLE XXI  
FIBER GLASS DATA

Material Description:	Fiber Glass	
Material Code:	8	
Density in Data File: (lb/ft <sup>3</sup> )	1.1	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
MIL-Hdbk. 304 (5)	Density: (lb/ft <sup>3</sup> )	1.1
"	Drop Heights: (in.)	18*, 24*, 30, 36*
"	Thicknesses: (in.)	2, 3, 4
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.03 to 0.20
Estimated	Safe Low Temperature: (°F)	-20
	<u>Parameters for VIBRATION DATA</u>	
Wilson, L. T. (7) Sandia Labs	Density: (lb/ft <sup>3</sup> )**	2.0
"	Static Stress: (lb/in. <sup>2</sup> )	.256
"	Thickness: (in.)	3.0
"	Temperature: (°F)	72
	<u>COST DATA</u>	
Estimated	Material Cost: (\$/ft <sup>3</sup> )	1.00
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

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

\*\*Compression of 15.8%.

TABLE XXII  
RUBBER FOAM DATA

Material Description:	Rubber Foam	
Material Code:	9	
Density in Data File: (lb/ft <sup>3</sup> )	11.9	
Data Reference Source	<u>Parameters for SHOCK DATA</u>	
Estimated	Density: (lb/ft <sup>3</sup> )	11.9
"	Drop Heights: (in.)	18, 24, 30, 36
"	Thicknesses: (in.)	2, 3, 4, 5
"	Temperature: (°F)	72
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.01 to 0.15
Mustin, SVM-2 (1)	Safe Low Temperature: (°F)	-20
	<u>Parameters for VIBRATION DATA</u>	
Wilson, L. T. (7) Sandia Labs	Density: (lb/ft <sup>3</sup> )*	11.9
"	Static Stress: (lb/in. <sup>2</sup> )	1.28
"	Thickness: (in.)	3.0
"	Temperature: (°F)	72
	<u>COST DATA</u>	
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	4.20
Estimated	Fabrication Cost: (\$/min)	0.05
Estimated	Packing Cost: (\$/min)	0.01

\* Compression of 3.0%.

TABLE XXIII  
AIR CAP DATA

Material Description:		Air Cap	
Material Code:		10	
Density in Data File: (lb/ft <sup>3</sup> )		1.1	
Data Reference Source	<u>Parameters for SHOCK DATA</u>		
Kinetic Systems, Inc. (8)	Density: (lb/ft <sup>3</sup> )	1.0	
	Drop Heights: (in.)	18, 24, 30, 36	
	Thicknesses: (in.)	1, 2, 3	
	Temperature: (°F)	72	
From Data Plots	Range of Optimum Static Stress: (lb/in. <sup>2</sup> )	0.02 to 0.80	
Estimated	Safe Low Temperature: (°F)	-20	
<u>Parameters for VIBRATION DATA</u>			
Estimated	Density: (lb/ft <sup>3</sup> )	1.8	
"	Static Stress: (lb/in. <sup>2</sup> )	0.08	
"	Thickness: (in.)	4.0	
"	Temperature: (°F)	72	
<u>COST DATA</u>			
Commercial Quote to SwRI	Material Cost: (\$/ft <sup>3</sup> )	2.11	
Estimated	Fabrication Cost: (\$/min)	0.05	
Estimated	Packing Cost: (\$/min)	0.01	

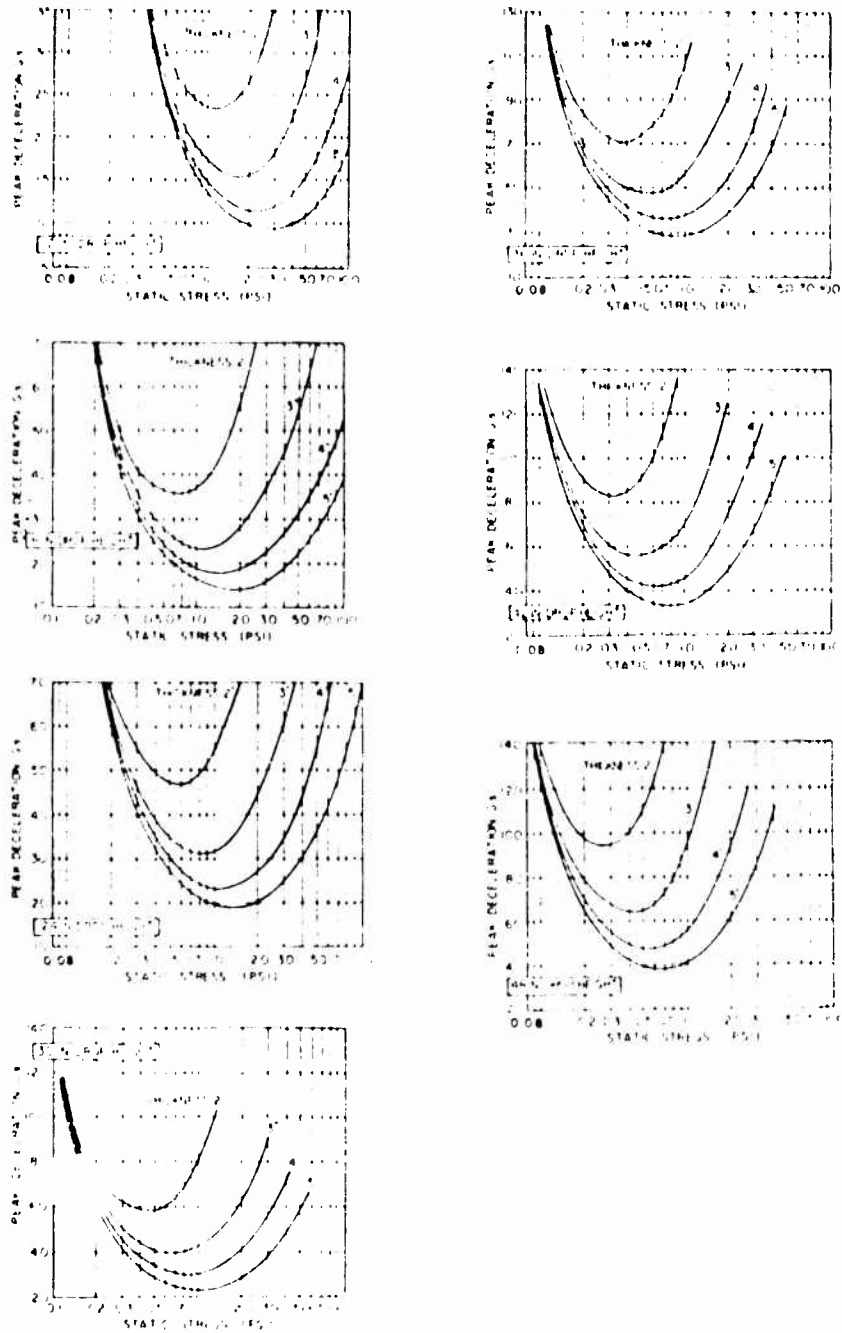


FIGURE 9. PEAK ACCELERATION VERSUS STATIC STRESS  
 CURVES FOR POLYETHYLENE FCAM  
 [Mustin, G. S. ]<sup>(1)</sup>

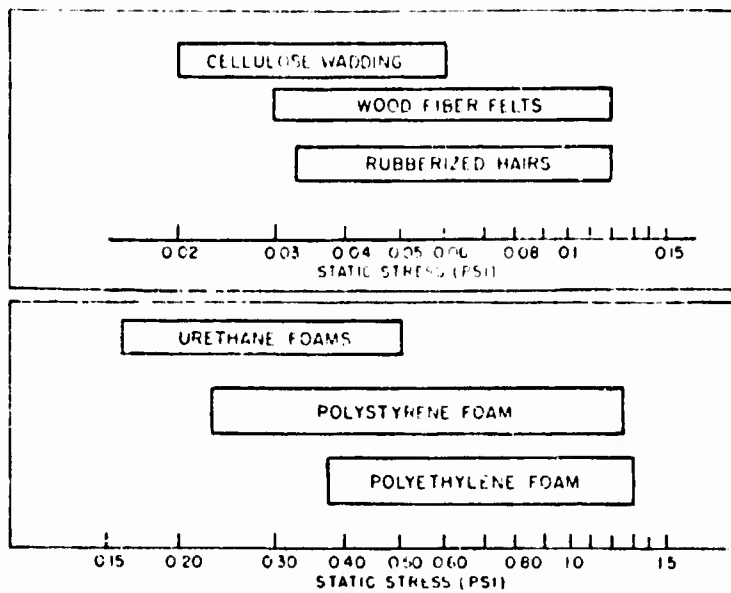


FIGURE 10. RANGE OF RECORDED OPTIMUM STATIC STRESSES

### 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

Shock Environment

<u>Format</u>	<u>Record No.</u>	
(E7.0, 5I2)	1	RHOM, DRPH, ICODE
E7.0		RHOM - Specific weight of the material (PCF)
I2		DRPH - Drop height
I2		ICODE - Code used in updating files
(5I2)	2	NT, NTH, NS
I2		NT - Number of temperatures (Max. = 5)
I2		NTH - Number of thicknesses (Max. = 10)
I2		NS - Number of stresses (Max. = 10)

<u>Format</u>	<u>Record No.</u>	
(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) (TAB <sub>i</sub> (I, J, K), J = 1, NS)
	thru	
	(NT) * (NTH)	TAB <sub>i</sub> (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  $lrs + 1$ , since the last record of the shock data ( $lrs$ ) will be

$$lrs = 4 * 5 + (NT_{18}) * (NTH_{18}) + (NT_{24}) * (NTH_{24}) \\ + (NT_{30}) * (NTH_{30}) + (NT_{36}) * (NTH_{36})$$

where for  $NT_i$  and  $NTH_i$  the subscript  $i$  denotes the indicated drop height.

## Input Data - Disk Files

### Vibration Environment

<u>Format</u>	<u>Record No.</u>	
(E7.0, 5I2)	lrs + 1	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)	lrs + 2	(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)	lrs + 3 thru lrs + MOMS	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)	lrs + MOMS + 1 thru lrs + MOMS + 1 + MOMS	XX READ (MS, F2) (TAB2 (I, J, 1), J = 1, MTS) TAB2 (I, J, 1) = EL/ER = F (Temp., Freq.)

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<sup>(8)</sup> 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 contained 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.

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

<u>Input Data on Card Number One</u>	
<u>Step 1.</u>	What is the shipping container material? Wood - NIC = _____ Paperboard - NIC = _____ etc.
<u>Step 2.</u>	Which type of vibration optimization is to be used? MIL-STD-810B - IC = 1 Multiple sine - IC = 2 Random - IC = 3
<u>Step 3.</u>	What is the Item Number? Set IITM = 1
<u>Step 4.</u>	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
<u>Step 5.</u>	Set MXI = 0
<u>Step 6.</u>	What is the number of environmental frequencies which are going to be provided as input? (Up to a maximum of 11) MOMJ = _____
<u>Step 7.</u>	What is the cost of shipping? CS = _____ (\$/lb)
<u>Step 8.</u>	What is the cost of the item? CI = _____ (\$)
<u>Step 9.</u>	What is the thickness of the shipping container? TCON = _____ (in.)
<u>Step 10.</u>	What is the lowest environmental temperature ( $^{\circ}$ F) to which the item will be exposed? TEML = _____ ( $^{\circ}$ F)

TABLE XXIV (Contd.)

Step 11. What is the highest environmental temperature ( $^{\circ}\text{F}$ ) to which the item will be exposed?

TEMH = \_\_\_\_\_ ( $^{\circ}\text{F}$ )

NOTE If  $(\text{TEMH} - \text{TEML}) \leq 20^{\circ}\text{F}$ , 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?

\_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_.

If the environmental frequencies are UNKNOWN, use  
 6.283, 62.83, 125.66, 314.159, 628.300, 1884.96,  
 3114.59, 4398.23, 5654.87, 5969.03, 6283.19  
 (rad/sec).

Input Data on Card Number Three

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

If the environmental frequencies of Step 12 are used and PSD values are UNKNOWN, use

0.000366, 0.000517, 0.000191, 0.000191, 0.000113,  
 $4.09(10)^{-7}$ ,  $5.83(10)^{-6}$ ,  $5.09(10)^{-7}$ ,  $5.09(10)^{-7}$ ,  $5.09(10)^{-7}$   
 ( $\text{g}^2/\text{Hz}$ ).

Input Data on Card Number Four

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

If the environmental frequencies of Step 12 are used and acceleration levels are UNKNOWN, use

0.5, 0.5, 1., 3., 3., 3., 3., 3., 3., 3., 3. (g)





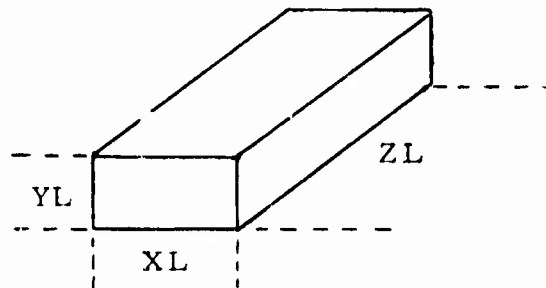


TABLE XXIV (Contd.)

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

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

where the lengths are:



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

$$NPCNT = \text{_____}$$

---

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?

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

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

$$PCTD(I) = \text{_____ (\%)}$$

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

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

Step 27. Repeat Steps 24, 25, 26 for each different percent damage allowable case indicated in Step 23 on a separate input data card.



Input Data on Card Number One

Step 1. The shipping container is cardboard.

$$\text{NIC} = 1$$

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

$$\text{IC} = 2$$

Step 3. The item number is No. 1

$$\text{IITM} = 1$$

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.

$$\text{MIC} = 20$$

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.

$$\text{CS} = 0.3359 \text{ (\$/lb)}$$

Step 8. The item cost is \$25.00.

$$\text{CI} = 25.00 \text{ (\$)}$$

Step 9. The shipping container is 0.125-in. thick.

$$\text{TCON} = 0.125 \text{ (in.)}$$

Step 10. 55°F is the lowest environmental temperature.

$$\text{TEML} = 55 \text{ (°F)}$$

Step 11. 72°F is the highest environmental temperature.

$$\text{TEMH} = 72 \text{ (°F)}$$

Since  $(\text{TEMH} - \text{TEML}) \leq 20^\circ\text{F}$ , make

$$\text{TEMH} = \text{TEML}$$

Input Data Card Number One would look like the following:













edit procedures in the NLABS U-1106 COMPUTER FACILITY 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.

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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 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 A-I. - URETHANE FOAM INPUT DATA

Static Stress W/A (psi)	5 in. thick GM <sub>5</sub> (g)	4 in. thick GM <sub>4</sub> (g)	3 in. thick GM <sub>3</sub> (g)	2 in. thick GM <sub>2</sub> (g)
0.04	62	70	80	100
0.05	54	60	70	90
0.07	43	48	55	75
0.09	35	40	45	65
0.14	26	29	34	54
0.16	24	25	30	52
0.18	22	24	29	50
0.20	20	22	28	50
0.50	19	25	42	78
0.80	30	48	79	124

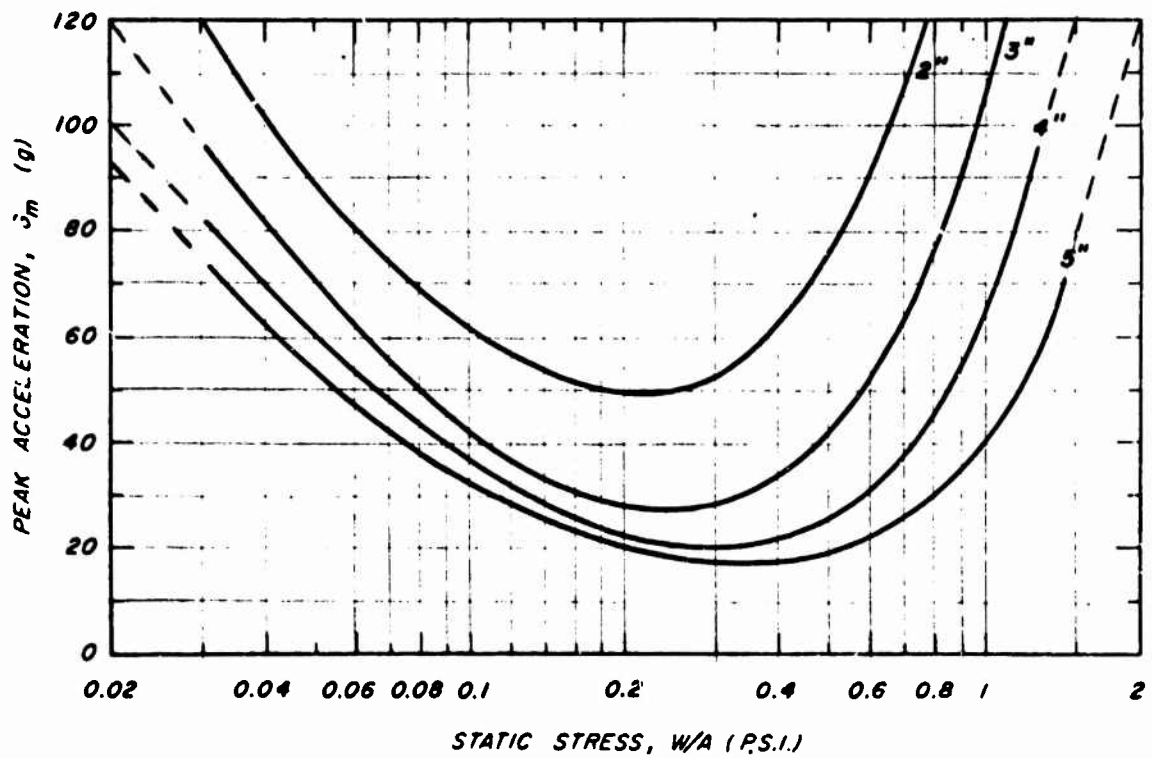


FIGURE A-1.  $G_m$ - $W/A$  Curves for Urethane Foam (Polyester Type, Large Celled, 4.0 pcf) for a 30-inch Drop Height.

\$NXYZ

NX = 10,  
NY = 4,  
NZ = 1,  
XV = 0.11E+00,  
YV = 0.32E+01,  
ZV = 0.0,

\$END

FUNCTION VALUE=	3.7802E+01		
XV= 1.1000E-01	YV= 3.2000E+00	ZV= 0.	
FUNCTION VALUE=	6.1657E+01		
XV= 1.0000E-01	YV= 2.0000E+00	ZV= 0.	
FUNCTION VALUE=	4.1943E+01		
XV= 1.0000E-01	YV= 3.0000E+00	ZV= 0.	
FUNCTION VALUE=	3.7224E+01		
XV= 1.0000E-01	YV= 4.0000E+00	ZV= 0.	
FUNCTION VALUE=	3.2343E+01		
XV= 1.0000E-01	YV= 5.0000E+00	ZV= 0.	
FUNCTION VALUE=	2.9836E+01		
XV= 1.0000E-01	YV= 5.5000E+00	ZV= 0.	
FUNCTION VALUE=	2.8000E+01		
XV= 2.0000E-01	YV= 3.0000E+00	ZV= 0.	
FUNCTION VALUE=	4.2000E+01		
XV= 5.0000E-01	YV= 3.0000E+00	ZV= 0.	
FUNCTION VALUE=	1.0500E+02		
XV= 2.0000E-02	YV= 3.0000E+00	ZV= 0.	
FUNCTION VALUE=	9.8000E+01		
XV= 2.0000E-02	YV= 4.0000E+00	ZV= 0.	
FUNCTION VALUE=	8.8000E+01		
XV= 2.0000E-01	YV= 1.0000E+00	ZV= 0.	
FUNCTION VALUE=	9.6371E+01		
XV= 1.0000E-01	YV= 1.0000E+00	ZV= 0.	
FUNCTION VALUE=	9.6371E+01		
XV= 1.0000E-01	YV= 1.0000E+00	ZV= 0.	

TABLE A-II. OUTPUT DATA

TABLE A-III. - URETHANE FOAM OUTPUT DATA

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

interpo-  
lated

extrapo-  
lated

```

000003      PROGRAM TEST(INPUT,OUTPUT,TAPE1=INPUT,TAPE2=OUTPUT)
000003      DIMENSION X(20),Y(20),Z(20),TAB(20,20,20),F(20)
000003      COMMON /N/ NZ,N',NX,YV,XV,ZV
000003      NAMELIST /NXYZ/ NX,NY,NZ,XV,YV,ZV
000003      READ(1,NXYZ)
000006      WRITE(2,NXYZ)
000011      READ 1000,(X(I),I=1,NX)
000024      IF(NY.GT.1)READ 1000,(Y(I),I=1,NY)
000041      IF(NZ.GT.1)READ 1000,(Z(I),I=1,NZ)
000056      READ 1000,(((TAB(I,J,K),I=1,NX),J=1,NY),K=1,NZ)
000104      GO TO 20
000105      10 CONTINUE
000105      IF(EOF,1)9999,15
000110      15 CONTINUE
000110      READ(1,NXYZ)
000113      20 CONTINUE
000113      CALL LAGINT(TAB,Z,Y,X,FV,F)
000117      PRINT 2000,FV,XV,YV,ZV
000133      1000 FORMAT(10F8.0)
000133      2000 FORMAT(1H 2X,*FUNCTION VALUE= *E12.4,/,
1          3X,*XV=*E12.4,2X,*YV=*E12.4,2X,*ZV=*E12.4,)
000133      GO TO 10
000134      9999 CONTINUE
000134      STOP
000136      END

```

TABLE A-IV. MAIN PROGRAM, TEST

```

SUBROUTINE LAGINT(A,ALF,BETA,GAM,VAL,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 ----- HORIZONTAL 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
000011 DIMENSION A(20,20,20),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
000011 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 5 F(K) = A(I,J,K)
000032 B(I,J) = FLAGR(NPTSA,ALF,F,ZA)
000044 10 CONTINUE
000050 GO TO 120
C      CHECK FOR TWO DIMENSIONS
000051 100 CONTINUE
000051 IF(NPTSB.EQ.1)GO TO 200
000053 DO 110 I=1,NPTSG
000055 DO 110 J=1,NPTSB
000056 110 B(I,J)=A(I,J,1)
C      SOLVE TWO DIMENSIONAL CASE
000073 120 CONTINUE
000073 DO 150 I=1,NPTSG
000075 DO 140 J=1,NPTSB
000076 140 F(J) = B(I,J)
000107 B(I,1)=FLAGR(NPTSB,BETA,F,XB)
000117 150 CONTINUE
000121 GO TO 220
C      SOLVE ONE DIMENSIONAL CASE
000122 200 CONTINUE
000122 DO 210 I=1,NPTSG
000124 210 B(I,1) = A(I,1,1)
000133 220 CONTINUE
000133 VAL = FLAGR(NPTSG,GAM,B,YG)
000142 RETURN
000143 END

```

TABLE A-V. SUBROUTINE, LAGINT

```

000007      FUNCTION   FLAGR(NPTS,XIK,F,XK)
000007      DIMENSION XIK(1),F(1),W(3)
C          LAGRANGE INTERPOLATING FUNCTION
000007      DO 200 I=1,NPTS
000010          IT=I
000011          IF(XK.LE.XIK(I))GO TO 210
000014      200 CONTINUE
000016      210 IF(XK.EQ.XIK(I))GO TO 500
000021          IGC = 3
000021          IF(IT.LE.2)IGO=1
000025          IF(IT.EQ.NPTS) IGO = 2
000030          B=0.0
000031          IF(IGO.EQ.2) GO TO 350
C          PARABOLA FROM THE RIGHT
000033          IF(IT.EQ.1)IT=2
000036          DO 300 I=1,3
000040          IARG = IT-2+I
000042          WEIGHT = 1.
000044          DO 290 J=1,3
000045          IF(J.EQ.I)GO TO 290
000047          JARG = IT - 2 + J
000050          WEIGHT = WEIGHT*((XK-XIK(JARG))/(XIK(IARG)-XIK(JARG)))
000057      290 CONTINUE
000061          W(I) = WEIGHT
000063      300 CONTINUE
000065          DO 310 K=1,3
000067          IARG = IT - 2 + K
000071          B = B + W(K)*F(IARG)
000075      310 CONTINUE
000077          IF(IGO.EQ.1)GO TO 600
C          PARABOLA FROM THE LEFT
000101      350 CONTINUE
000101          DO 400 I=1,3
000103          IARG = IT - 3 + I
000105          WEIGHT = 1.0
000107          DO 390 J=1,3
000110          IF(J.EQ.I)GO TO 390
000112          JARG = IT - 3 + J
000113          WEIGHT = WEIGHT*((XK-XIK(JARG))/(XIK(IARG)-XIK(JARG)))
000122      390 CONTINUE
000124          W(I)= WEIGHT
000126      400 CONTINUE
000130          DO 410 K=1,3
000132          IARG = IT - 3 + K
000134          B = B + W(K)*F(IARG)
000140      410 CONTINUE
000142          IF(IGO.EQ.2)GO TO 600
000144          B = B * 0.5
000145          GO TO 600
000146      500 CONTINUE
000146          B = F(IT)
000150      600 CONTINUE
000150          FLAGR = B
000152          RETURN
000152          END

```

TABLE A-VI. FUNCTION, FLAGR