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U. S. ARMY ROCKET & MISSILE CONTAINER ENGINEERING GUIDE

NOVEMBER 1967

U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama

CONTAINER BRANCH
INDUSTRIAL ENGINEERING DIVISION
PROCUREMENT & PRODUCTION DIRECTORATE

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CHAPTER I

PRINCIPLES OF MILITARY CONTAINER DESIGN

The degree of protection provided by a container is dependent upon its components and their performance when functioning collectively. The challenge to the designer lies in the selection of the type and amount of materials, which when assembled according to scientific principles, will perform both effectively and efficiently within the pertinent operating environment. The contents of this chapter are oriented toward the provision of essential definitions, instructions, and reference data useful in establishing the basic design requirements for the working mechanical components of a container.

A. *FRAGILITY.* The level of protection required of a container is dictated by the characteristics of the object to be protected and the environment in which the container must operate. Of prime import to container design is the characteristic of fragility. This relates to the ability of an object to withstand the effects of externally applied forces. The term fragility pertains to the sensitivity of the object to damage and alludes to its degree of inherent elasticity.

B. *The Gm FACTOR.* The basis for the measurement of fragility is the Gm factor; a dimensionless ratio of the maximum acceleration that an object can safely withstand to the acceleration of gravity:

$$Gm = a/g \quad \begin{cases} a = \text{ft/sec}^2 \text{ (maximum allowable acceleration an object can safely withstand.)} \\ g = 32 \text{ ft/sec}^2 \text{ (acceleration due to gravity)} \end{cases}$$

At present, there are no suitable analytical techniques for determining Gm. Since Gm is a nebulous number, it appears that duplication of the impact environment is probably the best way to determine a value for Gm.

Prior to conducting costly, time consuming destructive tests, it may be more practical to apply the "educated guess" technique. Table 1 may be used as a guide to assist in establishing a fragility level where the Gm factor of the item is not known. An item with a low Gm factor is considered fragile; one with a high Gm factor is considered rugged. The Gm factor is often provided by the manufacturer of the item to be protected. When this value is not known, the table may serve as an approximate guide; however, it should never be considered a substitute for test information.

Essentially, the Gm factor is a measure of an item's elasticity, i.e. its inherent capacity to retain or recover its shape upon or after the application of a distorting force. If the distorting force is in excess of the item's Gm factor, the elastic limit of the item may be exceeded resulting in permanent distortion and possible failure. The function of the container is to attenuate the forces transmitted to its contents to a level equal to or less than the critical Gm factor of the item to be protected. The magnitude of these forces and their duration constitute the hazard and it is these forces with which the designer is most concerned.

TABLE I

APPROXIMATE FRAGILITY OF TYPICAL PACKAGED ARTICLES

Extremely Fragile	
Missile guidance systems, precision instruments	15-25 Gm
Very Delicate	
Mechanically shock mounted instruments and electronic equipment	25-40 Gm
Delicate	
Aircraft accessories and other electrically operated equipment	40-60 Gm
Moderately Delicate	
Television receivers and components	60-85 Gm
Moderately Rugged	
Appliances, etc.	85-115 Gm
Rugged	
Machinery, weldments, etc.	115 Gm and up

C. *IMPACT SHOCK*. The most critical of externally applied forces imposed upon the container is that of shock. Shock occurs when the container is subjected to a suddenly applied force. The most severe shock is generally that which occurs when the container is dropped upon a rigid surface. This may be expected when the container is dropped freely from a truck onto a loading platform.

The principal methods of investigating shock phenomena in use today are 1) analytical calculations and 2) physical testing. Analytical calculations are used primarily as a starting point. Beyond this point, most problems involve calculations so complex that it is impractical to pursue this approach as after hours of calculation, the results are at best only approximate. The majority of impact-shock problems can be solved most economically by physical testing; however, in order to obtain a test specimen or prototype, the design procedure must begin with analytical calculations.

Impact shock results when a container is dropped through a vertical distance onto a relatively non-resilient surface. In practice it is impossible to predict impact conditions as the container will not impinge in exactly the same manner each time it is dropped; consequently, any assessment of shock experienced by the container is at best approximate.

To simulate and subject the test specimen to the most critical condition of impact, the testing of military containers is normally performed with the test specimen impinging upon a concrete slab having insignificant shock mitigating qualities. This qualification criteria establishes a design parameter affecting the analytical calculations.

The maximum impact force, imposed upon the free falling container is dependent upon the deflection experienced by either or both impacting bodies. As the impacting surface has been established as having insignificant shock mitigating characteristics, it can be assumed that any deflection will be experienced only by the container. The impact force (shock) imposed upon the container will depend upon the amount of deflection necessary to bring the container to rest; the smaller the deflection, the larger will be the impact force.

To determine the magnitude of an impact force, the kinetic energy of the container at the instant immediately preceding impact must be calculated. This kinetic energy (inch-pound units) is equal to the potential energy of the container before it is dropped, which in turn is equal to the weight of the container (pounds) multiplied by the vertical distance (inches) through which it is dropped. To bring the container to rest after impact, the container must absorb all of the kinetic energy developed by the fall (Note: within the scope of this document, it is assumed that the concrete impact surface functions as a rigid, non-resilient barrier and as such absorbs no energy). The function of the container is to absorb this energy by either distortion and/or recoverable deflection. Crushing of the container body or flexing of a resilient suspension system provides physical displacement of a mass through a distance in a specific time. The physical relationship which defines this contention is expressed as:

$$Ft = mV \quad \left\{ \begin{array}{l} F \text{ is the force of impact.} \\ t \text{ is the time interval required to dissipate} \\ \quad \text{the force } F. \\ m \text{ is the mass of the container.} \\ V \text{ is the velocity of the container at moment} \\ \quad \text{of impact.} \end{array} \right.$$

The product of mV, the momentum of the container, is independent of the nature of the impact surface. It becomes apparent that the product of Ft must be the same whether the impact surface is hard or soft, and the smaller the t, the greater will be F.

Note: When calculating the shock imposed upon a packaged item (using either an elastomeric, mechanical or bulk cushioning system), the weight of the container does *not* enter into any of the calculations - provided two assumptions are made:

1. Container impinges on a non-resilient surface.
2. Container is considered to be a rigid body.

Only the weight of the item and the spring constant of the suspension system influence the shock transmitted to the item. (For this reason, a suspension system can be designed to provide protection to an item *before* a container body or shell is designed).

Therefore, when an object is stopped in a very short time, such as when it strikes a hard surface, the force developed is very large. Consequently, any reference to the magnitude of impact in G's ($G = F/W$) must necessarily include a time factor; otherwise, this ratio (G) or indication of applied force cannot be correlated to any impact damage criterion (G_m factor). Shock can therefore be described as the disturbance produced by a suddenly applied force in the form of a complex pulse that can be completely described only by a Fourier analysis. In container design, it will suffice to describe shock by its amplitude in G's and its duration in milliseconds.

D. SHOCK PULSE. The result of an impact is a shock pulse comprised of a combination of superimposed responses in the form of a complex wave. Since it is difficult to describe the shock wave in detail, the pulse is characterized by its peak amplitude in G-units (acceleration) and its time duration in milliseconds.

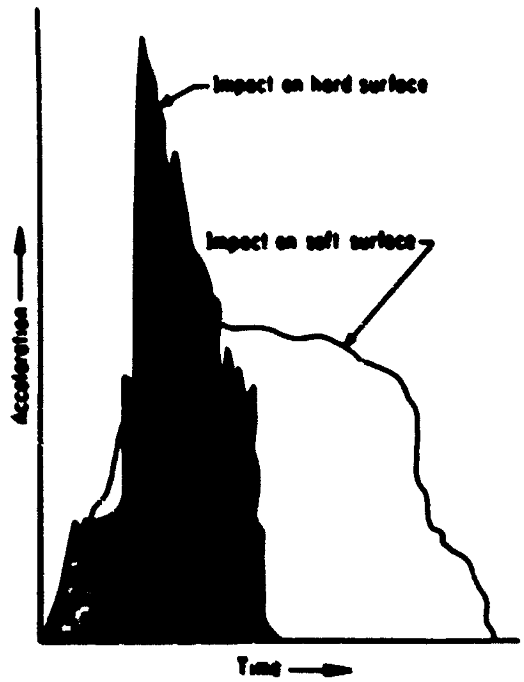


FIGURE 1. IMPACT SHOCK PULSE

Impact on a hard surface produces shock pulses of a large amplitude but brief duration; impact on soft surfaces produces low-amplitude shock pulses of long duration. The area under the curve of a shock pulse is the energy of impact which is imposed upon the container. If the amplitude of the shock pulse in G's produces a shock in excess of the critical fragility factor (Gm), the impact results in failure. If the total energy is distributed over a greater time base, the container will be subjected to a shock falling within its ability to absorb.

If Gm = 30, $A_1 = A_2$ i.e. $KE_1 = KE_2$

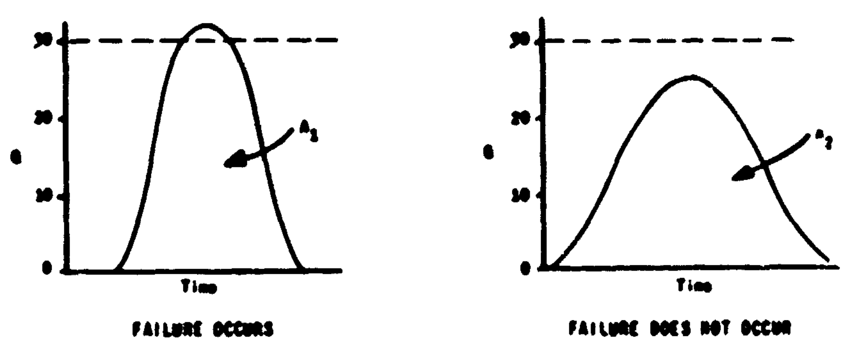


FIGURE 2. SHOCK PULSE AND THE CRITICAL FRAGILITY LEVEL

E. PULSE DURATION. The time base of the shock pulse wave is the pulse duration. Figure 3 graphically depicts the reaction of a container to impact. The impact force, generated by the free fall, builds up from a value of zero at the instant of impact to a maximum value upon final arrest. The time consumed by deceleration of the container is the shock-rise time and represents the duration of deflection experienced as the result of impact. The balance of the pulse duration is referred to as the shock-decay time and reflects upon the resiliency of the container (or suspension system) and its ability to recover.

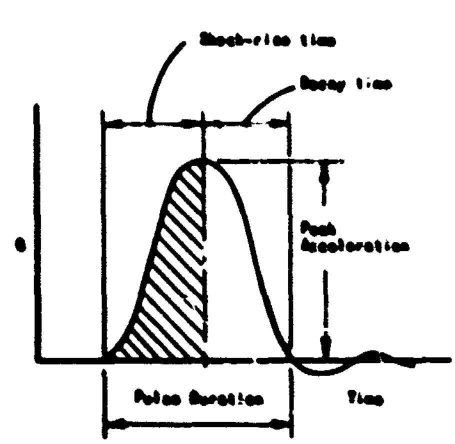


FIGURE 3. SHOCK RISE AND DECAY

The shock-rise time is dependent upon the yielding mass and is a function of its compressibility and elasticity. Other factors affecting shock-rise time include the resiliency of the impact surface and the extent of contact area which may be a flat or curved surface, an edge or a point. Data relating to shock-rise time has been determined for a variety of conditions by careful instrumentation and are included in Table 2 to assist in the analytical design process. The importance of the shock-rise time and the ability of the designer to manipulate its value cannot be over emphasized as this constitutes the means by which shock loads are mitigated and is the basis of container technology. Subsequent chapters will present data and describe techniques to permit the selection of a material and/or design which will provide the shock-rise time necessary to mitigate the imposed shock (G) to within the fragility level (Gm) of the container and its contents.

TABLE 2

TYPICAL VALUES FOR SHOCK-RISE TIME

Condition	Flat Face Contact (milliseconds)	Point Contact (milliseconds)
Rigid Steel against Concrete	1	2
Rigid Steel against Wood or Mastic	2-3	5-6
Steel or Aluminum against Compact Earth	2-4	6-8
Steel or Aluminum against Sand	5-6	15
Product Case against Mud	15	20
Product Case against 1-inch Felt	20	30

F. G's DEVELOPED BY FREE-FALL IMPACT. Shock damage is caused by acceleration forces developed during impact. These forces can be measured by accelerometers and associated instrumentation; however, this is a costly procedure and is dependent upon the availability of a test specimen. For the analytical computations pertinent to the design of a prototype, useful values for maximum acceleration can be computed from the shock-rise time and drop height by the formula:

$$G = \frac{72}{t}\sqrt{h} \quad \left\{ \begin{array}{l} G = \text{acceleration} \\ t = \text{shock-rise time, msc} \\ h = \text{drop height, inches.} \end{array} \right.$$

Table 3 tabulates the magnitude of developed G's for various free-fall drop conditions and permits the designer to estimate the shock imposed upon the container and/or its contents.

TABLE 3

G - MAXIMUM ACCELERATION EXPERIENCED BY A FREE-FALLING OBJECT

Drop Height h (inches)	Pulse Duration in Milliseconds																			
	1	2	3	4	5	6	8	10	11	12	14	15	16	18	20	22	24	26	28	30
6	176	88	55	44	35	29	22	18	16	15	13	12	11	10	9	8	7	7	6	6
12	252	126	84	62	50	42	31	25	23	21	18	17	16	14	12	11	10	10	9	8
18	305	152	101	76	61	51	38	30	28	25	22	20	19	17	15	14	13	12	11	10
20	322	161	107	80	64	53	40	32	29	26	23	21	20	17	16	14	13	12	11	10
24	352	176	117	88	70	58	44	35	32	29	25	23	22	19	17	16	14	13	12	11
30	394	197	131	98	78	65	49	39	35	32	28	26	24	21	19	17	16	15	14	13
36	432	216	144	108	86	72	54	43	39	36	30	28	27	24	21	19	18	16	15	14
40	455	227	151	113	91	75	56	45	41	38	32	30	28	25	22	20	19	17	16	15
42	466	233	155	116	93	77	58	46	42	39	33	31	29	25	23	21	19	18	16	15
48	498	249	166	124	99	83	62	49	45	41	35	33	31	27	25	22	20	19	17	16
60	557	278	185	139	111	93	69	55	50	46	39	37	34	31	27	25	23	21	19	18

G. *MINIMUM SHOCK-RISE TIME.* To develop a practical working tool, the formula presented in the previous paragraph can be modified to reflect the shock-rise time necessary to result in a specific force falling within the Gm parameter:

$$tm = \frac{72}{Gm}\sqrt{h}$$

tm is the maximum shock-rise time in msc.
Gm is the fragility level of the container contents.
h is the drop height in inches.

The data in Table 3 may then be used to establish the minimum shock-rise time necessary to assure effective performance. In practice, this is accomplished by varying the resiliency of the cushioning or suspension system to provide increasingly longer pulse duration.

H. *DEFLECTION OR DISPLACEMENT.* The underlying principle behind all protective packaging is that every object in a free fall possesses kinetic energy which it must dissipate by decelerating through a given distance and time interval. The function of the parachute and the prizefighter's technique of "rolling with the punch" are examples of this principle.

The rate of this deceleration is determined by the maximum gravity force (Gm) the item can withstand. An attempt to stop an object within too short a distance runs the risk of exceeding the maximum force Gm, resulting in damage to the object.

The rate of deceleration of the impacting object becomes a function of the object's resistance to crushing or as is found in practice, the density of the protective cushion or elasticity (K) of the suspension system. The response of the cushion or suspension is dictated by its density or spring constant which in turn is determined by the supported weight at any particular moment during deceleration. To further complicate the analytical calculations, it has been found that the response of various materials used as cushions or springs varies with the applied load and the relationship may be linear, non-linear, or a combination of both. Within the scope of this guide, the following data is adequate; derivations and more detailed presentations are available in the literature.

Consequently, it will suffice to state that the density or elasticity of the suspension material and its ability to provide the deflection required determines the amount of shock experienced by the object subjected to impact. These constitute the tools available to the designer; by varying the material and its configuration adequate deflection or displacement can be provided to control the rate of deceleration to within the safe limits of fragility.

I. LINEAR SUSPENSION SYSTEMS.

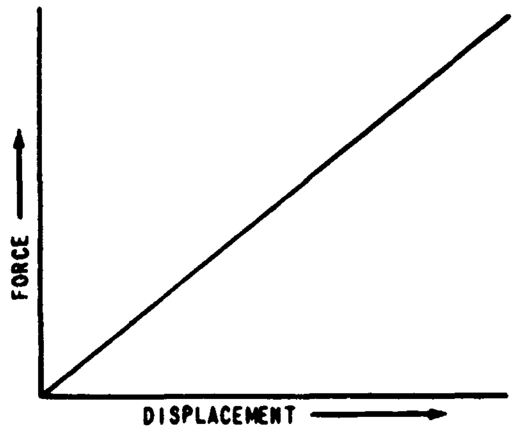


FIGURE 4. FORCE - DISPLACEMENT CURVE FOR LINEAR SUSPENSION SYSTEMS

In the isolation of shock, large deflections are encountered which result in nonlinear response of the suspension system. It is often, particularly in the environment peculiar to Army materiel, impossible to predict the maximum shock which will be encountered; consequently, large deflections must be anticipated. If the suspension does not provide for sufficient deflection and gradual increase in stiffness, bottoming may occur with consequent transmission of excessive forces. This consideration makes the use of a linear isolator undesirable. It is often preferable to employ a nonlinear isolator having anomalous force-deflection characteristics. Such an isolator may be considered linear for small deflections; additional factors must be considered however, if the applied shock causes deflections well into the nonlinear range. The analysis of nonlinear isolators involves complex formulae which may, for the sake of expediency, be circumvented. To satisfy the intent of this document it will suffice to merely be aware of the nonlinearity of conventional cushioning media and the resulting deflections which dictate the spatial requirements of the container body.

For a linear system, where the displacement is proportional to the applied load, the formula

$$d = \frac{2h}{Gm - 2}$$

indicates the relationship between drop height (h); fragility factor (Gm) and minimum deflection (d). Deflection d is numerically equal to the distance required to decelerate the contained object dropped from a height h such that the G force experienced by the container will be mitigated to a level not exceeding the established fragility level Gm of the protested contents. Note that Gm and "d" are inversely proportional; as the fragility factor Gm is lowered, larger deflections must be provided.

TABLE 4

LINEAR SYSTEM - DEFLECTION SELECTOR CHART $d = \frac{2h}{Gm-2}$

Gm	Drop height h										
	6"	12"	18"	20"	24"	30"	36"	40"	42"	48"	60"
10	1.5"	3.0"	4.5"	5"	6"	7.5"	9"	10"	10.5"	12.0"	15"
15	0.92	1.85	2.79	3.00	3.7	4.6	5.5	6.2	6.5	7.4	9.2
20	0.67	1.33	2.0	2.22	2.7	3.3	4.0	4.4	4.7	5.4	6.6
30	0.43	0.86	1.28	1.43	1.7	2.1	3.6	2.9	3.0	3.4	4.2
40	0.32	0.63	0.95	1.05	1.3	1.6	1.9	2.1	2.2	2.6	3.2
50	0.25	0.50	0.75	0.83	1.0	1.3	1.5	1.7	1.8	2.0	2.6
60	0.21	0.42	0.62	0.69	0.84	1.0	1.2	1.3	1.5	1.68	2.0
75	0.17	0.34	0.49	0.55	0.68	0.82	0.98	1.1	1.2	1.36	1.64
100	0.12	0.24	0.37	0.41	0.48	0.61	0.74	0.82	0.86	0.96	1.22
125	0.096	0.19	0.29	0.33	0.38	0.49	0.58	0.66	0.68	0.76	0.98

In summation, the distance through which an impacting object moves, prior to coming to rest, is dictated by the phenomenon of energy dissipation. This is reflected in the relationship between the peak acceleration (G) experienced by the impacting container and the length of time (shock pulse) during which the acceleration lasts. The pulse is a function of distance and to maintain a specific level of maximum acceleration (Gm) experienced by the contained object, the minimum distance the contained object must travel (deflection) in being brought to rest is fixed and is theoretically independent of the suspension system or cushion provided. *This deflection (d) determines the minimum sway space which must be provided within the container and as such, dictates the spatial dimensions of the container cavity.* A linear suspension is rarely encountered in practice; however, because of its simplicity it is usually used to determine minimum spatial requirements. A steel spring is an example of a linear-type suspension where the spring rate (k in lbs. per inch) is constant throughout the range of its use. This simplified analysis, which ignores damping and friction, is entirely adequate for many purposes particularly those involving small deflections.

J. NONLINEAR SUSPENSION SYSTEMS.

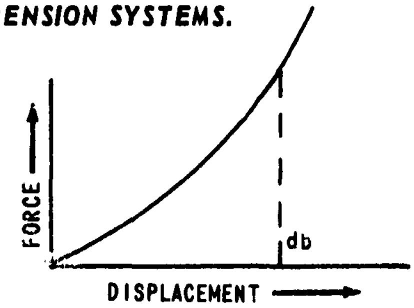


FIGURE 5. FORCE - DISPLACEMENT CURVE FOR NONLINEAR SUSPENSION SYSTEMS

Many of the nonlinear (anomalous) cushions have force-displacement curves resembling the trigonometric tangent function which cannot be expressed by simple mathematical equations. The figure shows how the stiffness of the suspension (i.e. the shape of the curve) increases as the displacement approaches the maximum available (db) at hard bottoming. The minimum amount of displacement required for nonlinear (tangentially elastic) cushioning may be mathematically expressed:

$$dm = \frac{3.9h}{Gm}$$

dm = displacement in inches
h = drop height in inches
Gm = force of impact dimensionless ratio

It is interesting to compare the displacements for linear and nonlinear suspensions and note that the spatial requirements are greater for nonlinear suspensions.

TABLE 5

NONLINEAR SYSTEMS - DEFLECTION SELECTOR CHART $dm = \frac{3.9h}{Gm}$

	Drop Height h										
Gm	6"	12"	18"	20"	24"	30"	36"	40"	42"	48"	60"
10	2.34"	4.68"	7.02"	7.80"	9.36"	11.7"	14.04"	15.60"	16.38"	18.72"	23.40"
15	1.56	3.12	4.68	5.20	6.24	7.80	9.36	10.4	10.92	12.48	15.60
20	1.17	2.34	3.51	3.90	4.68	5.85	7.02	7.80	8.19	9.36	11.70
30	0.78	1.56	2.34	2.60	3.12	3.90	4.68	5.20	5.46	6.24	7.80
40	0.58	1.17	1.75	1.95	2.34	2.93	3.51	3.90	4.10	4.68	5.85
50	0.47	0.94	1.40	1.56	1.87	2.34	2.81	3.12	3.28	3.74	4.68
60	0.39	0.78	1.17	1.30	1.56	1.95	2.34	2.60	2.73	3.12	3.90
75	0.31	0.62	0.94	1.04	1.25	1.56	1.87	2.08	2.18	2.50	3.12
100	0.23	0.47	0.70	0.78	0.94	1.17	1.40	1.56	1.64	1.87	2.34
125	0.19	0.37	0.56	0.62	0.75	0.94	1.12	1.25	1.31	1.50	1.87

K. RATE OF TRAVEL. To attain a required level of protection, (Gm-factor) it has been shown that the item to be protected must decelerate through a specific distance (d) to dissipate the energy of impact generated as the result of a free fall from a particular height. Travel through any distance entails time and the ratio of this distance and time establishes the rate of travel of the object during deceleration.

$$R = \frac{d}{t} \text{ or } d = Rt \quad \left\{ \begin{array}{l} d = \text{distance} \\ t = \text{time} \\ R = \text{rate} \end{array} \right.$$

It has been previously shown that the desired force of impact as determined by the fragility level of the object to be protected is inversely proportional to the pulse duration "t" of the above formula (time to decelerate).

$$Gm = \frac{72}{tm}\sqrt{h}$$

Relating the two formulae; substituting for tm its equivalent d/R.

$$\left. \begin{array}{l} Gm = \dfrac{72}{tm}\sqrt{h} \\[2ex] Gm = \dfrac{72}{d/R}\sqrt{h} \\[2ex] Gm = R\left[\dfrac{72}{d}\sqrt{h}\right] \end{array} \right\} t = \frac{d}{R}$$

Considering the value $\left[\frac{72}{d}\sqrt{h}\right]$ a constant, we conclude that R, the rate of travel during deceleration is directly proportional to the Gm factor. To reduce the value of Gm we must reduce the numerical value of R; i.e. prolong the time of deceleration which in effect is the pulse duration. The state-of-the-art makes available to packaging technology various means by which the designer can provide for the required displacement (d) and simultaneously control the rate of travel during deceleration (R) through this distance (d). The value of the controlled rate of travel during deceleration (R) as determined by the required pulse duration (t) establishes the magnitude of the shock (Gm) experienced by the object to be protected. The various means available to the design engineer include elastomeric, mechanical, and bulk cushioning suspension systems which, because of their contribution and performance are discussed in depth in subsequent chapters of this guide.

L. IMPOSED VIBRATION. A condition peculiar to materiel in transit is that of vibration generated by the carrier vehicle. The carrier, functioning as a fluctuating force imparts to the container a forced vibration and the container (assumed to be restrained) is forced to vibrate at the same frequency as that of the carrier. Should these vibrations coincide with the natural frequency of the suspended contents the associated forces may become great enough to cause fracture or damage to the contained item. Carrier vehicles in transit are subjected to conditions resulting in vibrations peculiar to the environment in which they operate. Many studies have been conducted to determine the most common forcing frequencies that will be encountered by different carriers and, although exceptions are found, the following summary is generally applicable.

1. Railroad - 2 to 7 cps
2. Truck - 20 to 200 cps
3. Aircraft - 20 cps and 60 cps
4. Ships - 11 to 100 cps

The mode of transportation and the applicable frequencies tabulated provide the required data relating to imposed vibrations.

M. NATURAL FREQUENCY. Determination of the natural frequency of a container system is of the greatest importance to permit comparison with the forced vibration introduced by the carrier. This comparison of frequency is essential if a damaging resonant condition is to be avoided. The natural frequency of a suspended system, is that frequency at which it will vibrate if displaced and allowed to vibrate freely. Any system comprised of a body suspended on cushioning has a natural frequency at which it will vibrate with greater amplitude than at a frequency just above or below it. To determine a rough approximation of the vertical natural frequency of a container system:

$$fn = \frac{2Gm}{\sqrt{h}}$$

Gm = G-factor of the container as designed
h = drop height in inches
fn = approximate natural frequency in cycles per second

N. RESONANCE. Bodies subjected to periodic impulses imparted by outside agents are said to execute forced vibrations. When conditions are so adjusted that the frequency of forced vibrations is the same as the natural frequency of the body upon which they are impressed, the free vibrations reinforce the received ones; an effect which is known as resonance. When the impressed vibration has a different frequency from that of the free vibration of the body, the received impulses will not affect the free vibrations appreciably. There are instances where resonance may build up free vibrations of such amplitude as to produce dangerous results. The amplitude of vibration, depends upon the magnitude of the forced vibration and the ratio of its frequency to the natural frequency of the object or system being vibrated. When this ratio becomes equal to unity, the amplitude of the vibration may build up to a dangerous value.

$$r = \frac{f}{fn} \quad \left\{ \begin{array}{l} r = \text{frequency ratio} \\ f = \text{forced frequency in cps} \\ fn = \text{natural frequency in cps} \end{array} \right.$$

When r = 1, there is said to be resonance between the frequency of the shaking force and the natural frequency of the system. In all practical problems, the maximum amplitude obtainable would be limited by failure of the system or limitations of space. Theoretically, for the effective isolation of vibratory forces, the ratio between disturbing frequency (f) and the natural frequency of the system (fn) must always be greater than $\sqrt{2}$; and, as this ratio assumes values greater than $\sqrt{2}$, the system becomes progressively more efficient. Conversely, as the ratio f/fn becomes less than $\sqrt{2}$, magnification of the vibratory forces will occur, and this condition must be avoided. As the ratio of f/fn approaches the value of unity (1), the vibratory forces are multiplied, until at unity (1), resonance occurs and the forces become infinite. Mathematically this relationship is expressed by the following formula which is known as the transmissibility formula:

$$\text{Transmissibility} = \frac{1}{\left(\frac{f}{fn}\right)^2 - 1}$$

Where: f = disturbing frequency

fn = natural frequency of mounted assembly

The purpose of most vibration investigations is to avoid the occurrence of resonance.

The preceding data has been presented as orientation; to acquaint the reader with the principles of container design. These and other aspects of this technology are discussed in depth in subsequent chapters.

To minimize the design effort, the service requirements with respect to shock and vibration have been established for those conveyances most common to the transport of Army material. When permissible, it is desirable to investigate all aspects of an environment and the hazards it presents; however, should time be of the essence, it is suggested that the critical condition cited in the following be investigated first:

a. ***Rail Shipments*** - failures are most often caused by high impact shocks; a single transient shock wave is imparted to the equipment and failure is instantaneous. Vibration becomes a secondary consideration.

b. ***Truck Shipments*** - same as rail.

c. ***Marine Vessel Shipments*** - same as rail.

d. *Aircraft Shipments* - fatigue failures of equipment, caused by components being vibrated at, or near their resonant frequency are common. Steady-state vibrations at frequencies in the range of from 10 to 500 cps are prevalent. The magnitude of the shocks to which the equipment is subjected is much less than in other applications, and the shock requirements become a secondary factor.

CHAPTER II

INVENTORY OF ARMY MISSILES & ROCKETS AND THEIR CONTAINERS

The effectiveness of any container design effort is dependent upon the availability of adequate and accurate data relating to the item to be protected. These data shall include:

a. Detailed geometric outline dimensions.

b. Weight.

c. Location of center of gravity.

d. Maximum allowable vibration and shock loads.

e. Support points with corresponding allowable loads.

f. Load factors (computed from structural analysis).

g. Susceptibility to environmental hazards including pressure vibrations.

h. Pertinent electronic or magnetic characteristics.

i. Frequency and degree of periodic inspection and maintenance requirements.

j. Test and checkout facilities.

k. Military characteristics and logistical support plans of the system.

l. The characteristics of any applicable aircraft, marine vessel, or landbased vehicle peculiar to the logistic support plan.

m. Projected storage life.

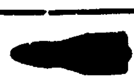
n. Degree of permissible disassembly which will not require special skills or tools.

o. Other pertinent significant data.

The missile developer shall be required to provide these data to the container designer and shall be further required to advise of all changes subsequent to initial release.

The following is presented as an inventory to make available, in ready reference form, data relating to Army Missiles and Rockets encompassed within the scope of this document.

TABLE 6
U. S. ARMY MISSILES AND ROCKET

MISSILE & ROCKET	PROFILE	DIMENSIONS O.A. (IN INCHES) LENGTH	DIA.	SPAN	WEIGHT IN POUNDS	LOCATION OF CENTER OF GRAVITY	MISSILE DRAWING NUMBERS	MFG. (PRIME)	MISSILE SECTION & DWG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT IN POUNDS	LOCATION OF CENTER OF GRAVITY	TEMPERATURE LIMITS
SS-10		33 3/8	6.4	29 1/2	33	NOT AVAILABLE	NOT AVAILABLE	NORD AVIATION (FRANCE)	WARHEAD & POWERED BODY (SHIPPED TOGETHER)	STEEL CONTAINER DRAWING NO. NOT AVAILABLE	33 3/8	6.4	29 1/2	33	NOT AVAILABLE	-4°F TO +140°F
SS-11		47.6	6.4	19.7	66.1	24.8" FROM FWD END	[illegible]	NORD AVIATION (FRANCE)	WARHEAD & POWERED BODY (SHIPPED TOGETHER)	[illegible]	47.6	6.4	19.7	66.1	24.8 FROM FWD END	[illegible]
ENTAC		(C)	(C)	(C)	27 37 WITH LAUNCHER	UNKNOWN	[illegible]	NORD AVIATION (FRANCE)	WARHEAD & BODY SHIPPED TOGETHER	STEEL CONTAINER	(C)	(C)	(C)	27 37 WITH LAUNCHER	UNKNOWN	[illegible] STORAGE UP TO +160°F
TOW LAUNCHER EXTENDER [illegible]		30 3/16	9 1/2	NOT APPLIC	42	GEOMETRIC CENTER 15 3/4 FROM END	[illegible]	HUGHES	COMPLETE MISSILE IN LAUNCHER EXTENDER	[illegible]	30 3/16	9 1/2	NOT APPLIC	42	GEOMETRIC CENTER 15 3/4 FROM END	-65° TO +160° F
REDEYE LAUNCHER [illegible]		44 N.A.	2.75 N.A.	(C) N.A.	31.6 N.A.	31.6 IN FROM FWD CAP	[illegible]	GENERAL DYNAMICS	COMPLETE MISSILE IN LAUNCHER [illegible]	[illegible]	44 N.A.	2.75 N.A.	(C) N.A.	21.6 N.A.	31.6" FROM FWD CAP	+125°F TO -65°F
SHILLELAGH		40	6	NOT APPLIC.	(C)	10 1/2 FROM AFT END	(C)	FORD AERO-NUTRONIC	COMPLETE MISSILE	MODULAR TYPE ALUM. CONTAINER DRAWING NO. NOT AVAILABLE	46	6	NOT APPLIC.	(C)	19 1/2 FROM AFT END	(C)
LITTLE JOHN		172	12.5	23 3/4	780	TO BE [illegible] FROM AFT END	NOT AVAILABLE	ARMY MISSILE COMMAND	WARHEAD PRACTICE M49	XM103	80.1	12.5	N.A.	262 ±4	52.8" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: -20°F TO [illegible]
									WARHEAD [illegible] GAS M206	XM103	80	12.5	N.A.	262 ±4	52.7" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: [illegible]
									WARHEAD HE M144 [illegible]	XM103	80	12.5	N.A.	262	52.7" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: [illegible]
									WARHEAD ATOMIC M50 OR M70	XM103	80	12.5	N.A.	266.16 ±4 -0.4	53.4" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: [illegible]
									ROCKET MOTOR [illegible] M26 [illegible]	[illegible]	94.1 [illegible]	12.5	23.75	521 [illegible] THRUST [illegible] 546 TOT.	42.3" FROM AFT END [illegible]	STORAGE: -65°F TO +130°F FIRING: -20°F TO +130°F

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(C)-REFERS TO CLASSIFIED INFORMATION

TABLE 6

S. ARMY MISSILES AND ROCKETS

MFG. (NAME)	MISSILE SECTION & DRG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT IN POUNDS	LOCATION OF CENTER OF GRAVITY	TEMPERATURE LIMITS	PRESSURE LIMITS	HUMIDITY LIMITS	FRAGILITY LEVELS	ALLOWABLE BENDING MOMENT	HARD POINTS	HANDLING DEVICES	FINS	LOGISTIC REQUIREMENTS
ORD ATION RANCE)	WARHEAD & FINNED BODY (SHIPPED TOGETHER)	STEEL CONTAINER DRAWING NO. NOT AVAILABLE	$33\frac{7}{8}$	6.4	$29\frac{1}{2}$	33	NOT AVAILABLE	-4°F TO +140°F	NO LIMITS	NO LIMITS	NOT AVAILABLE	NOT AVAILABLE	NOT APPLICABLE	NONE	4 STRAIGHT FINS SHIPPED ATTACHED TO BODY	WORLDWIDE
ORD ATION RANCE)	WARHEAD & FINNED BODY (SHIPPED TOGETHER)	WOOD, STEEL, & FIBERGLASS CONTAINERS DRAWING NOS. NOT AVAILABLE	47.6	6.4	19.7	66.1	24.8 FROM FWD END	-22°F TO +122°F	SEA LEVEL TO 40000 FT	NONE, PROLONGED STORAGE IN A SALINE ATMOS. IS PROHIBITED	NOT AVAILABLE	NOT AVAILABLE	NOT APPLICABLE	NONE	4 SWEPT BACK FINS SHIPPED ATTACHED TO BODY	WORLDWIDE
ORD ATION RANCE)	WARHEAD & BODY SHIPPED TOGETHER	STEEL CONTAINER	(C)	(C)	(C)	27 37 WITH LAUNCHER	UNKNOWN	-25°TO+125°F STORE AT -40°TO+125°F LIMITED STORAGE UP TO +160°F	SEA LEVEL TO 40,000 FT	NONE, PROLONGED STORAGE IN A SALINE ATMOS IS PROHIBITED	UNKNOWN	UNKNOWN	NOT APPLICABLE	NONE	4 FINS ON BODY	WORLDWIDE
UGHES	COMPLETE MISSILE IN LAUNCHER EXTENDER	WIRE BOUND BOX	$50\frac{7}{16}$	$8\frac{1}{2}$	NOT APPLIC.	42	GEOMETRIC CENTER $25\frac{7}{32}$ FROM END	-65° TO +165° F	SEA LEVEL TO 10,000 FT.	NONE	CAN WITHSTAND 100 g's, 10 MILLI SEC. ½ SINE WAVE, ALL DIRECTIONS	NOT DETERMINED	RIGID ROUND TUBE	WEBBING STRAP (HAND CARRIED)	NONE	WORLDWIDE
NERAL NAMICS	COMPLETE MISSILE IN LAUNCHER (MISSILE *[illegible])	*10-100784	MISSILE: 44 LAUNCHER: N.A.	MISSILE: 2.75 LAUNCHER: N.A.	MISSILE: (C) LAUNCHER: N.A.	MISSILE: 21.6 LAUNCHER N.A.	21.6" FROM FWD CAP	+165°F TO -65°F	15.4 PSI TO 10.8 PSI	95% RH @ +85°F - 20 HRS 100% RH @ +80°F - 4 HRS	VIB: 2-20 cps, [illegible] 20-50 cps, 50-500 cps 4 G's [illegible] ANY AXIS 1 HR.	1300 IN-LB. @ [illegible] FROM FRONT	15.5", 20.12" & 40" FROM FRONT	NONE	LAUNCHER: NONE MISSILE: (C)	WORLDWIDE PALLETIZED AIR DROPS
FORD AERO-NUTRONIC	COMPLETE MISSILE	MODULAR TYPE ALUM. CONTAINER DRAWING NO. NOT AVAILABLE	APPROX 40	APPROX 6	NOT AVAIL.	(C)	$19\frac{1}{4}$ FROM AFT END	(C)	NONE	(C)	100 g's LONGITUDINAL 40 g's TRANSVERSE	10,000 IN LB MAX	(C)	HAND CARRIED	4 STRAIGHT COLLAPSIBLE FINS	WORLDWIDE
ARMY MISSILE COMMAND	WARHEAD PRACTICE M8	XM143	80.1	17.5	N.A.	262 ±4	52.8" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: -30° TO +120°	NONE	NONE	(C)	(C)	NOT APPLICABLE	HANDLING UNIT M872 AND SLING	NONE	WORLDWIDE
	WARHEAD NON-PERSISTANT GAS M206	XM143	80	12.5	N.A.	262 ±4	52.7" FROM NOSE	STORAGE: -65°F TO +130°F FIRING: -30° TO +120°	(C)	(C)	(C)	(C)	NOT AVAILABLE	SAME	NONE	WORLDWIDE
	WARHEAD HE M146 PXP108685	XM143	80	12.5	N.A	262	52.7" FROM NOSE	STORAGE -65°F TO +130°F FIRING: -30° TO +120°	(C)	(C)	(C)	(C)	NOT AVAILABLE	SAME	NONE	WORLDWIDE
	WARHEAD ATOMIC M50 OR M78	XM143	80	12.5	N.A.	266.16 +4 -9.16	53.6" FROM NOSE	STORAGE -65°F TO +130°F FIRING: -30° TO +120°	(C)	(C)	(C)	(C)	NOT AVAILABLE	SAME	NONE	WORLDWIDE
	ROCKET MOTOR 318MM M26 *J8533020	M455; M498	94.5 100.6 (WITH THRUST NEUT-RALIZER)	12.5	23.75	521 W/O THRUST NEUTRALIZER 546 TOT.	43.3" FROM AFT END WITH THRUST NEUTRALIZER (46.1 W/O)	STORAGE: -65°F TO +130°F FIRING: -30°F TO +120°F	NONE	NOT AVAILABLE	40 g's ALL DIREC.	1.25x10⁶ IN-LB	NOT AVAILABLE	SLING AND HANDLING UNIT M872 M18 USED WITH M498 CONTAINER	4 STRAIGHT FINS SHIPPED ATTACHED TO BODY	WORLDWIDE

(C) REFERS TO CLASSIFIED INFORMATION

TAB

U. S. ARMY MISSILES

MISSILE OR ROCKET	PROFILE	DIMENSIONS O.A. (IN INCHES) LENGTH	DIA	SPAN	WEIGHT IN POUNDS	LOCATION OF CENTER OF GRAVITY	MISSILE DRAWING NUMBERS	MFG. (PRIME)	MISSILE SECTION & DWG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	[illegible]
HAWK - XM3E1		190	14	47.4	1275	122.5 FROM NOSE	[illegible]	RAYTHEON	ASSEMBLED W/H & BODY SECTIONS [illegible]	TACTICAL CONTAINER XM430 [illegible]	198	[illegible]
									BODY SECTION [illegible]	XM417E2 [illegible]	(C)	[illegible]
									WARHEAD: [illegible]	[illegible] AND [illegible]	(C)	[illegible]
									BODY SECTION AFT [illegible]	XM430 [illegible]	(C)	[illegible]
LACROSSE M4 (OBSOLETE)		230	20.5	WING SPAN 108 FIN SPAN 55	2360	NOT AVAILABLE	NOT AVAILABLE	MARTIN/ORLANDO	WARHEAD HE [illegible] M139	XM471 [illegible]	80	[illegible]
								MAIN ASSEMBLY AND [illegible]	GUIDANCE & POWER	XM376 E1 OR XM374E2 [illegible]	151½	[illegible]
									ROCKET MOTOR M10 [illegible]		102¾	[illegible]
									WARHEAD XM135 & XM135E1	M484 [illegible] M484E1 [illegible]	(C)	[illegible]

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(C)-REFERS TO CLASSIFIED INFORMATION

TABLE 6

ARMY MISSILES AND ROCKETS (cont)

[illegible]	MISSILE SECTION & DWG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT IN POUNDS	LOCATION OF CENTER OF GRAVITY	TEMPERATURE LIMITS	PRESSURE LIMITS	HUMIDITY LIMITS	FRAGILITY LEVELS	ALLOWABLE BENDING MOMENT	HARD POINTS	HANDLING DEVICE	FINS	LOGISTIC REQUIREMENTS
[illegible]	ASSEMBLED W/H & BODY SECTIONS [illegible]	TACTICAL CONTAINER M430 [illegible]	198	14	47.4	1275	122.9 FROM NOSE	(c)	(c)	(c)	(c)	(c)	(c)	NOT AVAILABLE	4 FINS SHIPPED DETACHED IN M430	WORLDWIDE
	BODY SECTION [illegible]	[illegible]	(c)	14	N.A.	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	NOT AVAILABLE	NONE	WORLDWIDE
	WARHEAD: [illegible]	[illegible] AND [illegible]	(c)	14	N.A.	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	NOT AVAILABLE	NONE	WORLDWIDE
	BODY SECTION AFT [illegible]	M430 [illegible]	(c)	14	47.4	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	NOT AVAILABLE	4 FINS	WORLDWIDE
[illegible]	WARHEAD HE [illegible] M135	[illegible]	80	20½	N.A.	540	15 [illegible] FROM AFT END	-80°F TO +160°F	NONE	NOT AVAILABLE	(c)	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT APPLICABLE	WORLDWIDE
[illegible]	GUIDANCE & POWER	[illegible] OR [illegible]	151½	20½	108	1805	87½ FROM OPEN END	-60°F TO +140°F	NOT AVAILABLE	NOT AVAILABLE	(c)	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	WORLDWIDE
	ROCKET MOTOR M10 [illegible]	[illegible]	102¾	16	55	832	51 [illegible] FROM FWD END 40.8 FROM THRUST [illegible]	-40°F TO +140°F	NONE	NOT CONTROLLED	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	4 WINGS & 4 MOVABLE FINS	WORLDWIDE
	WARHEAD AM135 & EM135E1	M484 [illegible] M484E1 [illegible]	(c)	(c)	N.A.	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	(c)	NOT AVAILABLE	(c)	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	WORLDWIDE

(c) CLASSIFIED INFORMATION

TABLE 6
U. S. ARMY MISSILES AND ROCKETS

MISSILE OR ROCKET	PROFILE	DIMENSIONS O.A. (IN INCHES) LENGTH	DIA	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY	MISSILE DRAWING NUMBER	MFG.	MISSILE SECTION & DWG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY
HONEST JOHN		M31: 327 [illegible] 296.5	30 30	104 52.75	5913 4307	STA. [illegible] STA. 161 (heavy wh) STA. 169 (light wh)	[illegible]	[illegible] ELECTRIC/ DOUGLAS	WARHEAD [illegible]	UNDER SHEATHED CONTAINER	115	30	NOT APPLIC.	1631	(C)
									[illegible]	[illegible]6321	212	27.7	104	4278	STA. [illegible]
									[illegible] MOTOR M66 ([illegible])	—	183	30	52.75	3080	STA. [illegible]
LANCE		APPROX. 237	22	N.A.	(C)	80½ IN. FORWARD OF AFT END	NOT AVAILABLE	LTV & ROCKETDYNE WARHEAD: PICATINNY ARSENAL	WARHEAD SECTION	REFER TO CONTAINER CHART	APPROX. 100	22 MAX.	NOT APPLIC.	(C)	(C)
									ROCKET MOTOR	OPEN TYPE WITH [illegible] REMOVABLE COVER	137	22	NA	1976 LESS FINS	64½ IN FORWARD OF AFT END
SERGEANT		413	31	60	10,000	237 AFT OF STATION 0	[illegible]	SPERRY UTAH	WARHEAD XM38 [illegible]	[illegible]	139	31 (MAX.)	N.A	1611	38" FWD OF REAR END
									ROCKET MOTOR XM33	XM486 AND XM419	202	31	N.A.	7143	105" FWD OF AFT PLANE OF MISSILE
									CONTROL & GUIDANCE AN/[illegible]	XM487 AND XM430	78.5	31	N.A	1255	372" AFT OF FWD END

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(C) - REFERS TO CLASSIFIED INFORMATION

TABLE 6
S. ARMY MISSILES AND ROCKETS (cont)

[illegible]	Missile Drawing Number	MFG.	Missile Section & Dwg No	Container Used	Dimensions (in inches) Length	Dia	Span	Weight (in pounds)	Location of Center of Gravity	Temperature Limits	Pressure Limits	Humidity Limits	Fragility Levels	Allowable Bending Moment	Hard Points	Handling Devices	Fins	Logistic Requirements
[illegible]	[illegible]	[illegible] Electric/ [illegible]	Warhead (Quantity of warheads [illegible])	[illegible] weather container	115	30	Not Applic.	1631	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	None	Worldwide
[illegible]	[illegible]		Rocket motor [illegible]	[illegible]6321	212	27.7	104	4275	STA. 224	[illegible]	Operates from below sea level to [illegible] ft.	No limits	Not available	Not available	STA 134 to STA 280	Handling beam [illegible]	4 straight fins	Worldwide
			Rocket motor [illegible] ([illegible])	—	183	30	3575	3080	STA. 200	[illegible]	Same as above	No limits	Not available	Not available	STA 134 to STA 240	Handling beam modified [illegible]	4 straight fins	Worldwide
[illegible]	Not available	LTV & [illegible] Warhead: Picatinny Arsenal	Warhead section	Refer to container chart	Approx. 100	22 max	Not applic.	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	None	Worldwide
			Rocket motor	Open type with [illegible] removable cover	137	22	NA	1976 less fins	64½ in forward of aft end	(C)	(C)	None (motor sealed)	(C)	Not available	Not available	Not finalized	4 fins 44 lb (total)	Worldwide
[illegible]	[illegible]-[illegible]	Sperry Utah	Warhead XM 38 [illegible] ([illegible])	[illegible]	139	31 (max)	NA	1611	30" fwd of rear end	(C)	(C)	[illegible]	(C)	(C)	(C)	(C)	None	(C)
			Rocket motor XM 33	XM 486 and XM 419	202	31	NA	7143	105" fwd of exit plane of nozzle	(C)	(C)	Same as above	(C)	Not available	Not available	Not available	4 fins shipped in four containers	(C)
			Control & Guidance AN/[illegible]	XM 487 and XM 420	78.5	31	NA	1255	372" aft of fwd end	(C)	(C)	Same as above	(C)	Not available	Not available	Not available	None	(C)

[illegible]ERS TO CLASSIFIED INFORMATION

TABLE 6
U. S. ARMY MISSILES AND ROCKETS

MISSILE OR ROCKET	PROFILE	DIMENSIONS O.A. (IN INCHES)			WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY	MISSILE DRAWING NUMBER	MFG.	MISSILE SECTION & DWG NO	CONTAINER USED	DIMENSIONS (IN INCHES)			WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY
		LENGTH	DIA	SPAN							LENGTH	DIA	SPAN		
PERSHING M14		408	40	—	30,000	NOT AVAILABLE	NOT AVAILABLE	MARTIN	WARHEAD XM137	R-L0565A1 10623212	(C)	(C)	(C)	(C)	(C)
									GUIDANCE & CONTROL XM474	R-L0559A2 10625225 9	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE
									2ND STAGE XM476	R-L0560B1 10625227-9	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE
									1ST STAGE XM475	R-L0560A1 106252269	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE
CORPORAL (PHASED OUT)		544	30 3/8	84	AT LAUNCH 11,247 UNFUELED 4461	NOT AVAILABLE	NOT AVAILABLE	FIRESTONE	WARHEAD INERT XM18	FAP 97901	46.57	28 3/4 WITH MOUNT. RING	—	1330	NOT AVAILABLE
									FORE BODY SECTION 8112776	8199478	108	30	—	NOT AVAILABLE	NOT AVAILABLE
									AFT BODY SECTION 8189464	M331 8138851	436	30 3/8	N.A.	2531 [illegible]	NOT AVAILABLE
NIKE-AJAX (PHASED OUT)		409	14.6	52	2259	NOT AVAILABLE	[illegible]	PRIME: WESTERN ELECTRIC	BODY-M2 8164430	M326 8051738	251	12	N.A.	450	NOT AVAILABLE
									ROCKET MOTOR M5 8682075	8026310 M15	158 7/8	16 1/4	N.A.	1208	NOT AVAILABLE
									WARHEAD M2 8796000	76-1-1550	N.A.	N.A.	—	12	(C)
									WARHEAD M3 8796030	7548248	23	11	—	177	(C)
									WARHEAD M4 8796061	7548249	21	11	—	121	(C)

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(C)-REFERS TO CLASSIFIED INFORMATION

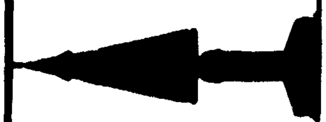
TABLE 6

S. ARMY MISSILES AND ROCKETS (cont)

[illegible]	MFG.	MISSILE SECTION & DWG NO	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY	TEMPERATURE LIMITS	PRESSURE LIMITS	HUMIDITY LIMITS	FRAGILITY LEVELS	ALLOWABLE BENDING MOMENT	HARD POINTS	HANDLING DEVICES	FINS	LOGISTIC [illegible]
NOT AVAILABLE	MARTIN	WARHEAD AM137	R-10565A1 P10683812	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	NOT AVAILABLE	NONE	WORLDWIDE
		GUIDANCE & CONTROL AM476	R-10559A2 10625225-9	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	(C)	(C)	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	NONE	WORLDWIDE
		2ND STAGE AM476	R-10560B1 10625227-9	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	(C)	(C)	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	4 FINS SHIPPED SEPARATELY	WORLDWIDE
		1ST STAGE AM475	R-10560A1 10625226-9	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	(C)	(C)	(C)	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	4 FINS SHIPPED SEPARATELY	WORLDWIDE
NOT AVAILABLE	FIRESTONE	WARHEAD [illegible]	FAP 97301	46.37	28.47 WITH MOUNT. RING	—	1350	NOT AVAILABLE	NONE	NONE	NONE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	—
		FORE BODY SECTION P8115776	8189078	108	30	—	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	NOT AVAILABLE
		AFT BODY SECTION P8189066	M351 P8138881	436	30 3/8	N.A.	2531 [illegible]	NOT AVAILABLE	NONE	NOT AVAILABLE	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	4 FINS SHIPPED SEPARATELY	NOT AVAILABLE
[illegible]	PRIME: WESTERN ELECTRIC	BODY-M2 P8164480	M326 8001738	231	12	N.A.	450	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	HOIST BEAM P8003[illegible]	4 FINS SHIPPED SEPARATELY	NOT AVAILABLE
		ROCKET MOTOR M5 P8082075	[illegible] M13	158 3/8	16 1/4	N.A.	1208	NOT AVAILABLE	-20°F TO +130°F	NOT AVAILABLE	(C)	(C)	NOT AVAILABLE	NOT AVAILABLE	HANDLING YOKE [illegible]	4 FINS SHIPPED SEPARATELY	NOT AVAILABLE
		WARHEAD M2 P8786800	76-1-1350	N.A.	N.A.	—	12	(C)	(C)	(C)	(C)	(C)	—	—	SAME AS ABOVE	NONE	NOT AVAILABLE
		WARHEAD M3 P8786830	7540246	23	11	—	177	(C)	(C)	(C)	(C)	(C)	—	—	SAME AS ABOVE	NONE	NOT AVAILABLE
		WARHEAD M4 P8786[illegible]	7540249	21	11	—	121	(C)	(C)	(C)	(C)	(C)	—	—	ADAPTER HOIST [illegible]	NONE	NOT AVAILABLE

[illegible]ERS TO CLASSIFIED INFORMATION

TABLE 6
U. S. ARMY MISSILES AND ROCKETS

MISSILE OR ROCKET	PROFILE	DIMENSIONS, O.A. (IN INCHES) LENGTH	DIA.	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY	MISSILE DRAWING NUMBER	MFG.	MISSILE SECTION & DRG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA.	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY
NIKE-HERCULES		490½	31½	[illegible] 90 / [illegible] 138	10,670	292 IN. FROM NOSE		WESTERN ELECTRIC	BODY SECTION (FORE & AFT) [illegible]	M410 [illegible]	262½	31½	90	1329	NOT AVAILABLE
									WARHEAD SECTION	M489 [illegible]	62½	31	N.A.	1230	(C)
									ROCKET MOTOR [illegible]	[illegible]1177	173½	WIDTH 38½ HEIGHT 37	N.A.	5275	NOT AVAILABLE
									ROCKET MOTOR M30 [illegible]	[illegible]	105	N.A.	N.A.	NOT AVAILABLE	NOT AVAILABLE
NIKE-ZEUS		600	[illegible] 43	117 (MAX)	(C)	(C)	[illegible]	PRIME: WESTERN ELECTRIC	WARHEAD SECTION [illegible]	[illegible]	74.0	36.0	NOT APPLIC.	(C)	(C)
									GUIDANCE SECTION [illegible]	[illegible]	34[illegible]	42[illegible] MAX	NOT APPLIC.	(C)	(C)
									SUSTAINER ROCKET MOTOR [illegible]	[illegible]	[illegible] (MAX)	36.[illegible]	N.A.	(C)	(C)
									THIRD STAGE MOTOR [illegible]	[illegible] ([illegible])	37.0	31.7	N.A.	(C)	(C)
									BOOSTER ROCKET MOTOR (FIRST STAGE) [illegible]	[illegible]	204.1 (MAX)	43.6	117	(C)	(C)
CHAPARRAL	UNDER DEVELOPMENT														
SPRINT	"														
MAW	"														

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(C) - REFERS TO CLASSIFIED INFORMATION

TABLE 6
ARMY MISSILES AND ROCKETS (cont)

[illegible]	MFG.	MISSILE SECTION & DRG. NO.	CONTAINER USED	DIMENSIONS (IN INCHES) LENGTH	DIA	SPAN	WEIGHT (IN POUNDS)	LOCATION OF CENTER OF GRAVITY	TEMPERATURE LIMITS	PRESSURE LIMITS	HUMIDITY LIMITS	FRAGILITY LIMITS	ALLOWABLE BENDING MOMENT	HARD POINTS	HANDLING DEVICES	FINS	LOGISTIC REQUIREMENTS
	WESTERN ELECTRIC	BODY SECTION (FWD & AFT) [illegible]	M410 [illegible]	262[illegible]	31½	90	1329	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		WARHEAD SECTION	M403 [illegible]	62½	31	N.A.	1230	(c)	(c)	(c)	(c)	(c)	(c)	(c)	[illegible]	NOT AVAILABLE	NOT AVAILABLE
		ROCKET MOTOR [illegible]	[illegible]	173½	[illegible] 38½ [illegible] 37	N.A.	5275	NOT AVAILABLE	STORAGE LIMITS: [illegible] FIRING LIMITS: [illegible]	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	[illegible]	4 [illegible] FINS, SPAN OF [illegible]	NOT AVAILABLE
		ROCKET MOTOR M 20 [illegible]	[illegible]	105	N.A.	N.A.	NOT AVAILABLE	NOT AVAILABLE	[illegible]	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	[illegible]	NOT AVAILABLE	NOT AVAILABLE
[illegible]	PRIME: WESTERN ELECTRIC	WARHEAD SECTION [illegible]	[illegible]	74.0	26.0	NOT APPLIC.	(c)	(c)	[illegible]	NONE	[illegible]	NOT AVAILABLE	NOT AVAILABLE	[illegible]	[illegible]	NONE	(c)
		GUIDANCE SECTION [illegible]	[illegible]	34[illegible]	42[illegible]	NOT APPLIC.	(c)	(c)		NONE		NOT AVAILABLE	NOT AVAILABLE		[illegible]	NONE	(c)
		SUSTAINER ROCKET MOTOR [illegible]	[illegible]	[illegible] (N.A.)	36.[illegible]	N.A.	(c)	(c)	SAME AS ABOVE	NONE	SAME AS ABOVE	NOT AVAILABLE	NOT AVAILABLE		[illegible]	NOT AVAILABLE	(c)
		THIRD STAGE MOTOR [illegible]	[illegible] ([illegible])	37.0	31.7	N.A.	(c)	(c)	SAME AS ABOVE	NONE	SAME AS ABOVE	NOT AVAILABLE	NOT AVAILABLE	SAME AS ABOVE	[illegible]	NOT AVAILABLE	(c)
		BOOSTER ROCKET MOTOR (FIRST STAGE) [illegible]	[illegible]	20[illegible] (N.A.)	43.6	117	(c)	(c)	SAME AS ABOVE	NONE	SAME AS ABOVE	NOT AVAILABLE	NOT AVAILABLE	SAME AS ABOVE	SAME AS SUSTAINER MOTOR	4 FINS [illegible]	(c)

[illegible] INFORMATION

The following tabulation of Army Rocket and Missile Containers as presented, will function to orient the designer in the current state-of-the-art and serve as an historical record of previous design effort.

A cursory review is sufficient to impress one with the need for a standardized design approach, if not a standard modular design capable of convenient spatial modification. Obviously, the result of such an ambitious program will be a compromise; however; the design effort should strive for the ideal container providing:

a. Adequate performance

b. Multi-functional utility

c. Simplicity

d. Durability

e. Minimum cost

TABLE 7

U. S. ARMY MISSILE AND ROCKET CONTAI

MISSILE OR ROCKET	PROFILE	[illegible]	[illegible]	[illegible]	OUTSIDE DIMENSIONS (INCHES)			[illegible]	CENTER OF GRAVITY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
					[illegible]	[illegible]	[illegible]												
SS-10		[illegible]	[illegible]	[illegible]	22.0	22.4	23.2	55 [illegible]	℄	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SS-11		[illegible]	[illegible]	[illegible]	33	17	23	78.2 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	℄	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ENTAC		[illegible]	[illegible]	[illegible]	28.1	16.7	13.7	55 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOW		[illegible]	[illegible]	[illegible]	55	19	10½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
REDEYE		[illegible]	[illegible]	[illegible]	60	22	20	60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SHILLELAGH		[illegible]	[illegible]	[illegible]	36	22	20	[illegible]	℄	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LITTLE JOHN		[illegible]	[illegible]	[illegible]	100	20½	20½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	38	41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE 7

ARMY MISSILE AND ROCKET CONTAINERS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7

U. S. ARMY MISSILE AND ROCKET CONTAI

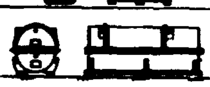
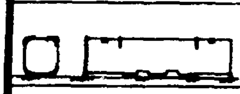
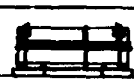
MISSILE OR ROCKET	PROFILE	COMPONENT PACKAGED	MFG. OF CONTAINER	CONTAINER DRAWING NUMBER	OUTSIDE DIMENSIONS (IN INCHES) LENGTH	WIDTH	HEIGHT	WEIGHT OF EMPTY CONTAINER (IN POUNDS)	CENTER OF GRAVITY	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER
HAWK		COMPLETE MISSILE XM3 OR MOTOR SECTION XM22 AND FOUR FINS	RED APPLIED DESIGN PRODUCTION WILLIAMSON MFG CO	XM430 #9073970	216	26¾	41½	1950	EMPTY 11 5/16 FROM CLOSED END LOADED: 121 5/16" FROM CLOSED END	STEEL	OVAL	END (ONE)	20 ELASTOMERIC MOUNTS - ORD. PRESENT 2 SHOCK ABSORBERS ORD #9139714	LONGITUDINALLY 25 g's FROM 160° TO -40°F ALL OTHER DIRECTIONS: 26 g's FROM 160° TO -25°F	NONE	SHIPPED & STORED AT 2½ ±½ PSIG CONTAINER TESTED AT 7 PSIG. AIR SHIPPED DEPRESSURIZED	DESICCANT	STORAGE LIMITS -40° TO +160°F
		FORE BODY SECTION & GUIDANCE SECTION	SEE ABOVE	XM461E2 #9073375	89 9/16	28 9/32	33 5/16	555	EMPTY: 47" FROM CLOSED END LOADED: 31" FROM CLOSED END	STEEL	CYL.	END (ONE)	8 HELICAL COMP. SPRINGS #9085015 & #9082016 RUBBER BUMPER #9085045	LONGITUDINALLY 30 g's FROM -65° TO 160°F ALL OTHER DIRECTIONS: 20 g's FROM -65° TO 160°F	NONE	SHIPPED & STORED AT 2½ PSIG DEPRESSURIZE PRIOR TO AIR SHIPMENT TESTED [illegible]	DESICCANT	NOT AVAILABLE
		WARHEAD (ALL TYPES) ONE PER BOX	PICATINNY ARSENAL	#8837892	18 1/16	18 1/16	17 29/32	38 GROSS: 157	℄	LUMBER SHEATHED	RECT.	TOP & SIDES REMOVED AS A UNIT	THIN CUSHIONING PAD USED UNDER WARHEAD	VERY LITTLE	NONE	NONE	NONE	NO LIMITS
		WARHEAD (ALL TYPES) TWO PER BOX	PICATINNY ARSENAL	#8830878	32 15/16	18 1/16	21 17/32	83 GROSS: 304	℄	LUMBER SHEATHED	RECT	TOP & SIDES REMOVED AS A UNIT	THIN CUSHIONING PADS USED UNDER WARHEADS	VERY LITTLE	NONE	NONE	NONE	NO LIMITS
LACROSSE (PHASED OUT)		WARHEAD M130	PICATINNY ARSENAL	#8838740 XM471	96	35.6	38.6	649 GROSS: 1200	EMPTY: ℄ LOADED: 37¼ FROM AFT END	STEEL	CYL.	TOP	8 ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	BUILT TO STAND 3 PSIG PRESSURIZATION DROPPED BECAUSE IT WAS IMPRACTICABLE	DESICCANT (10 LB.)	NOT AVAILABLE
		BODY ASSEMBLY W/MOTOR XM4E2 W/WING & FINS	NOT AVAILABLE	XM374E2 XM374E1 #8301400	182	41	45	1576 GROSS: 3074	EMPTY: ℄ LOADED: 87½ FROM OPEN END	STEEL	RECT.	END (ONE)	ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	TO MAINTAIN PRESSURE BETWEEN 3 & 3.7 PSI	DESICCANT (16 LB.-224 UNITS)	STORAGE LIMITS -60°F TO +160°F
		WARHEAD M139	PICATINNY ARSENAL	M484 #8810628	NOT AVAIL.	NOT AVAIL.	NOT AVAIL.	630	NOT AVAILABLE	ALUMINUM	CYL.	TOP	8 ELASTOMERIC SHEAR MOUNTS	NOT AVAILABLE	NONE	SEALED DEGREE OF PRESSURIZATION NOT AVAILABLE	DESICCANT	NOT AVAILABLE
		WARHEAD XM135E1	PICATINNY ARSENAL	M484E1 #88[illegible]604	102.5	37.2	38.8	655	NOT AVAILABLE	STEEL	OVAL	TOP	ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	SEALED DEGREE OF PRESSURIZATION NOT AVAILABLE	DESICCANT	NOT AVAILABLE

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TABLE 7

Y MISSILE AND ROCKET CONTAINERS (cont)

CENTER OF GRAVITY	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER	ALLOWABLE BEARING LOAD	STACKING DEVICES	UNITIZING DEVICES	HANDLING DEVICES	SUPPORTS	COVER ALIGNING DEVICES	SEALING DEVICES	LATCHING DEVICES	COMPONENT CHECKOUT DEVICES	DISPOSITION AND [illegible]	[illegible] LIFE
EMPTY: 11[illegible] FROM CLOSED END LOADED: 121[illegible]" FROM CLOSED END	STEEL	OVAL	END (ONE)	20 ELASTOMERIC MOUNTS - ORD. [illegible] & SHOCK ABSORBERS ORD [illegible]	LONGITUDINALLY 25 G's FROM 160° TO -40°F ALL OTHER DIRECTIONS: 26 G's FROM 160° TO -65°F	NONE	SHIPPED & STORED AT 2½ [illegible] PSIG CONTAINER TESTED AT 7 PSIG. AIR SHIPPED DEPRESSURIZED	DESICCANT	STORAGE LIMITS -40° TO +160°F	6200 LB (TOTAL)	4 STACKING PADS ON CORNERS OF BODY	4 STEEL STRAPS ON SIDES; CONNECT STACKING PAD TO BODY FRAME ABOVE SKID	TRANSVERSE FORK CHANNELS 4 LIFT EYES ON BRK'S ON TOP OF BODY TOWING HOLE NEAR SKIDS HAND GRIPS ON COVER	4 WOODEN SKIDS LOCATED IN FOUR CORNERS [illegible]	THREE TAPERED PINS ON CONTAINER BODY	RUBBER GASKET	12 "T" HEAD BOLTS	HUMIDITY INDICATOR	REUSABLE	[illegible]
EMPTY: 47" FROM CLOSED END LOADED: 51" FROM CLOSED END	STEEL	CYL.	END (ONE)	8 HELICAL COMP SPRINGS [illegible] & [illegible] RUBBER [illegible]	LONGITUDINALLY 30 g's FROM -65° TO 160°F ALL OTHER DIRECTIONS 20 g's FROM -65° TO 160°F	NONE	SHIPPED & STORED AT 2½ PSIG DEPRESSURIZE PRIOR TO AIR SHIPMENT [illegible]	DESICCANT	NOT AVAILABLE	CAN BE STACKED 4 HIGH	SAME AS ABOVE	SAME AS ABOVE	4 LIFT EYES ON BRK'S ON TOP OF BODY TOWING HOLES NEAR SKIDS HAND GRIP ON COVER	4 LONGITUDINAL WOOD SKIDS [illegible]	TWO TAPERED PINS ON CONTAINER BODY	RUBBER GASKET	10 "T" HEAD BOLTS [illegible]	HUMIDITY INDICATOR [illegible] RELIEF VALVE [illegible]	REUSABLE	SAME AS ABOVE
℄	LUMBER SHEATHED	RECT.	TOP & SIDES REMOVED AS A UNIT	THIN CUSHIONING PAD USED UNDER WARHEAD	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	NOT AVAILABLE	NONE	NONE	NONE	NONE	CONSTRUCTION OF BOX ALIGNS TOP AND SIDES	NONE	CAP SCREWS	NONE	DISPOSABLE WORLDWIDE	—
℄	LUMBER SHEATHED	RECT	TOP & SIDES REMOVED AS A UNIT	THIN CUSHIONING PADS USED UNDER WARHEADS	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	NOT AVAILABLE	NONE	NONE	NONE	3 TRANSVERSE WOOD SKIDS	CONSTRUCTION OF BOX ALIGNS TOP AND SIDES	NONE	CAP SCREWS, & 2 STEEL STRAPS	NONE	DISPOSABLE WORLDWIDE	—
EMPTY: ℄ LOADED: 37½ FROM AFT END	STEEL	CYL	TOP	8 ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	BUILT TO STAND 7 PSIG PRESSURIZATION DROPPED BECAUSE IT WAS IMPRACTICABLE	DESICCANT (10 LB)	NOT AVAILABLE	STACKED 4 HIGH OUTDOOR STORAGE ONLY 2 HIGH	4 STACKING PADS ON COVER	FOUR 1½" WIDE STEEL STRAPS CONNECT STACKING PADS TO [illegible] ON CONTAINER	2 LIFTING RINGS ON COVER TIE DOWNS & TOW HOLES IN FRAME	4 LONGITUDINAL WOOD SKIDS	[illegible] PINS ON BOTTOM HALF OF CONTAINER	SEALED BY 'O' RING	24 TEE BOLTS & LOCK NUTS	HUMIDITY INDICATOR EQUALIZATION PLUG	REUSABLE	NOT AVAIL.
EMPTY: ℄ LOADED: 87½ FROM OPEN END	STEEL	RECT.	END (ONE)	ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	TO MAINTAIN PRESSURE BETWEEN 2 & 2.7 [illegible]	DESICCANT (14 LB.-224 UNITS)	STORAGE LIMITS -60°F TO +140°F	STACKED 3 HIGH	4 STACKING PADS ON TOP OF BODY	NONE	4 LIFT EYES ON TOP OF BODY, 2 HAND GRIPS ON COVER, BODY NOTCHED FOR FORK TINES	4 LONGITUDINAL WOOD SKIDS	TWO PINS ON BODY OF CONTAINER	SEALED BY GASKET	12 QUICK RELEASE LATCHES	HUMIDITY INDICATOR & RELIEF VALVE 3	REUSABLE	NOT AVAIL.
NOT AVAILABLE	ALUMINUM	CYL.	TOP	8 ELASTOMERIC SHEAR MOUNTS	NOT AVAILABLE	NONE	SEALED DEGREE OF PRESSURIZATION NOT AVAILABLE	DESICCANT	NOT AVAILABLE	NOT AVAILABLE	REINFORCING RIBS FROM A FLAT BASE ON COVER FOR STACKING	4 STEEL STRAPS	TRANSVERSE FORK CHANNELS ON BOTTOM	4 LONGITUDINAL WOOD SKIDS	FOUR PINS ON BASE	RUBBER GASKET IN BASE	28 WING TYPE CLAMPS	HUMIDITY INDICATOR	REUSABLE	NOT AVAIL.
NOT AVAILABLE	STEEL	OVAL	TOP	ELASTOMERIC MOUNTS	NOT AVAILABLE	NONE	SEALED DEGREE OF PRESSURIZATION NOT AVAILABLE	DESICCANT	NOT AVAILABLE	NOT AVAILABLE	4 STACKING PADS ON COVER	NOT AVAILABLE	2 LIFTING EYES ON COVER, TOW EYES IN BASE	4 LONGITUDINAL WOOD SKIDS	TWO PINS, ONE ON EACH END AT ℄	RUBBER GASKET IN BASE	30 WING TYPE CLAMPS	HUMIDITY INDICATOR RELIEF VALVE	REUSABLE	NOT AVAIL.

TABLE 7

U. S. ARMY MISSILE AND ROCKET CONTAI

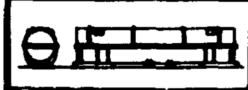
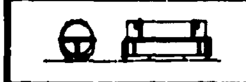
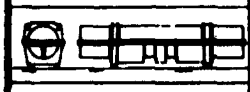
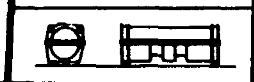
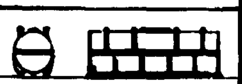
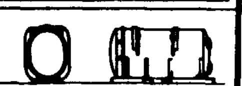
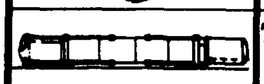
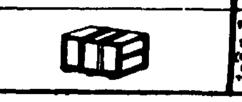
MISSILE OR ROCKET	PROFILE	COMPONENT PACKAGED	MFG	CONTAINER DRAWING NUMBER(S)	OUTSIDE DIMENSIONS (IN INCHES) LENGTH	WIDTH	HEIGHT	WEIGHT OF EMPTY CONTAINER (IN POUNDS)	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER	ALLOW[ABLE] STA[CKING] LOA[D]
SERGEANT		WARHEAD XM38	PICATINNY ARSENAL	[illegible] F9826576	$109\frac{1}{2}$	48	$49\frac{1}{2}$	819	ALUMINUM	OVAL	TOP HINGED	POLYURETHANE FOAM SKIDS	20G'S SHOCK 10G'S VIB. ACCEL.	NOT AVAILABLE	4.5±.5PSI CAN STAND [illegible]	DESICCANT	SHIPPING AND STORAGE -40° TO +[illegible]	NOT AVAIL[ABLE]
		ROCKET MOTOR XM83	DESIGNER: APPLIED DESIGN	XM 486 F10397884 (APPLIED DESIGN NO. 594A1)	$220\frac{1}{8}$	$47\frac{1}{8}$	$48\frac{1}{8}$	1710	STEEL	CYL.	TOP 8 HINGES	ELASTOMERIC MOUNTS	20G'S VERT & LATERAL 30G'S LONG.	30RB HEATER MESH TYPE +10°±3°F WITH OUTSIDE TEMP -65°F POLYURETHANE INSULATION	+3PSIG±.5 -1PSIG±.5 APRV.	DESICCANT	OPERATE: -65° TO +125°F STORAGE: -80° TO +[illegible]	TWICE [illegible] GROSS [illegible]
		GUIDANCE & CONTROL AN/DJW-8	DESIGNER: APPLIED DESIGN	XM487 F10387334 (APPLIED DESIGN NO. 593A1)	$107\frac{1}{4}$	$47\frac{1}{8}$	$47\frac{3}{8}$	810	STEEL	CYL.	TOP 6 HINGES	ELASTOMERIC MOUNTS (APPLIED DESIGN #593A136)	25G'S IN THREE AXIS	3 MESH TYPE HEATERS -20°±3°F, WITH TEMP -65°F	+3PSIG±.5 -1PSIG±.5 TESTED AT 4.5[illegible]	DESICCANT	-65°F TO +125°F STORAGE: -80° TO +[illegible]	3960 [illegible] SNOW [illegible]
		ROCKET MOTOR XM53	DESIGN: JET PROPULSION LAB PRIME: SPERRY	XM419 F11065436	226	48	49	1240	ALUMINUM	CYL.	HINGED TOP COUNTER-BALANCED BY TORSION BARS	PACKED IN RIGID POLYURETHANE FOAM, SHOCK MITIGATION FROM POLYURETHANE FOAM SKIDS	20G'S TRANSVERSE 30G'S LONGITUDINAL	ELECTRIC BLANKET TEMPERATURE KEPT NOT LESS THAN 20°F WITH OUTSIDE TEMP AT -65°F	BREATHER VALVES OPERATE AT -.5 OR +.5 PSIG.	NO DESICCANT IN CONTAINER. SILICA GEL DESICCANT SEALED IN ROCKET MOTOR	STORAGE LIMITS -65°F TO +130°F	CANNOT STACK MORE T[HAN] TWO HI[GH]
		GUIDANCE & CONTROL AN/DJW-8	DESIGN: JET PROPULSION LAB PRIME: SPERRY	XM420 F11065435	123	48	49	827	ALUMINUM	CYL.	HINGED TOP COUNTER-BALANCED BY TORSION BARS	MOUNTED RIGIDLY IN CONTAINER. SHOCK MITIGATION FROM POLYURETHANE FOAM SKIDS.	25 G'S IN 12 MILLISEC ALL DIRECTIONS	SPACE HEATER PROVIDES TEMPERATURE CONTROL	BREATHER VALVES OPERATE AT -.5 OR +.5 PSIG.	SILICA GEL DESICCANT, 30-40% MAXIMUM RELATIVE HUMIDITY	STORAGE LIMITS -65°F TO +160°F	SAME [AS] ABOV[E]
PERSHING		WARHEAD XM137	PICATINNY ARSENAL	XM483 F10623212	168	$52\frac{1}{2}$	53	1800	STEEL	CYL.	TOP	ELASTOMERIC SHEAR MOUNTS	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILA[BLE]
		GUIDANCE & CONTROL XM474	SPACE CORP (DALLAS)	R-L05584A2 F10625225 BASE ASS'Y F11025[illegible]	90	65	72	1947	STEEL	OVAL	END	4 SHEAR MOUNTS 4 HYDRAULIC SHOCK ABSORBERS	NOT AVAILABLE	ELECTRIC WRAP END NOT HEATED ELECT. SOURCE REQUIRED	UNPRESSURIZED SEALED CONTAINER WITH RELIEF VALVE TESTED @ [illegible]	176 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ON[LY] BE STA[CKED] TWO HI[GH]
		2ND STAGE XM476	SPACE CORP (DALLAS)	R-L05605I F10625227-5 BASE ASS'Y F11[illegible]	$144\frac{1}{2}$	65	70	3745	STEEL	OVAL	END	16 SHEAR MOUNTS LORD J 7784 36 12 GABRIEL HYD. SHOCK ABSORBERS 1P-330-A	NOT AVAILABLE	CAN MAINTAIN TEMP BETWEEN 30°-110°F WITH EXTERNAL TEMP AT -65°F STRIP TYPE HEATER	SAME AS ABOVE	256 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ON[LY] BE STA[CKED] TWO HI[GH]
	SAME AS 2ND STAGE ABOVE	1ST STAGE XM475	SPACE CORP (DALLAS)	R-L05606A1 F10625226 BASE ASS'Y F11025541	$144\frac{1}{2}$	65	70	3793	STEEL	OVAL	END	16 SHEAR MOUNTS LORD J 7784 36 12 GABRIEL HYD. SHOCK ABSORBERS 1P-330-A	NOT AVAILABLE	ELECTRIC SOURCE IS REQUIRED 1ST & 2ND STAGES ARE IDENTICAL	SAME AS ABOVE	256 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ON[LY] BE STA[CKED] TWO HI[GH]
CORPORAL (PHASED OUT)		INERT WARHEAD XM15	PICATINNY ARSENAL	PXP 97301	$34\frac{13}{16}$	$34\frac{13}{16}$	$45\frac{3}{4}$	EMPTY: 260 GROSS: 1614	WOOD	RECT.	TOP AND SIDES REMOVED AS A UNIT	WOOD CRADLE	NONE	NONE	NONE	NONE	NO LIMITS	STACK[ING] MAXIMU[M] THREE H[IGH]
		AFT BODY SECTION M4	NOT AVAILABLE	M351 F8136851	461	49	58	EMPTY: 6376 END BELL 648 GROSS: 9107	STEEL	CYL.	END BELL TYPE COVER	TORSION BARS (SEE CHAPTER [illegible] FOR DETAILS)	NOT AVAILABLE	NONE	5 PSIG KEPT BETWEEN 3 & 7 PSIG	MAXIMUM 35% R.H. 800 UNITS OF DESICCANT (32 LB.)	NOT AVAILABLE	CAN ON[LY] BE STAC[KED] TWO HI[GH]
		FORE BODY SECTION [illegible] (COMPONENTS SHIPPED TOGETHER)	NOT AVAILABLE	DIBBOTS (NEW DESIGN TABULATED) SIMILAR AND DESIGN #AB9046	$68\frac{3}{4}$	$40\frac{3}{4}$	$31\frac{3}{16}$	EMPTY: 282 GROSS: 407	PLYWOOD, CARDBOARD INNERPACK	RECT.	TOP, ENDS AND SIDES REMOVABLE	NOT AVAILABLE	UNKNOWN	NONE	NONE	BARRIER BAG 176 UNITS OF DESICCANT USED	NO LIMITS	RECOMME[NDED] STACKIN[G] THREE [HIGH] (CAN BE [STACKED] HIGHER)

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TABLE 7

MY MISSILE AND ROCKET CONTAINERS (cont)

[illegible]	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER	ALLOWABLE BEARING LOAD	STACKING DEVICES	UNITIZING DEVICE	HANDLING DEVICES	SUPPORTS	COVER ALIGNING DEVICES	SEALING DEVICES	LATCHING DEVICES	[illegible] DEVICES	DISPOSITION AND [illegible]	[illegible]	LIFE
0	ALUMINUM	OVAL	TOP HINGED	POLYURETHANE FOAM SKIDS	20G'S SHOCK 10G'S VIB. ACCEL.	NOT AVAILABLE	4.5±.5PSI CAN STAND 8.5±.5PSI	DESICCANT	SHIPPING AND STORAGE -40° TO +165°	NOT AVAILABLE	[illegible] STACKING PADS ON BODY STRUCTURAL MEMBERS	NOT AVAILABLE	[illegible] 4 LIFT PTS ON STACKING PADS [illegible]	[illegible] WOOD SKIDS	4 PINS ON CONTAINER BODY	NOT AVAILABLE	12 [illegible] & LOCKING STUDS	[illegible] FITTINGS HUMIDITY INDICATOR	REUSABLE	NOT AVAILABLE	NOT AVAIL.
10	STEEL	CYL.	TOP 8 HINGES	ELASTOMERIC MOUNTS	20G'S VERT & LATERAL 30G'S LONG.	300 W HEATER MESH TYPE +10°±3°F WITH OUTSIDE TEMP -65°F POLYURETHANE INSULATION	+3PSIG±2.5 -1PSIG±.5 APRV.	DESICCANT	OPERATE: -65° TO +165°F STORAGE: -80° TO +160°	TWICE ITS GROSS WEIGHT	4 STACKING PADS ON BODY SHELL 2 HIGH	STEEL STRAP	8 TIE-DOWN AND LIFTING EYES ON STRUCTURAL MEMBERS BELOW ℄	LONGITUDINAL WOOD SKIDS	4 PINS	RUBBER 'O' RING SEAL	36 'T' BOLTS	HIGH & LOW TEMP. IND. HUMIDITY INDICATOR	REUSABLE	NOT AVAILABLE	NOT AVAIL.
0	STEEL	CYL.	TOP 6 HINGES	ELASTOMERIC MOUNTS (APPLIED DESIGN #[illegible])	25G'S IN THREE AXIS	3 MESH TYPE HEATERS -20°±3°F WITH TEMP -65°	+3PSIG±.5 -1PSIG±.5 TESTED AT 4.5PSIG	DESICCANT	-65°F TO +125°F STORAGE: -80° TO +160°	3960 lb 1010/ft² SNOW LOAD	4 STACKING PADS ON BODY SHELL	4 STEEL STRAPS USED IN UNITIZING	8 TIE DOWN AND LIFTING EYES ON STRUCTURAL MEMBERS BELOW ℄	LONGITUDINAL WOOD SKIDS	4 PINS	RUBBER 'O' RING SEAL	20 'T' BOLTS	ELECTRICAL HIGH & LOW TEMP. IND. HUMIDITY INDICATOR	REUSABLE	℄	NOT AVAIL.
40	ALUMINUM	CYL.	HINGED TOP COUNTER BALANCED BY TORSION BARS	PACKED IN RIGID POLYURETHANE FOAM. SHOCK MIT. BY [illegible] POLYURETHANE FOAM SKIDS	20G'S TRANSVERSE [illegible] LONGITUDINAL	ELECTRIC BLANKET TEMPERATURE KEPT NOT LESS THAN 20°F WITH OUTSIDE TEMP [illegible]	BREATHER VALVE OPERATE AT -0.5 OR +2.5 PSIG	NO DESICCANT IN CONTAINER. SILICA GEL DESICCANT SEALED IN [illegible]	STORAGE LIMITS -[illegible] TO +130°F	CANNOT BE STACKED MORE THAN TWO HIGH	SMALL [illegible] ON SKIDS FRAME SURROUNDS CONTAINER (NOT [illegible])	SMALL [illegible] CONNECTING STACKING [illegible]	4 LIFT HOLES IN TOP OF FRAME - STEEL EYES - BODY [illegible]	2 [illegible] STEEL SKIDS [illegible]	8 PINS (FRONT [illegible])	SILICONE GASKET	SCREW ACTUATED HOOKS	HUMIDITY & TEMPERATURE INDICATORS ELECTRICAL CHECKOUTS	REUSABLE	AT ℄	10 YRS.
7	ALUMINUM	CYL	HINGED TOP COUNTER-BALANCED BY TORSION BARS	MOUNTED RIGIDLY IN CONTAINER, SHOCK MIT. BY [illegible] POLYURETHANE FOAM SKIDS.	25 G'S IN 12 MILLISEC ALL DIRECTIONS	SPACE HEATER PROVIDES TEMPERATURE CONTROL	BREATHER VALVES OPERATE AT -0.2 OR +2.5 PSIG	SILICA GEL DESICCANT, 30-40% MAXIMUM RELATIVE HUMIDITY	STORAGE LIMITS -[illegible] TO +[illegible]	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	4 PINS (FRONT [illegible])	SILICONE GASKET	SAME AS ABOVE	HUMIDITY & TEMPERATURE INDICATORS ELECTRICAL CHECKOUTS	REUSABLE	℄	[illegible] 10 YRS
00	STEEL	CYL	TOP	ELASTOMERIC SHEAR MOUNTS	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	4 STACKING PADS ON BODY	NOT AVAILABLE	NOT AVAILABLE	4 LONGITUDINAL WOOD SKIDS	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	REUSABLE	NOT AVAILABLE	NOT AVAIL.
47	STEEL	OVAL	END	4 SHEAR MOUNTS 4 HYDRAULIC SHOCK ABSORBERS	NOT AVAILABLE	ELECTRIC WRAP END NOT HEATED ELECT SOURCE REQUIRED	[illegible] SEALED CONTAINER WITH RELIEF VALVE TESTED @ [illegible]	176 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ONLY BE STACKED TWO HIGH	4 STACKING PADS ON BODY STRUCTURAL MEMBERS	NONE	4 TOW RINGS 8 ANCHOR SHACKLES 4 SLING SHACKLES FOR LIFTING [illegible]	4 WOODEN SKIDS [illegible] BRG. AREA: [illegible]	8 PINS ON CONTAINER CLOSURE FLANGE	RUBBER 'O' RING	4 T-BOLTS & 50 CAM BOLTS	HUMIDITY TEMPERATURE & SHOCK INDICATORS ELECTRICAL CHECKOUTS	REUSABLE	[illegible]	NOT AVAIL.
745	STEEL	OVAL	END	16 SHEAR MOUNTS LORD [illegible] 12 GABRIEL HYD SHOCK ABSORBERS SP-350-[illegible]	NOT AVAILABLE	CAN MAINTAIN TEMP BETWEEN 30°-120°F WITH EXTERNAL TEMP AT -65°F STRIP TYPE HEATER	SAME AS ABOVE	256 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ONLY BE STACKED TWO HIGH	SAME AS ABOVE	NONE	[illegible] COVER [illegible] CHANNEL & (TRANSVERSE) ROLLOVER RINGS	4 WOODEN SKIDS THICK [illegible] BRG AREA: [illegible]	SAME AS ABOVE	RUBBER 'O' RING	4 T-BOLTS & 50 CAM BOLTS	[illegible]	REUSABLE	[illegible]	NOT AVAIL.
93	STEEL	OVAL	END	16 SHEAR MOUNTS LORD [illegible] 16 GABRIEL HYD SHOCK ABSORBERS SP-350-[illegible]	NOT AVAILABLE	ELECTRIC SOURCE IS REQUIRED 1ST & 2ND STAGES ARE IDENTICAL	SAME AS ABOVE	256 UNITS OF DESICCANT CHANGED WHEN R.H. REACHES 30%	NOT AVAILABLE	CAN ONLY BE STACKED TWO HIGH	SAME AS ABOVE	NONE	SAME AS ABOVE	[illegible] BRG. AREA: [illegible]	SAME AS ABOVE	RUBBER 'O' RING	4 T-BOLTS & 50 CAM BOLTS		REUSABLE	[illegible]	NOT AVAIL.
[illegible]	WOOD	RECT.	TOP AND SIDES REMOVED AS A UNIT	WOOD CRADLE	NONE	NONE	NONE	NONE	NO LIMITS	STACKED MAXIMUM OF THREE HIGH	NONE	NONE	NONE	3 WOOD SKIDS	NONE	NONE ON CONTAINER	WOOD SCREWS	NONE	REUSABLE OR SERVICEABLE	℄	—
[illegible]	STEEL	CYL	END BELL TYPE COVER	TORSION BARS (SEE CHAPTER [illegible] FOR DETAILS)	NOT AVAILABLE	NONE	5 PSIG KEPT BETWEEN 3 & 7 PSIG	MAXIMUM 35% R.H. [illegible] 800 UNITS OF DESICCANT ([illegible])	NOT AVAILABLE	CAN ONLY BE STACKED TWO HIGH	NONE	NONE	HANDLING BEAM ([illegible]) ATTACHED TO [illegible] ON GAS HOUSINGS FOR LIFTING	4 LONGITUDINAL WOODEN SKIDS	GUIDE PIN ON CONTAINER FLANGE	GASKET	13 BOLTS	[illegible] HUMIDITY INDICATOR ON EACH END. TWO [illegible]	REUSABLE	APPROX AT ℄	NOT AVAIL.
[illegible]	PLYWOOD, CARDBOARD, [illegible]	RECT.	TOP, ENDS AND SIDES REMOVABLE	NOT AVAILABLE	UNKNOWN	NONE	NONE	BARRIER BAG 176 UNITS OF DESICCANT USED	NO LIMITS	RECOMMEND STACKING THREE HIGH (CAN BE STACKED HIGHER)	NONE	NONE	NONE	[illegible] WOOD SKIDS	NONE	NONE ON CONTAINER, [illegible] WATER [illegible] AROUND TOP	BOLTS AND STEEL STRAPS	HUMIDITY INDICATOR & INSPECTION PORT IN BARRIER BAG	REUSABLE OR SERVICEABLE	℄	—

TABLE 7

U. S. ARMY MISSILE AND ROCKET CONT

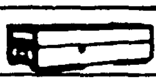
MISSILE OR ROCKET	PROFILE	COMPONENT PACKAGED	MFG.	CONTAINER DRAWING NUMBER	OUTSIDE DIMENSIONS (IN INCHES) LENGTH	WIDTH	HEIGHT	WEIGHT OF EMPTY CONTAINER (IN POUNDS)	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER
NIKE-AJAX (PHASED OUT)		NOSE WARHEAD M5 (T[illegible]) (TWO PER CONTAINER)	NOT AVAILABLE	76-1-1830	15½	7⅝	10 [illegible]	26 GROSS: 38	WOOD	RECT	HINGED COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS
		CENTER WARHEAD M6 (T[illegible])	NOT AVAILABLE	7548248	28 [illegible]	13 [illegible]	16 [illegible]	35 GROSS: 215.8	WOOD	RECT	REMOVABLE COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS
	SAME AS CENTER WARHEAD ABOVE	REAR WARHEAD M4 (T[illegible])	NOT AVAILABLE	7548249	26⅝	12¾	16 [illegible]	32 GROSS: 153	WOOD	RECT	REMOVABLE COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS
		ROCKET MOTOR M5 (THRUST [illegible])	NOT AVAILABLE	M13A1 [illegible]	174	27	28½	EMPTY: [illegible] GROSS: 1040	WOOD	RECT	TOP SPLIT AT ℄	RUBBER LINED WOOD SADDLES (6)	VERY LITTLE	NONE	NONE	NONE	STORAGE LIMITS -40° TO +130°F
		BODY M2 (MISSILE [illegible])	NOT AVAILABLE	M326 8031738	243½	38⅝	41	2045	STEEL	CYL	END (BOTH)	4 SHOCK ABSORBERS & [illegible] & ELASTOMERIC SHOCK MOUNTS [illegible]	10 G'S LONG. 13 G'S LAT. 15 G'S VERT.	NONE	5 PSIG TESTED AT 20 PSIG VALVE OPENS [illegible]	DESICCANT (140 UNITS)	NOT AVAILABLE
		ROCKET MOTOR M5 (BOOSTER [illegible])	NOT AVAILABLE	M13 8026310	175	24½	26½	EMPTY: 675 GROSS: 1883	WOOD	RECT	TOP, SIDES & ENDS REMOVED AS A UNIT	WOODEN CRADLES	VERY LITTLE	NONE	NONE	NONE	STORAGE LIMIT -40° TO +130°F
NIKE-HERCULES		WARHEAD HE	DESIGNED BY DOUGLAS MFG. FROM [illegible]	[illegible] 8031006	59½	54⅝	61½	1923 GROSS: 3178	STEEL	CYL	END (ONE)	8 COMPRESSION SPRINGS AND 8 HYDRAULIC SHOCK ABSORBERS	NOT AVAILABLE	NONE	5 PSIG	DESICCANT 30% RH	-65°F TO +165°F
	NOT AVAILABLE	WARHEAD M17 (T-45) [illegible]	NOT AVAILABLE	FSP 9008	34 [illegible]	34 [illegible]	39½	GROSS: 1250	WOOD	RECT	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	NONE	NONE	NO LIMITS
		BODY SECTION	DESIGNED BY DOUGLAS MFG. [illegible]	M410 8031007	223½	54½	61½	3375 GROSS WT. 4861	STEEL	CYL	END (ONE)	8 COMPRESSION SPRINGS AND 8 HYDRAULIC SHOCK ABSORBERS	NOT AVAILABLE	NONE	5 PSIG	DESICCANT 30% RH	-65° TO +165°F
	SEE M13 OR M13A1 ABOVE	ROCKET MOTOR M5E1 OR M30 (BOOSTER)	—	USES CONTAINER M13A1 OR M13 (SEE ABOVE)	—	—	—	—	—	—	—	—	—	—	—	—	—
		ROCKET MOTOR M30 [illegible]	NOT AVAILABLE	8034264	105⅛	43½	47 [illegible]	GROSS WT 3844	PLYWOOD SHEATHED	RECT	TOP, SIDES & ENDS REMOVED	NOT AVAILABLE	NOT AVAILABLE	NONE	NONE	NONE	NO LIMITS
		ROCKET MOTOR M42 [illegible]	NOT AVAILABLE	8031177	180	43	54½	1475	PLYWOOD SHEATHED (1⅜ IN.)	RECT	TOP AND SIDES ARE REMOVED AS A UNIT	2 METAL CRADLES SUPPORTING [illegible] ON RUBBER [illegible] CRADLE BOLTED TO WOODEN BASE	UNKNOWN	NONE	NONE	NONE, SCREENED VENTILATION [illegible] EACH END	NO LIMITS

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TABLE 7
ARMY MISSILE AND ROCKET CONTAINERS (cont)

[illegible]	WEIGHT OF [illegible] (LBS)	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER	ALLOWABLE STACKING LOAD	STACKING DEVICES	LIFTING DEVICES	HANDLING DEVICES	SUPPORTS	COVER ALIGNING DEVICES	SEALING DEVICES	LATCHING DEVICES	COMPONENT CHECKOUT DEVICES	[illegible] AND [illegible]	[illegible] OF [illegible]	[illegible]
[illegible]	26 GROSS: 30	WOOD	RECT	HINGED COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	CAN BE STACKED 9 HIGH	NONE	NONE	NONE	[illegible]	[illegible]	NONE	[illegible]	NONE	[illegible]	[illegible]	—
[illegible]	35 GROSS: 2:50	WOOD	RECT	REMOVABLE COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	CAN BE STACKED 9 HIGH	NONE	NONE	NONE	[illegible]	[illegible]	NONE	[illegible]	NONE	[illegible]	[illegible]	—
[illegible]	32 GROSS: 153	WOOD	RECT	REMOVABLE COVER	PADDED WOOD CRADLES	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	CAN BE STACKED 9 HIGH	NONE	NONE	NONE	[illegible]	[illegible]	NONE	[illegible]	NONE	[illegible]	[illegible]	—
[illegible]	EMPTY: GROSS: 1040	WOOD	RECT	TOP SPLIT AT ℄	RUBBER LINED WOOD SADDLES (6)	VERY LITTLE	NONE	NONE	NONE	STORAGE LIMITS [illegible] TO +130°F	STACKED 4 HIGH	NONE	NONE	2 COVER LIFTING [illegible]	[illegible]	[illegible]	NONE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2045	STEEL	CYL	END (BOTH)	[illegible]	[illegible]	NONE	5 PSIG TESTED AT 20 PSIG [illegible]	DESICCANT (160 UNITS)	NOT AVAILABLE	CAN BE STACKED 3 HIGH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	EMPTY: 675 GROSS: 1003	WOOD	RECT	TOP, SIDES & ENDS REMOVED AS A UNIT	WOODEN CRADLES	VERY LITTLE	NONE	NONE	NONE	STORAGE LIMIT [illegible] TO +130°F	STACKED 4 HIGH	NONE	NONE	2 COVER LIFTING [illegible]	[illegible]	NONE	NONE	[illegible]	NONE	[illegible]	[illegible]	[illegible]
[illegible]	1923 GROSS: 3170	STEEL	CYL	END (ONE)	[illegible]	NOT AVAILABLE	NONE	5 PSIG	DESICCANT 30% RH	-65° F TO +165°F	NOT AVAILABLE	4 STACKING PADS ON BODY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10 [illegible]
[illegible]	GROSS: 1250	WOOD	RECT	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	NONE	NONE	NO LIMITS	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NONE	NOT AVAILABLE	NONE	[illegible]	[illegible]	—
[illegible]	3375 GROSS WT. 4961	STEEL	CYL	END (ONE)	[illegible]	NOT AVAILABLE	NONE	5 PSIG	DESICCANT 30% RH	65°F TO +165°F	NOT AVAILABLE	4 STACKING PADS ON BODY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12 QUICK OPENING LATCHES	[illegible]	[illegible]	[illegible]	10 [illegible]
[illegible]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
[illegible]	GROSS WT 3844	PLYWOOD SHEATHED	RECT	TOP, SIDES & ENDS REMOVED	NOT AVAILABLE	NOT AVAILABLE	NONE	NONE	NONE	NO LIMITS	NOT AVAILABLE	NONE	NONE	[illegible]	[illegible]	NONE	NONE	[illegible]	NONE	[illegible]	[illegible]	—
[illegible]	1475	PLYWOOD SHEATHED [illegible]	RECT	TOP AND SIDES ARE REMOVED AS A UNIT	[illegible]	UNKNOWN	NONE	NONE	[illegible]	NO LIMITS	[illegible]	NONE	NONE	[illegible]	[illegible]	[illegible]	NONE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7

U. S. ARMY MISSILE AND ROCKET CONT

MISSILE OR ROCKET	PROFILE	COMPONENT PACKAGED	MFG	CONTAINER DRAWING NUMBER (C)	OUTSIDE DIMENSIONS (IN INCHES) LENGTH	WIDTH	HEIGHT	WEIGHT OF EMPTY CONTAINER (IN POUNDS)	MATERIAL	SECTIONAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF CONTAINER
LACROSSE ([illegible])	NOT AVAILABLE	ROCKET MOTOR [illegible]	NOT AVAILABLE	[illegible]	116	36 [illegible]	43 [illegible]	806	WOOD	RECT.	TOP AND SIDES ARE REMOVED AS A UNIT	NOT AVAILABLE	VERY LITTLE	NONE	NONE	NONE	NO LIMIT[illegible]
		ROCKET MOTOR [illegible]	NOT AVAILABLE	[illegible]	117	26	29 [illegible]	400	WOOD	RECT.	TOP AND SIDES ARE REMOVED AS A UNIT	NOT AVAILABLE	VERY LITTLE	NONE	NONE	NONE	NO LIMIT[illegible]
HONEST JOHN		[illegible]	[illegible]	[illegible]	146	40 [illegible]	33 [illegible]	1780	[illegible]	RECT.	TOP SIDES & ENDS ARE [illegible]	ELASTOMERIC SHEAR MOUNTS & RUBBER [illegible]	(C)	NONE	NONE	NONE	NO LIMIT[illegible]
		ROCKET MOTOR [illegible]	[illegible]	[illegible]	239 [illegible]	30 [illegible]	49	2430	[illegible]	RECT.	TOP, SIDES & ENDS ARE [illegible]	RUBBER LINED [illegible]	NONE	NONE	NONE	— NONE — VENTILATED HAS DRAIN HOLES	SHIPPING AND ST[illegible]
NIKE-ZEUS		[illegible]	[illegible]	[illegible]	104	34 [illegible]	35 [illegible]	844	STEEL [illegible]	CYL.	[illegible]	[illegible] RUBBERIZED HAIR PADS	[illegible]	NONE	NONE	SAME AS [illegible]	-65° TO [illegible]
		[illegible]	DOUGLAS	[illegible]	84 [illegible]	45 [illegible]	49	900 [illegible] 1740	STEEL	CYL.	TOP (HINGED)	RUBBERIZED HAIR PADS	NOT AVAILABLE	NOT AVAILABLE	NONE	NOT AVAILABLE	-65° TO [illegible]
		[illegible]	DOUGLAS	[illegible]	38	38	44	480 [illegible]	STEEL [illegible]	VERTICAL CYLINDER	HINGED COVER	RUBBERIZED HAIR PADS	[illegible]	NONE	NONE	SAME AS BELOW	-65° TO [illegible]
		[illegible]	DOUGLAS	[illegible]	221 [illegible]	50 [illegible]	53	3112 [illegible]	STEEL [illegible]	CYL.	TOP HINGED & COUNTER-BALANCED	RUBBERIZED HAIR PADS [illegible]	[illegible]	NONE	NONE	[illegible]	-65° TO [illegible]
	SAME AS SUSTAINER ABOVE	[illegible] MOTOR	DOUGLAS	[illegible]	221 [illegible]	50 [illegible]	53	2,464 [illegible]	STEEL [illegible]	CYL.	TOP HINGED & COUNTER-BALANCED	RUBBERIZED HAIR PADS	[illegible]	NONE	NONE	[illegible]	-65° TO [illegible]
LANCE		ROCKET MOTOR	LTV	NOT AVAILABLE	145	28	29 [illegible]	680	[illegible]	BASICALLY RECT.	OPEN TYPE WITH [illegible] REMOVABLE COVER	ELASTOMERIC PADS	35 G'S MIN	NO PROTECTION TO -40°F -65° [illegible] ARCTIC KIT	[illegible] PROTECTION [illegible] CONTAINER. THESE FUNCTIONS ARE INCORPORATED INTO MOTOR CASE DESIGN.		-65° [illegible] +165°[illegible]
		[illegible]	[illegible]	[illegible]	116	35	36	1000	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	30 G'S IN ALL DIRECTIONS	NONE	NONE	NONE	STORAGE -65°F +160°[illegible]
	NOT AVAILABLE	[illegible]	[illegible]	[illegible]	116	35	37	1000	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	20 G'S IN ALL DIRECTIONS	NONE	$3\frac{1}{2} \pm \frac{1}{2}$ PSI	DESICCANT 64 UNITS	-65°F +160°[illegible]
	NOT AVAILABLE	CHEMICAL [illegible] SECTION [illegible]	[illegible] COMPANY	[illegible]	116	35	37	1000	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	20 G'S IN ALL DIRECTIONS	NONE	$3\frac{1}{2} \pm \frac{1}{2}$ PSI	DESICCANT 64 UNITS	-65°F +160°[illegible]
CHAPARRAL	UNDER DEVELOPMENT																
SPRINT																	
MAW																	

(C)- REFERS TO CLASSIFIED INFORMATION

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TABLE 7
[illegible]RMY MISSILE AND ROCKET CONTAINERS (cont)

[illegible]	[illegible]	EXTERNAL CONFIGURATION	METHOD OF OPENING	SUSPENSION SYSTEM	SHOCK PROTECTION TO COMPONENT	TEMPERATURE PROTECTION TO COMPONENT	PRESSURE PROTECTION TO COMPONENT	HUMIDITY PROTECTION TO COMPONENT	OPERATING TEMPERATURE RANGE OF ASSEMBLY	MAXIMUM STACKING LOAD	STACKING DEVICES	VENTING DEVICES	HANDLING DEVICES	SUPPORTS	COVER [illegible] DEVICES	SEALING DEVICES	LATCHING DEVICES	COMPONENT CHECKOUT DEVICES	[illegible]	[illegible]	LIFE
[illegible]00	WOOD	RECT.	TOP AND SIDES ARE REMOVED AS A UNIT	NOT AVAILABLE	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	NOT AVAILABLE	NONE	NONE	NONE	[illegible]	[illegible]	NONE	[illegible]	NONE	[illegible]	[illegible]	—
[illegible]400	WOOD	RECT.	TOP AND SIDES ARE REMOVED AS A UNIT	NOT AVAILABLE	VERY LITTLE	NONE	NONE	NONE	NO LIMITS	CAN BE STACKED [illegible] HIGH	NONE	NONE	NONE	[illegible]	[illegible]	NONE	[illegible]	NONE	[illegible]	EMPTY [illegible]	—
[illegible]780	[illegible]	RECT.	TOP, SIDES & ENDS ARE [illegible]	ELASTOMERIC SHEAR MOUNTS & RUBBER [illegible]	(B)	NONE	NONE	NONE	NO LIMITS	(C)	NONE	NONE	[illegible]	[illegible]	COVER AND [illegible] LATCHES	NONE	30 BOLT [illegible]	NONE	[illegible]	[illegible] AFT. END	—
[illegible]430	[illegible]	RECT.	TOP, SIDES & ENDS ARE [illegible]	RUBBER [illegible]	NONE	NONE	NONE	— NONE — VENTILATED HAS DRAIN HOLES	SHIPPING AND STORAGE LIMITS: 0° TO 160°F	CAN BE STACKED [illegible] HIGH	NONE	NONE	[illegible]	[illegible]	COVER AND [illegible] LATCHES	NONE	[illegible] ACTUATED [illegible]	NONE	[illegible]	[illegible]	—
844	STEEL [illegible]	CYL.	TOP (HINGED)	MOLDED RUBBERIZED HAIR PADS	22 G'S AXIALLY 24 G'S TRANSVERSE [illegible]	NONE	NONE	SAME AS [illegible]	-65° TO +160°F	CAN BE STACKED 3 HIGH	NOT AVAILABLE	NOT AVAILABLE	[illegible]	[illegible]	[illegible] BY HINGES	NONE	2 [illegible] HINGE [illegible] LATCHES	NONE	REUSABLE	NOT [illegible]	5-10 YEARS [illegible]
300 [illegible] 1740	STEEL	CYL.	TOP (HINGED)	RUBBERIZED HAIR PADS	NOT AVAILABLE	NOT AVAILABLE	NONE	NOT AVAILABLE	-65° TO +160°F	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	[illegible]	[illegible]	[illegible] BY HINGES	NOT AVAILABLE	2 [illegible] LATCHES	NOT AVAILABLE	REUSABLE	NOT [illegible]	5-10 YEARS [illegible]
450 [illegible] 1200	STEEL [illegible]	VERTICAL CYLINDER	HINGED COVER	RUBBERIZED HAIR PADS	8 G'S AXIALLY 13 G'S TRANSVERSE [illegible]	NONE	NONE	SAME AS [illegible]	-65° TO +160°F	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	2 SETS OF [illegible]	[illegible]	[illegible] BY HINGES	NONE	[illegible] LATCH	NONE ON CONTAINER	REUSABLE	NOT [illegible]	5-10 YEARS [illegible]
2012 [illegible] 2819	STEEL [illegible]	CYL.	TOP HINGED & COUNTER-BALANCED	RUBBERIZED HAIR PADS CELOTEX [illegible]	19 G'S AXIALLY 24 G'S TRANSVERSE [illegible]	NONE	NONE	[illegible]	-65° TO +160°F	CAN BE STACKED 2 HIGH	[illegible]	NOT AVAILABLE	[illegible]	[illegible]	[illegible] BY HINGES	NONE	[illegible] LATCHES	NONE ON CONTAINER	REUSABLE	NOT [illegible]	5-10 YEARS [illegible]
[illegible]464 [illegible] [illegible]150	STEEL [illegible]	CYL.	TOP HINGED & COUNTER-BALANCED	RUBBERIZED HAIR PADS	19 G'S AXIALLY 20 G'S TRANSVERSE [illegible]	NONE	NONE	[illegible]	-65° TO +160°F	CAN BE STACKED 2 HIGH	[illegible]	NOT AVAILABLE	[illegible]	[illegible]	[illegible] BY HINGES	NONE	3 [illegible] LATCHES	[illegible]	REUSABLE	NOT [illegible]	5-10 YEARS [illegible]
[illegible]680	ALUMINUM	[illegible] RECT.	OPEN TYPE WITH [illegible] REMOVABLE COVER	ELASTOMERIC PADS	35 G'S MIN	NO PROTECTION TO -40°F [illegible] ARCTIC KIT	NO MEANS OF HUMIDITY PROTECTION [illegible] BY CONTAINER. THESE FUNCTIONS ARE [illegible] INTO MOTOR CASE DESIGN.		-65° TO +165°F	[illegible]	STRUCTURAL INTERLOCKING	[illegible]	[illegible]	[illegible]	[illegible]	NONE	BOLTS	ELECTRICAL [illegible]	REUSABLE [illegible]	[illegible]	10 YEARS
[illegible]	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	30 G'S IN ALL DIRECTIONS	NONE	NONE	NONE	STORAGE -65°F TO +160°F	STACKED [illegible] HIGH	4 BRACKETS ON COVER	[illegible]	[illegible]	[illegible]	[illegible]	NONE	[illegible] BOLTS	NONE	REUSABLE [illegible]	[illegible]	10 [illegible]
[illegible]	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	20 G'S IN ALL DIRECTIONS	NONE	3½ ± ½ PSI	DESICCANT 64 UNITS	-65°F TO +160°F	STACKED 3 HIGH	4 BRACKETS ON COVER	1-½ INCH BOLT THRU EACH SKID	[illegible]	[illegible]	[illegible]	[illegible]	"T" BOLTS	[illegible]	REUSABLE [illegible]	[illegible]	10 [illegible]
[illegible]	STEEL	CYL.	TOP	4 RESILIENT MOUNTS	20 G'S IN ALL DIRECTIONS	NONE	3½ ± ½ PSI	DESICCANT 64 UNITS	-65°F TO +160°F	STACKED 3 HIGH	4 BRACKETS ON COVER	1-½ INCH BOLT THRU EACH SKID	[illegible]	[illegible]	[illegible]	[illegible]	"T" BOLTS	NONE	REUSABLE [illegible]	[illegible]	10 [illegible]

[illegible]ATION

CHAPTER III

SOURCES OF DAMAGE AND HAZARDS PECULIAR TO ARMY MISSILE AND ROCKET CONTAINERS

Current Army policy, based on the need for worldwide deployment, dictates that all materiel, including containers, have characteristics capable of withstanding the rigors of a logistic pattern geared to "worldwide distribution." Consequently, the container and its contents, in combination, must provide for all environments and modes of transportation in addition to the hazards peculiar to the handling of materiel in transit.

The environment in which a container must operate, subjects it to hazards which may produce damage to both the container and its contents. To protect the integrity of the missile, current missile designs include built-in protection; however, the container must supplement these characteristics to provide for all of the hazards which may be encountered from the point of initial supply to the launch site. The "shoot and scoot" tactics currently employed by the field army require a high degree of reliability; consequently, the protective level of the container cannot be compromised.

The hazards to which a container is exposed are many, subjecting it to conditions which may result in physical damage caused by the rigors of the logistic pattern and deterioration as the result of prolonged climatic exposure.

The logistic pattern starts at the initial point of supply, usually the manufacturing plant. Regardless of the proven adequacy of the engineered prototype, the performance of the manufactured product may prove deficient as the result of an ineffective quality assurance program. Poor housekeeping, inferior materials, sub-standard workmanship and lack of effective quality control will result in a deficient container compounding the damaging effects of the hazards which the container will encounter. Unfortunately, these are beyond the control of the designer and consequently it must be assumed that the finished procured product, as represented by the prototype, will meet the contractual requirements and that the container will prove adequate within the established limits of the proposed application.

SOURCES OF LOGISTIC HAZARDS

A. ***Manual and mechanized handling*** of the loaded container, at the manufacturing plant subject it and its contents to physical abuse. The most severe condition is that of impact shock. Damaging shock forces within this category are normally the result of:

1. Accidental dropping
2. Conveyor system unloading
3. Abrupt stops and starts of mechanical devices

The anticipated height of drop, producing the most severe impact shock, is based on the potential hazards that may be encountered within this phase of the logistic pattern. By placing the container in its proper weight classification, an estimate of the severity of treatment it will receive can be made.

TABLE 8

TYPICAL DROP HEIGHTS

Weight Range Gross Weight in Lbs.	Type of Handling	Drop Height in Inches
0 - 20	1 man throwing	42
21 - 50	1 man throwing	36
51 - 250	2 men carrying	30
251 - 500	Light Equipment Handling	24
501 - 1000	Light Equipment Handling	18
1001 - up	Heavy Equipment Handling	12

B. In-Plant and Warehouse Storage operations expose the container to additional hazards. Of particular concern is the practice of stacking as dictated by efficient warehouse utilization. This subjects the container to static loads peculiar to this limited phase of the overall delivery cycle. Consequently, the structure of the container must often be made capable of withstanding high static loading.

To conserve space and reduce costs in both shipping and storage, missile containers are usually stacked two or more tiers high, depending upon the size and weight. Usually, containers in excess of 2500 pounds gross weight, are limited to stacks of two high; those less than 2500 pounds may be stacked three high (Figure 6). Containers with gross weight in excess of 5000 pounds are usually too large to stack.

Small rockets and missiles may be housed within containers having a configuration and gross weight compatible to high stacking. Containers within this category may be considered to be subject to stacking 15 feet high as governed by the lift of the conventional fork lift truck.

C. During transit to its ultimate destination, the container is subjected to rough handling, shock, and vibration. The delivery of Army containers is accomplished by an assortment of transport vehicles and more often combinations of these conveyances (railroad, truck, aircraft, marine vessel).

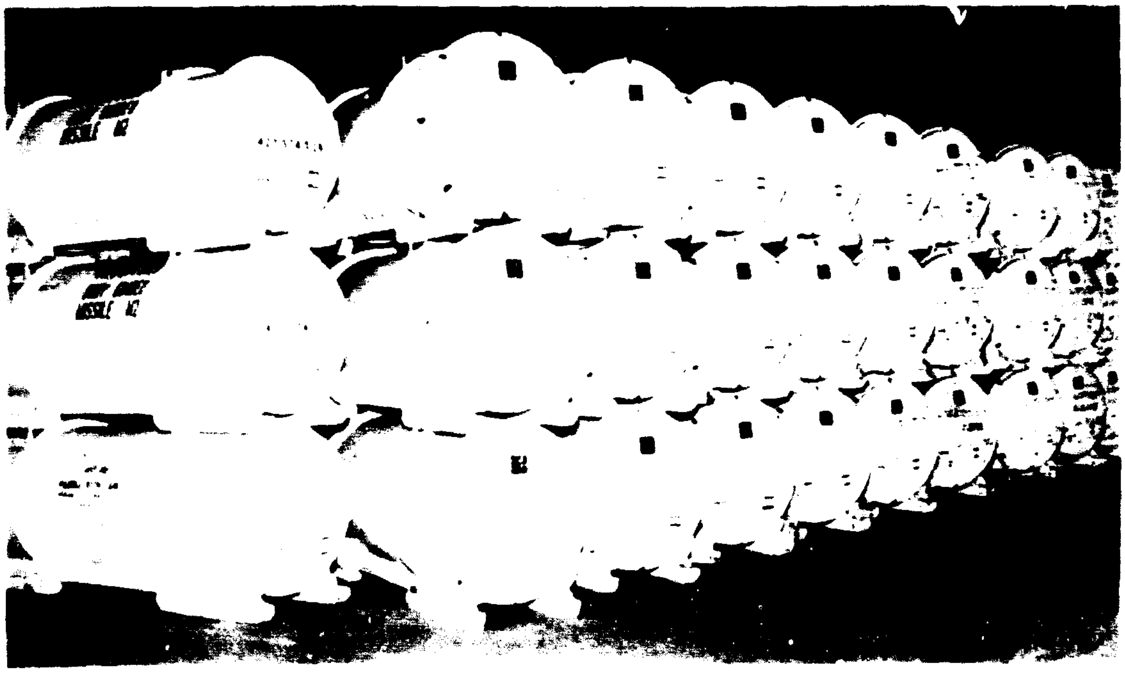


FIGURE 6. STACKING OF CONTAINERS IN STORAGE WAREHOUSE

1. Railroad Shipments

Railroad shipments (Figures 7 and 8) subject the container to high impact shocks as the result of humping during switching operations. It is generally believed that railroad switching operations in classification yards cause the most severe damage to lading imposed during rail shipment. Consequently, the analysis of rail shipments shall be concerned primarily with the imposed shock as the result of "humping."

Shock data recorded during flat car rail impact tests have been plotted and are depicted in Figure 9. These data may be applied to shock investigations relating to conventional lading of nonexplosive materiel. The test data indicates that the imposed shock is greatest in the longitudinal plane and is most prevalent at speeds of from 8 - 10 mph. The most severe conditions occur during flat car shipment; a conveyance most applicable to military transit requirements. Based on the recorded data and the prevalent transit parameters the following design criteria can be applied and will encompass the majority of impact conditions experienced within the military rail environment.

a. Rail flat car - nonexplosive lading
b. Impact speed - 10 mph
c. "G" Force imposed on lading in longitudinal plane - 10 g's
d. Pulse duration - 30 msc

In addition to shock, there are critical train speeds at which the rail-joint impulses become resonant with the natural frequencies of the car on its vertical suspension. These disturbances are the result of track and wheel irregularities and occur chiefly at rail joints, frogs, and crossings. From many tests conducted by both military and civilian agencies, forcing frequencies developed by a freight car moving at speeds ranging from 20 to 91 miles per hour are 2 to 7 cycles per second. The "G" forces imposed upon the lading by the steady-state vibration of the rail car are of appreciably less magnitude (0.5 g) than those generated by impact. The design of the container suspension system shall be based on the shock impact requirements and will encompass those relatively smaller forces produced by the prevalent vibrations. The suspension system must, however, be designed to provide a natural frequency in excess of 10 cps to avoid the critical range of 2 - 7 cps peculiar to rail transport. (See Chapter I - Resonance).

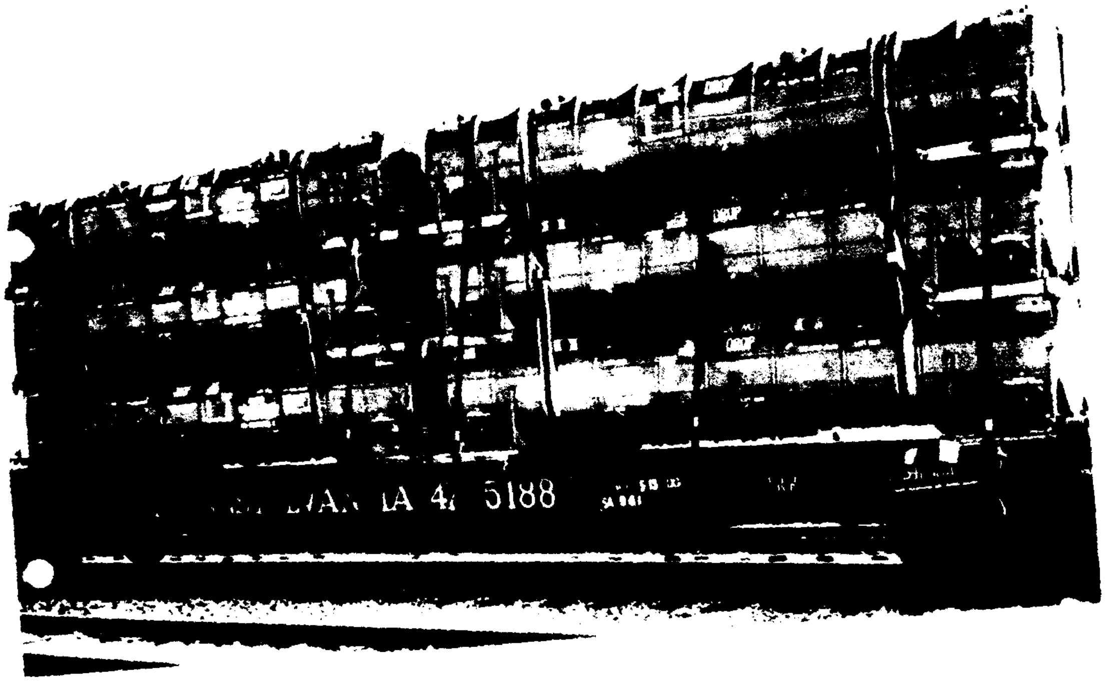


FIGURE 7. SHIPMENT OF CONTAINERS ON FLAT CAR

FIGURE 8. SHIPMENT OF CONTAINERS IN GONDOLA

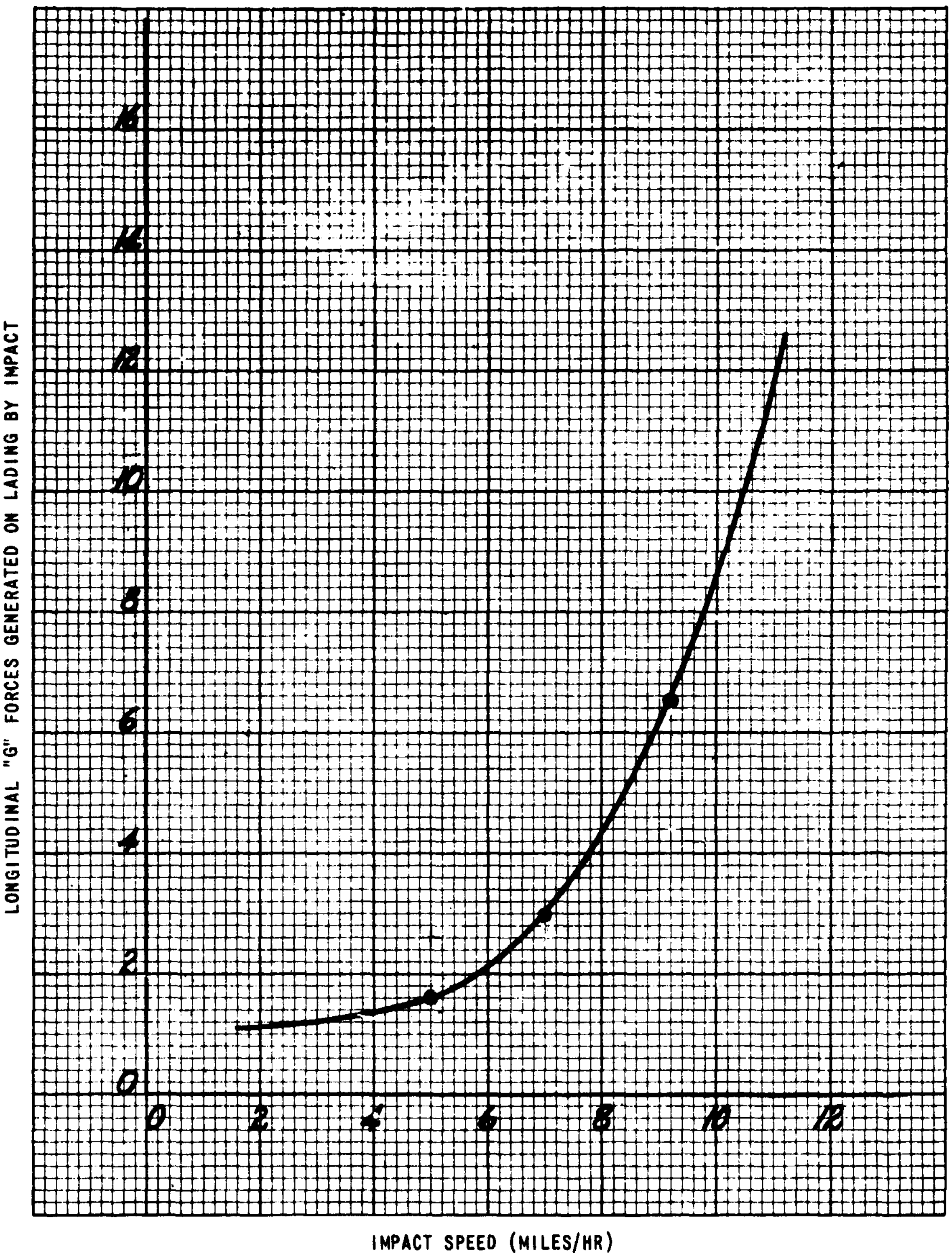


FIGURE 9. LONGITUDINAL "G" VERSUS IMPACT SPEED OF RAIL CAR HUMPING

2. Truck Shipments

The forces imposed by truck shipment (Figure 10) are so varied that it becomes difficult to isolate the area most prevalent for design consideration. The destructive forces prevalent in truck shipments are the result of:

a. Impact Shock
b. Fatigue
c. Vibrations

a. *Impact shock* imposed upon vehicular lading is often the result of a sudden change in motion. Sudden braking of the vehicle and irregularities of the road surface (potholes, etc.) impart to the lading a single transient shock wave and any resulting failure is instantaneous. Damage producing shock input is usually applied to the vertical axis of the lading and is most often the result of a bump in the road.

The Munson Road Test, adopted by the Army to evaluate the performance of over-the-road vehicles, introduces all of the mechanical disturbances prevalent in the transit environment of worldwide distribution. The accelerations measured at the cargo bed of a typical vehicle have been tabulated and are included in Figure 11. These reactions of the truck bed are typical of the forces imposed upon lading transported by truck.

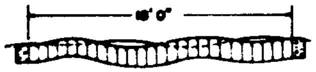
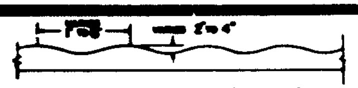
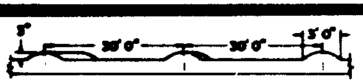
As previously stated, these forces vary and their values fluctuate; however, it may be assumed that only those applied vertically are significant and the magnitude of the average shock is equal to 3 g's.

Due to the nature of the test bed, the applied force can be considered repetitive and as having a spectrum comparable to that of a half-sine wave. The amplitude of the sinusoidol shock wave generated by the vehicle bed can be considered equal to the vertical displacement of the truck bed. The displacement amplitude of the spring suspended cargo deck can be conveniently measured and may be as great as 4 inches.

These data can be applied to graphically illustrate the nature of the induced shock; however, the frequency, being a function of vehicular speed and the irregularities of the road bed, becomes difficult to isolate.

To facilitate laboratory simulation of the effects of the over-the-road environment, Figure 12 equates the developed data (imposed G's and amplitude) into equivalent free fall drop heights.

FIGURE 10. SHIPMENT OF CONTAINERS ON TRUCK TRAILER

	TEST COURSE	PAY-LOAD	SPEED MPH	MAXIMUM ACCELERATIONS VERTICAL G's @ CPS	MAXIMUM ACCELERATIONS TRANSVERSE G's @ CPS	MAXIMUM ACCELERATIONS LONGITUDINAL G's @ CPS
 Profile approaches a sine wave with a double amplitude of six inches and a complete cycle occurring every six feet for 800 feet of concrete.	6 WASHBOARD	w/o	5	1.6 @ 3 2.7 @ 300	1.1 @ 1.3	.3 @ 2 3.6 @ 350
		w	5	1.2 @ 2.5 .8 @ 350	1.9 @ 220	.5 @ 13 .5 @ 300
 Cobblestone road provides irregular, bumpy surface with crests placed to subject vehicle to both pitching and rolling motions for 3936 feet.	BELGIAN BLOCK	w/o	20	1.1 @ 11 .4 @ 300	.3 @ 6 .4 @ 450	1.6 @ 15 1.9 @ 350
		w	20	.8 @ 2 1.9 @ 350	.4 @ 3 1.5 @ 300	.4 @ 6 .3 @ 250
 Two 90-degree radial turns incorporate symmetrical bumps varying from two to four inches in height and from one to six feet from crest to crest over a distance of 120 feet.	RADIAL WASHBOARD	w/o	5	.8 @ 5 .5 @ 350	.4 @ 450	.9 @ 2.5 .5 @ 300
		w	5	1 @ 2 .4 @ 350	.3 @ 2 .7 @ 150	.4 @ 7
 Series of rounded bumps three inches high and three feet wide are spaced 30 feet apart at various angles with respect to centerline of 831-foot course.	STAGGERED BUMP	w/o	20	2.1 @ 4 11.7 @ 250	.5 @ 10 2.4 @ 400	10.8 @ 350
		w	20	7.6 @ 320	5.2 @ 250	6.1 @ 10 1.1 @ 400
 Cross country test imposes varying and irregular disturbances to help in evaluation of overall mounting system effectiveness.	TRUCK CROSS COUNTRY	w/o	15	.6 @ 5 1.1 @ 450	.7 @ 12	.7 @ 10 1.9 @ 350
		w	15	.3 @ 5 .5 @ 400	.6 @ 25 .3 @ 110	.3 @ 1.5 .3 @ 250

Natural frequency vehicle suspension 1 to 3 cps.
Accelerations measured at cargo bed of standard 2½-ton 6 x 6 military truck.
Both high and low-frequency disturbances shown.

FIGURE 11. MUNSON ROAD TEST

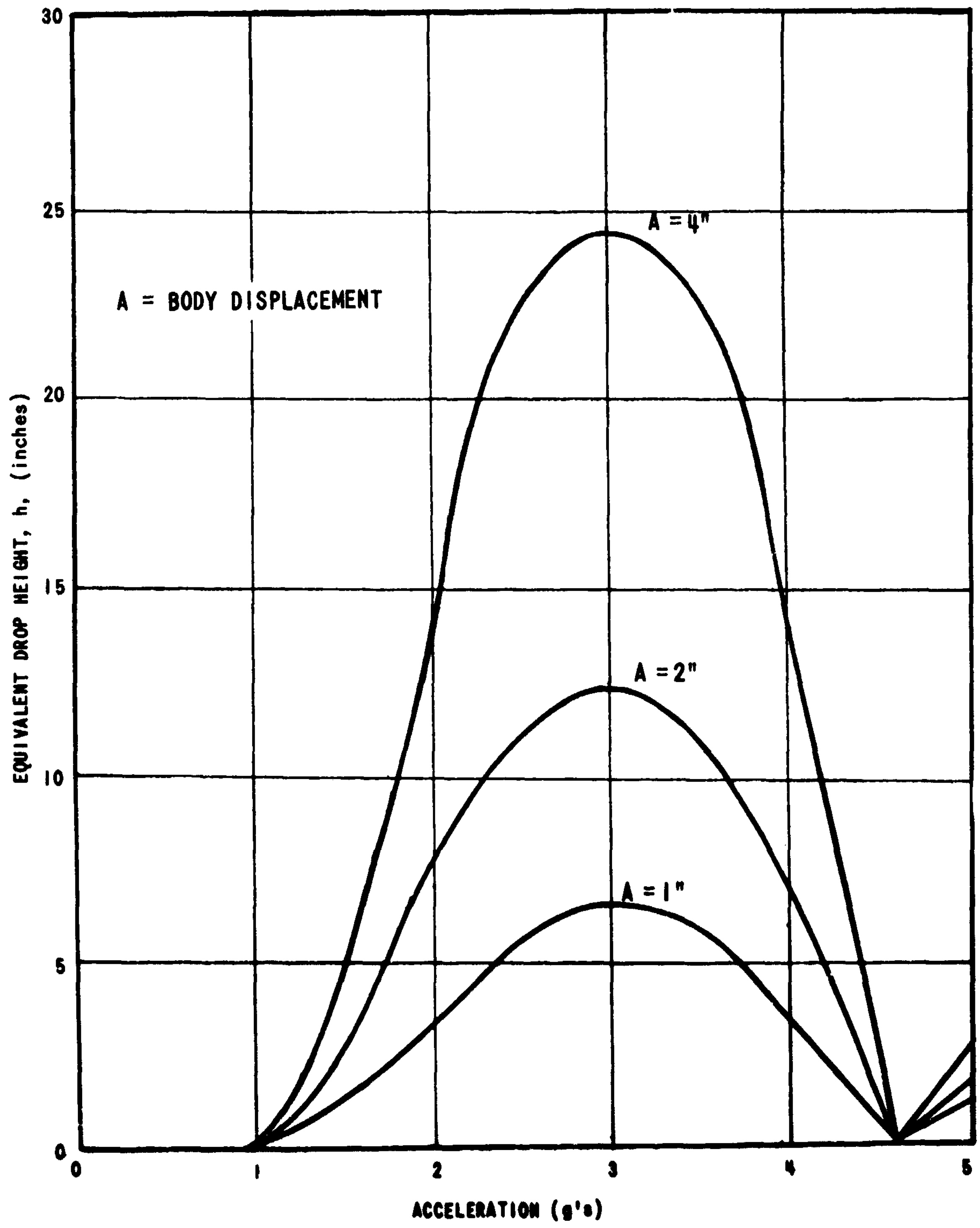


FIGURE 12. THE EQUIVALENT DROP HEIGHTS CORRESPONDING TO THE ACCELERATION FORCES USUALLY FOUND IN TRANSIT. A BODY MOVING ONLY A SHORT DISTANCE CAN LAND WITH AN IMPACT EQUAL TO A FREE-FALL MANY TIMES GREATER.

A typical condition prevalent in the environment of worldwide distribution subjects the lading to repetitive shock inputs of 3 g's with a vertical cargo deck displacement of 3 inches. Although the actual movement of the unlashed cargo is 3 inches the accumulative force of impact imposed upon the lading by the truck bed is several degrees greater than the force imposed by a single free-fall height from an equal distance upon a static impact surface.

Figure 12 shows that the magnitude of the imposed force under the conditions described is comparable to that generated if the lading were subject to a free-fall drop of 18 inches. Impacting upon the metal deck of a transport vehicle, the lading would be subject to a force of 101 g's assuming a shock rise time of 3 milliseconds (see Chapter I, Tables 2 and 3).

The laboratory simulation actually imposes a shock input substantially greater than that experienced by the lading; however, the cumulative effects of the repetitive disturbances of transit produce progressive abuse which in time results in failure comparable to that produced by the free-fall test.

b. Fatigue failure is prevalent in the environment of vehicular transit and occurs when unlashed lading is thrown into the air each time its upward acceleration exceeds the acceleration of gravity. The lading then falls freely upon the vehicle and its downward velocity is suddenly arrested. The height to which the lading is thrown is usually relatively small and the force of impact of insignificant magnitude; however, the many repetitions that occur in a long trip introduce accumulative impact and result in fatigue failure of the lading and/or its components.

As previously discussed, the designer can provide for this phenomena by equating the factors producing fatigue to a comparable drop test to conveniently produce the same effect upon the lading as that it would experience in the transit environment.

c. Vibrations are introduced when the vehicle hits frequent successive road irregularities producing oscillatory disturbances. Uniformly spaced irregularities producing repetitive disturbances are significant as the frequency of their application may introduce resonance. Disturbing frequencies prevalent in a truck transit environment are found within the 2 to 7 cps range. As the natural frequency of Army vehicles may occasionally be as great as 20 cps, a minimum natural frequency of the suspension system of 25 cps is recommended to avoid the occurrence of a resonant condition.

3. Aircraft Movement and Aerial Delivery

This category of transport media encompasses:

a. Air transport (cargo aircraft)
b. Air delivery (parachute drops)
c. External air transport (peculiar to helicopters)

The hazard relating to shock is greatest during landing. This may be the result of excessive downward velocity of the paradropped cargo, impact of the aircraft at moment of contact with the ground, or of arresting gear used to bring the aircraft to a stop. Normally, the magnitude of shock experienced by the aircraft is relatively small as the landing gear and arresting devices function as shock isolators. Paradrop slings incorporate a shock mitigating cushion to protect the delivered cargo. Consequently, the maximum acceleration experienced by the cargo is often appreciably less than that imposed upon the carrier. It has been established that shock requirements under these conditions are a secondary factor.

AR 705-35 establishes the following cargo restraint factors which can be considered as equal to or in excess of the acceleration which would be imposed upon the cargo during normal flight or in the event of an emergency:

Forward - 8 G's
Sideward - 1.5 G's
Vertical (up) - 2.0 G's
Aft - 1.5 G's

Impacts experienced by cargo subject to air delivery are controlled by introducing auxiliary shock absorbing devices. Parachutes and crushable pallets in combination, function to mitigate the impact imposed upon the cargo to a magnitude within the fragility level of the container. Calculations to determine the amount of auxiliary cushion required are based on assumed parachute drop velocities of 30 fps or 50 fps. These velocities are approximately equal to free-fall velocities from heights of 14 feet and 40 feet respectively.

The predominant vibration in aircraft results from the propulsion system. The numerical values of these frequencies cover a wide range, as they are dependent on the air velocity, the surface characteristics of the aircraft, and the natural frequencies of various structural components.

Other hazards to which air cargo is subjected include:

a. Temperature shock
b. Pressure differential as the result of altitude or sudden altitude change

High speed, fast climbing aircraft subject their cargo to rapid and severe variations in both temperature and pressure. Most cargo aircraft have pressurized compartments, however, there is the possibility that the cargo may be subjected to the hazards described and provision must be made to withstand the effects of these changes when required.

4. Marine Vessel Shipments

Marine vessel shipment subjects cargo to hazards similar to and comparable in intensity to those of other modes of transportation in addition to those peculiar to this particular transport medium. The cargo ship is a floating warehouse, as such, it encompasses those hazards peculiar to in-plant handling and also those normally associated with warehouse storage. Efficient storage of cargo makes high stacking an economic necessity. In addition, mechanical handling devices subject the cargo to severe physical abuse, pendulum, and extreme free-fall impacts are prevalent in cargo handling. Of particular concern are severe impact shocks - operating in an hostile environment, marine vessels are subject to ballistic shock resulting from noncontact underwater explosions.

An exact specification of ballistic shock does not appear possible. The general nature and maximum severity have been established by the shock motions of the high impact shock testing machines currently used to simulate the pertinent environment. The shock introduced by performance of the tests specified in MIL-S-901A represents the maximum probable within the marine environment. This test simulates the severity of shock encountered in naval service as represented by a velocity change of 100 in sec. This change is equivalent to a free-fall drop of 13.6 inches $h = \left(\frac{V^2}{2(368)}\right)$.

Assuming a shock rise time of 3 msc, the imposed force of impact becomes approximately 84 g's (see Chapter I). Based on the above, one may consider a shock input resulting from ballistic shock as having a magnitude of 100 g's.

The intensity of shock imposed upon shipborne cargo is however, dependent upon its location and proximity to the initial point of shock impingement. The magnitude of the imposed shock is attenuated as the shock wave travels through the ship's structure.

The predominant steady-state vibration of the structural members of a naval vessel is caused by the propeller action and differs from one type of vessel to another. The maximum vibration frequency generally encountered is approximately 20 cps. Suspension systems having a natural frequency of 25 - 30 cps represents the currently accepted standard for naval applications.

In addition to the physical hazards prevalent in marine vessel transport, the cargo is also subjected to the deteriorating effects of an environment peculiar to the sea. Pier, deck, and hold storage subjects the cargo to the damaging effects of:

a. Sunshine
b. Rain
c. Humidity
d. Fungus
e. Salt fog
f. Immersion

D. Field Depot Storage sites expose materiel to severe conditions which result in deterioration of the container causing degradation of its protective characteristics.

Worldwide deployment encompasses all of the geographic regions and the peculiar aspects of their environments.

Field depots are often remote, and as such, are lacking in materiel handling devices. Consequently, materiel is subject to severe shock resulting from rough and improvised handling.

Each environment introduces hazards peculiar to itself in addition to those hazards common to all environments. The hazards peculiar to geographic zones which materiel will encounter when exposed to the logistic pattern of worldwide distribution are many and varied.

The tropics present a hot humid atmosphere subjecting materiel to what is commonly referred to as "jungle-rot." Excessive rainfall, high humidity, heat and fungus in addition to the prevalence of vermin, insects, and reptiles all present problems relating to materiel protection and to the safety of personnel. The physical integrity of the container, often overlooked, cannot be compromised. Deadly snakes and germ ridden rodents are known to nest within the confines of a container. Broken containers introduce this additional hazard not normally associated with materiel protection.

The Arctic regions subject materiel to a very cold atmosphere. Subzero temperatures of -65°F are common; temperatures of -85°F have been recorded in underground ammunition storage "igloos." The physical characteristics of the container components, in particular the protective seals, and elastomeric mounts are radically altered under these conditions and the protective integrity of the container is jeopardized.

Consideration of moisture laden air accumulating within the container is a hazard peculiar to all environments. Various devices and schemes have been developed to overcome the deteriorating effects of condensation on missiles and their components.

Peculiar to all regions are hazards caused by intentional abuse, often comprising sabotage. The container must provide protection to resist arson, detonation by small arms, penetration of the missile shell by BB shot, etc. Often the need to conceal the item is of prime import; security requirements often dictate the need for concealing the deployment of weapon systems.

CHAPTER IV

CONTAINER QUALIFICATION TESTS

The objective of any test program is to qualify the test specimen by demonstrating its ability to satisfy the user's requirements. The test specimen must be a true representation of the end item and shall perform to satisfy the operational, technical and safety requirements in all of the environments of intended use. Qualification testing is usually performed on a prototype container having encased within its confines, a dynamically-simulated dummy or an inert missile or missile component.

Exposure of the test specimen to the hazards and environments of the actual logistic cycle is a costly, time consuming process. To expedite the availability of new materiel, a test specimen of the developed prototype is subjected to laboratory tests which simulate the progressive abuse and long time environmental exposure imposed upon the container by the logistic supply pattern. The level of abuse is a severe representation of some insignificant fraction of the logistic cycle.

Container performance evaluation encompasses a series of environmental tests which may be categorized under two general headings: mechanical and climatic. Those designated as mechanical subject the test specimen to physical abuse simulating the hazards associated with the anticipated methods of transit and handling. Those falling within the climatic category subject the specimen to the deteriorating effects of the projected environment peculiar to the geographic and spatial location in which it will operate. The conditions to which the specimen is exposed are normally set at a severe level to accelerate the effects of repetitive and progressive abuse and the effects resulting from prolonged exposure.

Test procedures and test apparatus have been developed to conveniently simulate the operating environment within the laboratory. An assortment of gymnasticators and climatic chambers are currently available; these, in addition to electronic recording devices constitute the tools required to conduct a scientific evaluation through controlled testing. The advance of container test technology becomes evident when the current state-of-the-art is compared with the early "Ready-Test" method consisting of kicking the specimen down a flight of stairs.

Evaluation processes and acceptance criteria are based on comparison with established standards. The best standard would be the ideal container, one capable of providing complete protection, weighing nothing, lasting forever, and costing nothing. Obviously, the challenge is the development of the *optimum* container; one demonstrating both technical and economic feasibility.

Numerous attempts have been made to develop a test procedure applicable to all containers. The plethora of data available is often tailored to the specific contents of the container or to the environments peculiar to only limited application. Obviously, any effort to standardize procedure must start with a common factor peculiar to all applications. A survey and evaluation of data favors establishing as this basis the all inclusive logistic pattern of the "worldwide distribution" policy.

Standard tests have been developed to simulate the effects of the environmental hazards experienced by containers during "worldwide distribution." These tests encompass all situations and conditions prevalent in the Army's current logistic supply concept.

MIL-Std-810(USAF) "Environmental Test Methods for Aerospace and Ground Equipment" is typical of the many procedures available which delineate a comprehensive test program. Those tests pertinent to missile and rocket container evaluation are listed below:

1. Rough Handling
2. Vibration
3. High Temperature
4. Low Temperature
5. Low Pressure
6. Rain
7. Sand and Dust
8. Salt Fog
9. Humidity
10. Sunshine
11. Fungus

A test specimen, subjected to these tests in the sequence presented, can be considered as having been exposed to progressive abuse peculiar to the environment of "worldwide distribution." The recommended sequence provides for those factors relating to scheduling, time, cost and the contingencies affecting most test programs. The recommended order may be modified to suit the prevailing situation, however, it is recommended that the rough handling test always precede the vibration test to introduce any loss of restraint experienced as the result of shock. (see Chapter VII).

Regardless of the outcome of the test, it is mandatory that the procedure followed and the data generated be fully documented, certified, and witnessed. These data shall be processed to provide input as a contribution to the state-of-the-art.

The formulation of a particular test plan need not provide for subjecting the test specimen to all of the eleven tests specified. The use of materials and/or designs certified as having met the requirements of DOD Specifications may be considered as acceptable and need not be subjected to retest. The physical response and performance of such materials, functioning as an assembly must however be evaluated. Obviously, a container assembly comprised of materials certified to be fungus resistant and inert to salt fog deterioration or penetration need not be subjected to all eleven tests. However, a container comprised of material certified as adequate for high temperature applications must be subjected to shock testing at elevated temperature as the degradation of physical response may not be covered by the applicable specification.

Consequently, it behooves the designer to select only those tests applicable to the projected environment and to subject the test specimen to only those test conditions to which it has not previously been exposed. Obviously, the use of materials and technique covered by DOD Specification will minimize the test procedure; however, this practice should not in any way affect advances in the state-of-the-art nor discourage the use of the best material for the proposed application.

The tests described in the following pages do not constitute a standard or specification but merely summarize the terms, conditions, and requirements found in numerous uncoordinated qualifying test procedures.

TABLE 9

TEST SELECTION CHART

TEST	Containers Weighing Less Than 200 Pounds Gross Weight		Containers With Gross Weight In Excess Of 200 Pounds
	No Dimension Greater than 60"	With Dimensions Greater than 60"	
1. ROUGH HANDLING			
a. Corner Free Fall Drop	Required	Not Applicable	Not Applicable
b. Flat Face Free Fall Drop	Performed at the discretion of the responsible agency		
c. 45 Degree Free Fall Drop	Required	Required	Not Applicable
d. Edge Drop Free Fall	Performed at the discretion of the responsible agency		
e. Pendulum Impact	Not Applicable	Required	Required
f. Edgewise Rotational Drop	Not Applicable	Required	Required
g. Cornerwise Rotational Drop	Not Applicable	Required	Required
h. Inclined Impact (Conbur)	Not Applicable	Used in lieu of Pendulum Impact when required apparatus is available.	
i. Tip Over j. Roll Over k. Rolling Impact l. Serviceability	Performed at the discretion of the responsible agency		
2. VIBRATION	Required	Required	Required
3. HIGH TEMPERATURE	Performed in conjunction with shock testing		
4. LOW TEMPERATURE	Performed in conjunction with shock testing		
5. LOW PRESSURE	Required for all sealed containers. Applicable where performance of components is jeopardized.		
6. RAIN	Applicable to all containers except those that are sealed		
7. SAND AND DUST	Performed at the discretion of the responsible agency		
8. SALT FOG	Performed at the discretion of the responsible agency		
9. HUMIDITY	Applicable to all containers except those that are sealed		
10. SUNSHINE	Performed at the discretion of the responsible agency		
11. FUNGUS	Performed at the discretion of the responsible agency		

REFERENCES: AR 705-35, AR 705-15, MIL-STD-810, MIL-P-116D, MIL-W-21927, WR-11, MIL-E-4970A, MIL-S-901A, MIL-STD-358

ROUGH HANDLING TESTS

Rough handling tests are conducted to verify the structural integrity of the container in addition to establishing the degree of shock mitigation provided by the suspension system.

The rough handling tests to which the container is exposed have been developed to simulate the anticipated environment in which the container will operate. The magnitudes of shock established are based on the theory of probability which predicts the frequency and type of handling to be encountered.

The magnitude of shock as the result of rough handling is predicated on the weight of the container and the method by which it will be handled. By placing the container in its proper weight classification, an estimate of the severity of treatment it will receive can be made.

The tests, developed to simulate the required conditions are listed below and described and discussed in subsequent pages of this section. No one test specimen need be subjected to all of the tests specified as some of the tests produce the same effects and are pertinent only to test specimens of a specific size. Example: A small container which can be conveniently subjected to a free-fall flat-end drop need not be subjected to the pendulum impact test which pertains to large, unwieldly containers. In both instances, the impact imposed upon the specimen will be comparable in magnitude. A test selection chart has been included within this chapter to assist in the development of a test plan; however, the guidance provided is contingent upon the characteristics of the container and the proposed application and environment.

ROUGH HANDLING TESTS

1. Corner Free-Fall Drop
2. Flat-Face Free-Fall Drop
3. 45 Degree Free-Fall Drop
4. Edge Free-Fall Drop
5. Pendulum Impact
6. Edgewide Rotational Drop
7. Cornerwise Rotational Drop
8. Inclined Impact (Conbur)
9. Tip-Over
10. Roll-Over
11. Rolling-Impact
12. Serviceability

Those containers likely to be affected by temperature extremes shall be conditioned prior to shock testing at those temperatures peculiar to their projected environment. The temperature extremes peculiar to the established "worldwide distribution" environment are:

Ambient: $+72^\circ \pm 5^\circ F$

Hot: $+160^\circ \pm 5^\circ F$

Cold: $-65^\circ \pm 5^\circ F$

The procedure for conditioning of test specimens is included in the sections of this chapter relating to High and Low Temperature Tests.

Containers whose function is to protect fragile, sophisticated materiel must include as part of shock testing, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

Damage to materiel and to their containers can often be determined by visual examination and an evaluation of serviceability determined; however, to conduct a scientific evaluation to assure reliability of performance, instrumentation of the test specimen is required.

Instrumentation and data recording is not within the scope of this design guide; however, it shall suffice to state that an assortment of transducers (accelerometers, thermocouples, vibration pickups, and shock recorders) are available which may be fastened to and/or included within the test specimen to pick-up and in conjunction with auxiliary apparatus record the magnitude and characteristics of the imposed shock.

TABLE 10

WEIGHT CLASSIFICATION CHART

The following tabulated drop heights are pertinent to those tests relating to free fall and are applicable where specified:

Container Gross Wt. in Lbs.	Drop Height in Inches*
0 - 20	42
21 - 50	36
51 - 250	30
251 - 500	24
501 - 1000	18
1001 - up	12

*NOTE: *The U.S. Army Development and Proof Services of Aberdeen Proving Grounds states that a drop height of 60" be substituted for the above when the container will be subject to truck transportation. This is particularly applicable to sophisticated missiles and/or missile components regardless of their weight. (see MIL-STD-325 and MIL-STD-358)*

CORNER FREE-FALL DROP TEST

The free-fall corner drop test is applicable to containers weighing less than 200 pounds and having no dimension greater than 60 inches. The impact generated by the free-fall drop subjects the structure of the container to a damaging force comparable to that it would experience during "worldwide distribution." The effects of this abuse is more deleterious to the container than to its contents. Consequently, *this test reflects only upon the structural integrity of the container shell and does not establish the degree of protection provided to the container contents.* The structural components of the container shell absorb a major portion of the force resulting from the concentrated impact of a corner drop. Very little of this force is transmitted to the contents or to any intermediate shock mitigating media. The force of impact is dissipated by distortion, fracture, or crushing of the container shell.

PROCEDURE

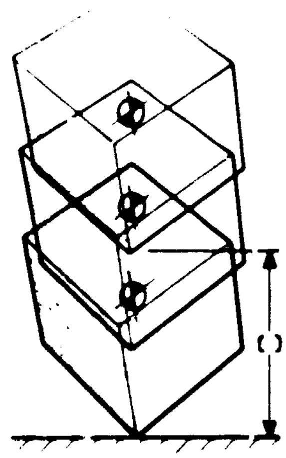


FIGURE 13. CORNER FREE-FALL DROP TEST

The container shall be dropped cornerwise from a height as determined by its weight and size classification. Impact shall be on a steel, concrete or stone surface of sufficient mass to absorb the shock without deflection in such a manner that the corner of the container absorbs the full force of the fall. This test shall be repeated until each of the eight corners of the container has received a fall. (The height of drop specified refers to the distance from the impacting surface to the nearest corner of the container when suspended prior to the fall.) The fall shall be a free fall, in that no ropes or other suspending media are attached to the container during the fall.

If the container is of the drum type, the top and bottom of the drum shall be marked so that the circle of the top and bottom is quartered, and the above test shall be applied to each of the quartered sections.

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and the characteristics of the imposed shock and that experienced by the contents may be measured.

CRITERIA FOR REJECTION

Any damage to materials and components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

FLAT-FACE FREE-FALL DROP TEST

The flat-face free-fall drop test is used to establish the maximum protection provided by the container assembly. *This test is used primarily to establish the protective level of the container and/or the suspension system.* Corner drops have a more deleterious effect on the container than do flat-face drops, while *flat drops will cause greater damage to the suspended contents.* With proper instrumentation the transmissibility (efficiency) of the container assembly can be determined and used to verify the analytical design calculations. The performance of *this test is not mandatory* and the acceptance criteria need not provide for this simulation of projected rough handling. The effects of this test and the data generated will, however, provide conclusive information to effectively evaluate the test specimen.

PROCEDURE

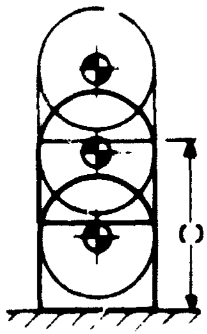


FIGURE 14. FLAT-FACE FREE-FALL DROP TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be dropped from a vertical distance as determined by its weight classification. The test specimen shall be allowed to fall freely onto a concrete or similarly hard surface such that the container strikes flat on its skids or surface involved. This test shall be limited to only two drops; one flat drop on bottom plus one flat drop on one end.

CRITERIA FOR REJECTION

Damage to or operational malfunction of the contained contents shall constitute a failure. The recorded data generated relating to transmissibility of the shock of impact shall not subject the contents to a force in excess of its established fragility level.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

45° FREE-FALL DROP TEST

The 45° free-fall drop test subjects the test specimen to abuse common to materiel in transit. The forces imposed upon the container are indicative of those experienced by rough handling; in particular, tail-gate unloading.

This test is *applicable to all containers under 200 lbs. regardless of length,* which because of their configuration can be manhandled.

The test procedure imposes an impact force on the leading edge of the test specimen followed by a rotational drop subjecting the aft end to a secondary impact, often of greater magnitude.

PROCEDURE

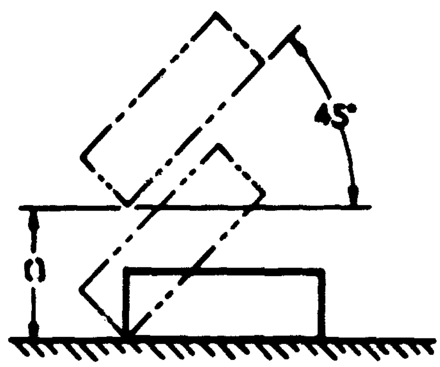


FIGURE 15. 45° FREE-FALL DROP TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be elevated to a height equivalent to that specified in the weight classification table for free-fall drops. That side of the container having the greatest surface area shall be positioned parallel to the impacting surface. That side with the longest dimension shall be elevated at one end to form a 45° angle between the impacting surface and the longest side of the container. The test specimen shall be dropped from this position onto the rigid nonyielding impacting surface, subjecting the container to first a primary shock at one end and a subsequent secondary shock at its opposite end. This test shall be conducted twice, subjecting each end to both a primary and secondary shock.

CRITERIA FOR REJECTION

Components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

EDGE-DROP FREE-FALL TEST

The edge-drop free-fall test is applicable to situations where *it is preferable to gradually increase the level of shock applied to the container.* The effects of this test are less severe than either the corner or flat-face impact. The performance of *this test is not mandatory* and its inclusion in any test program is at the discretion of the responsible agency and shall be conducted only in conjunction with subsequent corner drop tests.

PROCEDURE

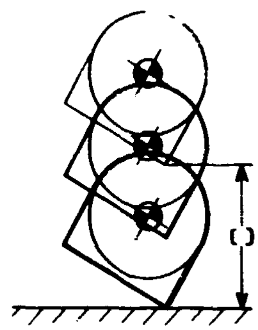


FIGURE 16. EDGE-DROP FREE FALL TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be raised the vertical distance as determined by its weight classification such that the container is suspended with the center of gravity vertically above the striking edge. The container shall be allowed to fall freely to a concrete or similarly hard surface, striking edge first. The test shall be applied to two diagonally opposite edges.

CRITERIA FOR REJECTION

Any damage to the container or to its contents shall be cause for rejection. However, *satisfactory performance does not qualify the test specimen* which must be further subjected to the corner free-fall drop test.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

PENDULUM IMPACT TEST

The pendulum impact test is *applicable to all* containers whose *length exceeds 60 inches* and to those containers whose *weight exceeds 200 lbs.* Containers too large or too heavy to subject to free-fall testing and *where no Conbur* (Incline Impact Testing Device) is available may be tested by a pendulum device suspended from overhead. This test produces shock comparable to that experienced during transit and simulates the effect of railroad "humping."

PROCEDURE

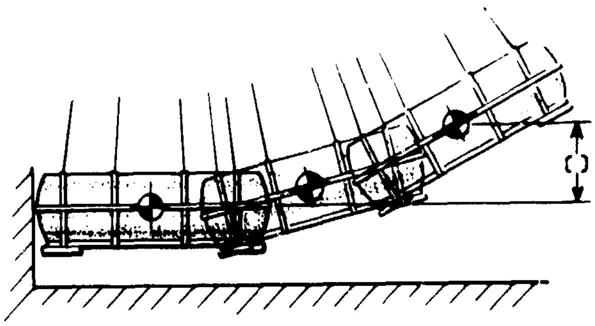


FIGURE 17. PENDULUM IMPACT TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be suspended by 4 or more ropes or cables 16 feet or more long. The suspended container shall be pulled back so that the center of gravity will have been raised the distance at least equivalent to that specified as drop height in the weight classification table. The container shall be released allowing the end surface or skid, whichever extends further, to strike on an unyielding barrier of concrete or similarly hard material that is perpendicular to the container at impact. One impact shall be applied to each end.

CRITERIA FOR REJECTION

Damage to either the container or its contents which affects the functional performance of either, shall be cause for rejection.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

CORNERWISE ROTATIONAL DROP TEST

The cornerwise rotational drop test is *applicable to all containers whose length exceeds 60 inches* and to those containers whose *weight exceeds 200 lbs.* This modified drop test subjects the container to abuse typical of that produced by mechanized handling. The effects upon the container are of sufficient magnitude to demonstrate the structural integrity of the outer shell.

PROCEDURE

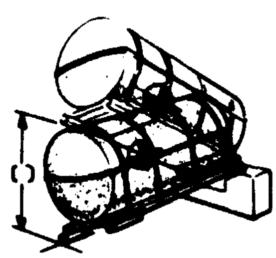


FIGURE 18. CORNERWISE ROTATIONAL DROP TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be supported at one corner of its base on a sill or block 5 inches in height. The other corner of the same end shall be supported by a 12 inch sill or block. The lowest point of the opposite end shall be raised to the vertical height as specified in the weight classification table and allowed to fall freely onto a concrete or similarly hard surface. If the size of the container and the location of its center of gravity prevent dropping from the prescribed height, the greatest attainable height shall be the height of drop. One drop shall be applied to each of the four corners.

CRITERIA FOR REJECTION

Any damage to materials and components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

EDGEWISE ROTATIONAL DROP TEST

The edgewise rotational drop test is *applicable to all* containers whose *length exceeds 60 inches* and to those containers whose *weight exceeds 200 lbs.* This modified drop test is applied to large containers which would not be handled manually in any phase of transportation. The effects produced, simulate the abuse of mechanized handling and provide a means to evaluate the mitigating characteristics of the container assembly.

PROCEDURE

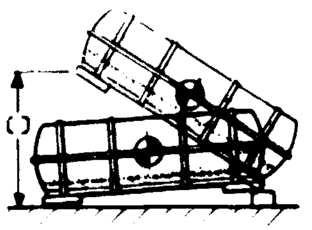


FIGURE 19. EDGEWISE ROTATIONAL DROP TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be supported at one end of the base on a sill or block 5 inches in height and at right angles to skids. The opposite end shall be raised to the vertical height specified in the weight classification table and allowed to fall freely onto a concrete or similarly hard surface. If the container size and center of gravity location prevent dropping from the prescribed height, the greatest attainable height shall be the height of drop. Two drops shall be applied to each end.

CRITERIA FOR REJECTION

Damage to either the container or its contents which affects the functional performance of either or both shall be cause for rejection.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

INCLINED IMPACT OR CONBUR TEST

The inclined impact or Conbur test may be applied to containers whose length exceeds 60 inches or whose weight is in excess of 200 lbs. This test is used to determine the ability of the container and its suspension system to protect the contents when subjected to impact stresses. The apparatus provides for the container to be placed on a dolly that rolls down a 10 degree incline against a rigid barrier to simulate the longitudinal shocks encountered in transit. The force of impact is controlled by the length of run (up to 25 feet).

PROCEDURE

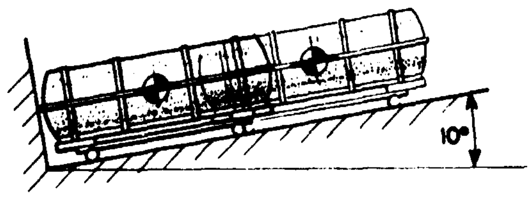


FIGURE 20. INCLINED IMPACT OR CONBUR TEST

Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test shall be in accordance with the American Society for Testing Materials Incline Impact Test for Shipping Containers, Procedure B, ASTM Designation D880. The travel distance on the incline impact testing device shall be as indicated for the weight specified:

TABLE II
GRADUATED IMPACT TEST - DOLLY RUN

Gross Weight of Container (Pounds)	Incline - Impact Dolly Run (Feet)
Through 250	7.0
Over 250 thru 500	5.5
Over 500 thru 1000	4.0
Over 1000	2.5

The ability to perform this test is predicated on the availability of the required apparatus. *The Pendulum Impact Test may be used to produce the same effects should the required equipment be unavailable.*

CRITERIA FOR REJECTION

Damage to either the container or its contents which affects the functional performance of either shall be cause for rejection.

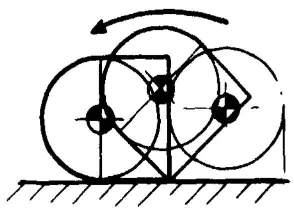
Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

OPTIONAL ROUGH HANDLING TESTS

The following tests are included to acquaint the reader with other less sophisticated tests often used to evaluate the integrity and performance of containers designed to provide a low level of shock mitigating protection.

These tests can be applicable to Rocket and Missile Containers only *in preparation for subsequent qualifying evaluation.* On occasion, it may be preferable to gradually increase the magnitude of abuse to determine the feasibility of the test item to satisfy the performance requirements. Critical, expensive and/or erratic test specimens may not permit immediate application of the full magnitude of the required force and a gradual, cautious approach may be required. Containers whose function is to protect fragile, sophisticated materiel must include, as part of the test, methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

TIP-OVER TEST



PROCEDURE

FIGURE 21. TIP-OVER TEST

The container, erect on its base, shall be slowly tipped (in the direction specified) until it falls freely and solely by its own weight to a concrete or similarly hard floor.

ROLLOVER TEST

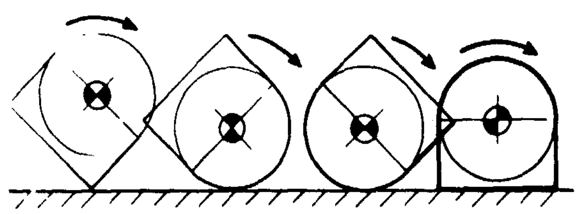


FIGURE 22. ROLLOVER TEST

The container, erect on its base, shall be tipped sideways until it falls freely and solely of its own weight to a concrete or similarly hard surface. This shall be repeated with falls from the side to top, from top to the other side, and from the other side to the base, thus completing one revolution.

ROLLING IMPACT TEST (cylindrical containers)

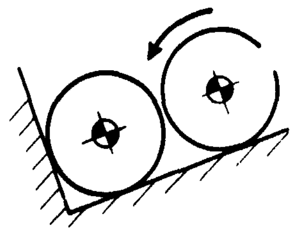


FIGURE 23. ROLLING IMPACT TEST

The container shall be allowed to roll down an incline on its rolling flanges and shall strike a vertical rigid flat surface at 10 feet per second.

CRITERIA FOR REJECTION

Any damage to the container or to its contents shall be cause for rejection. However, satisfactory performance does not qualify the test specimen which must be further subjected to the required qualifying procedure.

Undesirable response characteristics including accelerations in excess of the established limits (Gm) indicating inadequate isolation of the container contents from shock environment shall be cause for rejection.

SERVICEABILITY TESTS

The tests delineated below simulate the conditions which are prevalent in a logistic environment. The integrity of the container structure and its components are evaluated by subjecting the test specimen to the abuse described. These tests are applicable to containers whose configuration includes characteristics falling within the scope of the particular test and permits for assessment of handling compatibility.

CONCENTRATED LOAD TEST (Stacking)

Completed packs or pallet loads shall be loaded in a manner to simulate a height of stack of at least fifteen (15) feet, allowed to stand overnight, removed, and examined for damage. Containers constructed of materials likely to be affected by humidity shall be tested at a minimum of ninety (90) percent relative humidity at ninety (90) plus 5 degrees F. and allowed to stand twenty-four (24) hours before the stacking test operation. Broken seals or barriers, damage to items, or deformation of container which prevents removal of the item shall be cause for rejection. Seals shall be checked for leaking before and after tests.

FORK-LIFTING TEST

Loaded containers and completed packs which have skids and fork pockets, and palletized unit loads shall be lifted clear of the ground and transported a distance of at least fifty (50) feet, and lowered. When palletized unit loads are tested the test shall be conducted four (4) times i.e. forks entering the pallet form each of the four sides of the unit load. Any tendency for forks to puncture container, or for container or unit load to be unstable while on forks, or for difficulty in inserting or removing forks shall be cause for rejection. This test shall be conducted after the container or unit load has been subjected to all applicable rough handling, vibration and stacking tests.

HOISTING TEST

Containers having hoisting attachments shall be tested as follows:
The container shall be loaded with five (5) times its normal load and hoisted free from the floor, held for at least two (2) minutes, and lowered. Any breaking or permanent deformation shall be cause for rejection. Containers having handles shall be hoisted in like manner except that load shall be two (2) times the normal weight.

PUSHING AND TOWING TEST

Loaded shipping containers weighing more than 150 lbs. and all skidded containers shall be subjected to a sliding test. The loaded container or completed pack shall be tested by pulling across at least 5 feet of rough concrete. The test shall consist of pulling the container a distance of

5 feet or more axially, and 5 feet or more normally to the axis of the skids or to the major axis of nonskidded containers. Failure of this test shall be considered to have occurred if: The skids or the bottom of the container receive damage other than minor scuffing and scoring; any strapping or closing-components of the container are broken or loosened; the contents have been damaged; or there is any irreparable damage to the container if it is a reusable type.

VIBRATION TEST

The reliability requirements for missile and rocket containers are much more stringent than those established for commercial packaging. Inadequate protection or malfunction of the container assembly can result in mission failure. Conditions causing failures resulting from vibratory fatigue are prevalent within the environment of "worldwide distribution." The severity of vibrations peculiar to this logistic pattern have been increasing with the advent of new modes and methods of transportation.

Empirical data is available (see Chapter III) to estimate the probable environment and the forces imposed upon the container by this environment. These data and the predictions resulting from their application become the basis for design criteria and qualifying test procedure.

These predictions have been expanded to provide a qualifying test procedure applicable to containers subject to the environment of "worldwide distribution."

The purpose of this effort is to establish reliability-by-test; however, satisfactory performance does not necessarily imply optimum design as reliability through over design is not easily identified. The tests merely subject the test specimen to forces which are comparable to those which in its projected environment will produce fatigue failures. This exercise provides the designer with an experimental tool to evaluate design predictions and to discover unexpected phenomena sufficiently early to take corrective action.

The test procedure presented is concerned only with the evaluation of container performance particularly, its suspension system. This test *does not* comprise a valid basis for evaluation of the ability of the contained contents to withstand the effects of the imposed vibrations. The final results of testing will provide evidence to evaluate the structural integrity of the container and its components and an assessment of its performance to limit the transmissibility of the imposed vibration.

The test is a simulation of the vibrations encountered in shipment and not a duplication of the anticipated operating environment. To provide a realistic simulation, time scales have been reduced and the severity of imposed forces increased to introduce the concept of cumulative fatigue. It has been established that all vibrations imposed upon test specimens, subject to a military environment, shall be of the sinusoidal type. In addition, those frequencies pertinent to normal logistic transport are limited to the 5-500 cps range. Acceptance of these postulates minimizes the test procedure and provides a practical simulation of actual service conditions.

The test procedure is comprised of three distinct phases:

a. Resonancy Survey. This survey subjects the test specimen to the complete range of frequencies peculiar to the environment of "worldwide distribution," (5-500 cps). The magnitude of vibratory input specified is that most prevalent in the various frequency environments; (ship, rail, truck and air transport). This survey identifies those critical frequencies at which the response of the test specimen and the frequency of the excitation input produce or approach a resonant state (see Chapter I). It is these frequencies at which fatigue failure is most prevalent.

b. Suspension Proof Test. The second phase of the test subjects the container to those critical frequencies producing resonance and the maximum amplitudes associated with this phenomena. The suspension system, when exercised under these conditions may be considered as having been subjected to the cumulative effects of the forces it will experience in its projected environment. The ratio of test time to service life has been statistically derived according to D&PS Report No. 1190, "The Development of an Engineering Test Standard Covering the Transportation Environment of Material," and provides a test duration established at 15 minutes in each plane. By gymnasticating the test specimen at resonant frequency with the inputs specified for a duration of 15 minutes, it can be assumed that the effects due to resonance, comparable to the life span of the container, have been simulated.

Since test severity is directly related to response amplitude, it is only necessary to vibrate where response amplitude is the greatest, i.e. at the lowest resonant frequency.

c. Interpretation of Test Data. The final phase of the vibration test relates to the reduction of recorded data to allow for the evaluation of performance and assessment of reliability.

PROCEDURE

The test specimen shall be instrumented with vibration measuring pickups to detect and define critical resonancies and associated vibration mode shapes. Instrumentation shall consist of at least three accelerometers strategically located to detect the response of the container contents in each of its three orthogonal axes; longitudinal, lateral and vertical.

The test specimen shall be fastened securely to the vibration machine exciter head; (Use of slip table permissible only if head mounting is impossible). Attachment shall be by means of a rigid fixture capable of transmitting the specified vibrations.

a. Resonancy Survey (scanning). A survey to determine critical resonant frequency will be accomplished with the overpack alternately positioned in its: 1) longitudinal axis; 2) vertical axis. Excitation shall be applied in each axis throughout the frequency range of 5-500-5 cycles per second. Sweep duration and vibratory inputs shall be specified in the following table.

TABLE 12

SCANNING

35 minutes -	Sweep 5-52-5 cps at 1.3G input with two 17.5 minute cycles, limited by 1" in DA.
35 minutes -	Sweep 5-52-5 cps at 1.6G input with two 17.5 minute cycles, limited by 1" in DA.
6 minutes -	Sweep 5-52-5 cps at 2.5G input with one 6 minute cycle, limited by 1" in DA.
45 minutes -	Sweep 52-500-52 cps at 2.5G input with three 5 minute cycles, limited by 1" in DA.

If one or more resonancies are determined, a cushioning proof test shall be conducted in the applicable axis and at the lowest resonant frequency.

If a specific resonant condition is not found in the resonant survey, the overpack shall be positioned longitudinally and vibrated under the conditions of 268 cycles per minute (5 cps) for a period of 30 minutes (at 70° ± 5°F). Repeat this test with overpack positioned vertically.

b. *Cushioning Proof Test*. Vibrate at the established resonant frequency, with the test specimen positioned in its longitudinal plane; repeat with specimen in the vertical plane.

7.0 minutes at 1.3G input

6.5 minutes at 1.6G input

1.5 minutes at 2.5G input

c. *Interpretation of Test Data*. Any of the following conditions shall be cause for rejection:

1. Transmissibility of excitation forces in excess of factor of 5 during proof test.

2. Evidence of damage which would affect the utility of the container.

3. The recorded force imposed upon the protected item exceeds its Gm limit.

The above criteria establishes representative laboratory vibration time for distance (mileage) traveled by the missile container in both military transport media and common carriers. The approach used was to determine the reasonable "worldwide distribution" travel distance and apply the vibration time as related to that distance.

TABLE 13

DERIVATION OF DATA*

Distance	Mode	Input	Time	Vibration Time	Time at Resonance	Time Scanning
8500 miles	Ship, Aircraft	1.3G	10 min/1000 mi	85 min	14 min	71 min
4000 miles	Track and Truck (military convoy)	1.6G	20 min/1000 mi	80 min	13 min	67 min
1000 miles	Trailer (2-wheeled)	2.5G	15 min/1000 mi	15 min	2.5 min	12.5 min
100 miles	Helicopter (75 mph)	2.5G	Actual	80 min	0 min	80 min

*See AMCPM-SH-H Ltr dtd 27 Feb 1964, subject: Revised Transportation Vibration Criteria and Missile Allowable Criteria.

HIGH TEMPERATURE TEST

High temperature testing is conducted to determine the resistance of the container and its components to elevated temperatures that may be encountered in the environment of "worldwide distribution."

High temperature conditions may cause rubber, plastic and plywood to discolor, crack, bulge, check or craze. Closure and sealing strips may partially melt and adhere to mating parts. Cushions may collapse and distortion of structural components may result. Of particular interest is the degradation of physical response of the cushion system. The resiliency of metallic springs and that of natural and synthetic elastomers fluctuates with temperature change. Consequently, the test procedure delineated may be performed to determine the effects of high temperature exposure of the test specimen; *however, in container evaluation, this phase is normally performed in conjunction with rough handling tests.* One phase of the rough handling test requires that the test specimen be conditioned at high temperature prior to subjecting it to rough handling. As such, the conditioning phase preceding rough handling test is equivalent to the exposure required for high temperature testing and as such *need not be* conducted separately unless so specified. The effects of high temperature exposure can be evaluated after the rough handling tests have been conducted and the specimen has cooled to room temperature.

PROCEDURE

The test specimen shall be placed within a climatic chamber and conditioned to 71°C (160° ± 5°F) for a period of 24 hours or until it has been determined that the container has stabilized at the specified temperature. Conditioning of the specimen shall not be accelerated by raising nominal temperature of the chamber temperature input beyond the extreme limit of the range specified. The test specimen shall then be removed from the conditioning chamber, (*subjected to rough handling test*) and upon return to room temperature, examined for damage.

CRITERIA FOR REJECTION

Damage to the container resulting from this exposure or to any of its components which could in any manner prevent the test item from meeting operational requirements shall provide reason to consider the test item as having failed to withstand the conditions of the test.

LOW TEMPERATURE TEST

The low temperature test is conducted to determine the effects of low temperature on the container and its components during storage and service use. Differential contraction of metal parts and loss of resiliency of packings and gaskets are two of the difficulties associated with low temperatures. In addition, the physical characteristics of elastomeric mounts are radically altered under these conditions and the protective integrity of the container is jeopardized.

The Arctic regions subject materiel to a very cold atmosphere. Sub-zero temperatures of -65°F are common; temperatures of -85°F have been recorded in underground ammunition storage "igloos." For "worldwide distribution," -65°F has been established as standard.

The test procedure specified may be applied to determine the effects of low temperature exposure upon the test specimen; however, *in container evaluation, this is normally performed in conjunction with rough handling testing*. One phase of the rough handling test requires that the test specimen be conditioned at low temperature prior to subjecting it to rough handling. As such, the conditioning phase preceding rough handling test is equivalent to the exposure required for low temperature testing and as such, *need not be* conducted separately unless so specified. The effects of low temperature exposure can be evaluated after the rough handling tests have been conducted and the test specimen has stabilized at ambient temperature.

PROCEDURE

The test specimen shall be placed within a climatic chamber and conditioned to -54°C (-65° ± 5°F) for a period of 24 hours or until it has been determined that the container has stabilized at the specified temperature. Conditioning of the specimen shall not be accelerated by lowering the nominal chamber temperature input beyond the extreme limit of the range specified. The test specimen shall then be removed from the conditioning chamber, (*subjected to rough handling test*) and upon return to room temperature, examined for damage.

CRITERIA FOR REJECTION

Damage to the container resulting from this exposure or to any of its functional components which could in any manner prevent the test item from meeting operational requirements shall constitute cause for rejection.

LOW PRESSURE TEST

The low pressure test is conducted to determine the ability of the container and its components to withstand the reduced pressure encountered during shipment by air.

Damaging effects of low pressure include leakage through sealed enclosures, rupture of pressurized containers, degassing and collapse of closed cell plastic cushion compounds, overexpansion and rupture of air-bag suspensions, etc.

The structural integrity of free-breathing containers is normally unaffected by reduced pressure; however, the effects upon the functional components and their performance must be established.

Exposing controlled-breathing containers to low pressure tests exercises the control valves to permit verification of operating pressures. Proper functioning of the breather valves relieves the structure of abnormal stresses and protects the contents from the deleterious effects of reduced pressure.

Pressurized sealed containers are tested to evaluate the effectiveness of the protective seals and gaskets in addition to demonstrating the ability of the container to withstand the pressure differential imposed upon its structure.

PROCEDURE

The test specimen shall be examined under standard ambient conditions and a record made of all data necessary to determine compliance with required performance.

Pressurized containers and those equipped with controlled breathing devices shall contain a gage or recording device to permit monitoring of internal pressure. Pressurized containers shall be charged to the required level. Controlled breathing containers shall be sealed under ambient conditions and the level of internal pressure recorded.

The test specimen shall be placed in the test chamber and positioned in a manner that will simulate air transit conditions. The internal chamber temperature shall be uncontrolled during the test. The chamber internal pressure shall be reduced to 5.54 inches of mercury (40,000 feet above sea level) and maintained for a period of not less than 1 hour. The internal pressure of sealed containers (pressurized and controlled breathing) shall be monitored and their values recorded at five minute intervals. The chamber shall then be returned to room pressure and the test item inspected.

CRITERIA FOR REJECTION

Deterioration of any component which could in any manner prevent the equipment from meeting functional, maintenance and service requirements during service life shall provide reason to reject equipment for having failed to comply with the conditions of the test.

Pressurized sealed containers shall experience no pressure drop during the 1 hour exposure period and when returned to room pressure shall indicate initial charge gage reading.

Containers equipped with controlled breathing shall maintain their initial pressure level to within a tolerance of ± 3 psi.

All containers equipped with bulk cushion suspensions shall show no sign of physical degradation as evidenced by loss of content restraint.

Deterioration, condensation, or change in performance tolerance limits of any internal or external component which could in any manner prevent the container from meeting operational requirements shall provide reason to consider the test specimen as having failed to withstand the effects of a high altitude unprotected transit environment.

RAIN TEST

The rain test is conducted to demonstrate the ability of the container to shield its contents when exposed to rain under service conditions.

Sealed containers which have satisfied the low pressure test may be considered to be resistant to rain penetration and will adequately protect their contents. Open and free-breathing containers must be subjected to test and their ability to protect their contents in a rain environment demonstrated.

PROCEDURE

The container shall be placed in a rain chamber, equal to that specified in MIL-C-8811 and positioned as it would be under transit and field storage conditions. The rain chamber temperature shall be uncontrolled, except as regulated by water introduced as rain, throughout the test period. The test item shall be exposed to a simulated rainfall of 4 ± 1 inches per hour as measured at the surface of the test item by a U. S. Weather Bureau-Type Gauge. The rainfall shall be produced by means of a water spray nozzle of such design that the water is emitted in the form of droplets having a minimum diameter of 1.5 millimeters.

The temperature of the water shall be uncontrolled provided the water supply temperature is between 11° and 35°C (51.8° and 95°F). The direction of rainfall shall be capable of variation from vertical up to 45° from the vertical by introduction of blowing wind of 35 knots. The rainfall shall be dispersed uniformly over the test area within the limits specified above. Each of the major sides of the test item shall be exposed to the simulated rainfall for a period of 30 minutes, for a total test duration of not less than 3 hours. At the conclusion of the test period the test item shall be removed from the test chamber and subjected to inspection.

CRITERIA FOR REJECTION

Lack of drainage ports and the inability of the container to purge itself of any rain penetration as evidenced by accumulation of water pockets, swelling or other deterioration shall be cause for rejection.

SAND AND DUST TEST

The sand and dust test is conducted to determine the resistance of containers to blowing fine sand and dust particles. Because of its abrasive character, sand and dust may affect items having moving parts. Hinges and latches may bind and protective finishes may deteriorate when subjected to the sand blast effects of this environment. Dust particles may form nuclei for condensation of moisture, thus introducing a source for corrosion. Air valves may malfunction due to clogging of intake ports and protective filters.

Quite often, one may circumvent the need to conduct this costly test entailing special test equipment by using only certified components and finishes. Many paints and protective finishes are certified as being sand resistant. The use of sealed bearings negates the need for testing. Commercially available valves which have been certified as functionally resistant to sand and dust can be used. In addition, the pressure test if successful, provides sufficient evidence to qualify the container to resist the penetration of sand and dust. The following procedure is included to permit testing of either containers or their components in situations where the item or items have not been previously tested and certified.

PROCEDURE

The sand and dust characteristics used in this test are described in MIL-Std-810 (USAF) Method 510. This compound is commercially known as "140-mesh silica flour."

The test item shall be placed in a test chamber equal to that specified in MIL-C-9436. The sand and dust density shall be raised to and maintained at 0.1 to 0.25 gram per cubic foot as measured at three different locations within the test area utilizing approved collection devices. The relative humidity shall not exceed 30 percent at any time during the test. The internal temperature of the test chamber shall be maintained at 25°C (77°F) for a period of not less than 2 hours with the air velocity through the test chamber at 100 to 500 feet per minute. Following this 2-hour period the temperature shall be raised to and maintained at 71°C (160°F). These conditions shall be maintained for not less than 2 hours. At the end of this exposure period, the test item shall be removed from the test chamber and allowed to cool to room temperature. Accumulated dust shall be removed from the test item by brushing, wiping, or shaking, care being taken to avoid introduction of additional dust into the test item. Under no circumstances shall dust be removed by either air blast or vacuum cleaning.

CRITERIA FOR REJECTION

The container or component items subject to test shall be functionally operated and inspected. Pitting, flaking or any damage to the protective finish affecting its protective qualities shall constitute a failure. Malfunction of functional components and/or penetration of sand and dust to within the confines of sealed containers shall be cause for rejection.

SALT FOG TEST

The salt fog test is conducted to determine the resistance of containers to the effects of a salt environment. Damage to be expected from exposure to salt fog is primarily corrosion of metals, although in some instances salt deposits may result in clogging or binding of moving parts.

The effects of salt fog exposure can be predicted and will permit the designer to circumvent this phase of the test program. The usefulness of conducting the salt fog test on the complete container is unrealistic; component parts and material samples can be tested separately.

Many materials and finishes are qualified as resistant to salt fog deterioration and the electrolytic corrosion between dissimilar metals can be predicted. As such, the salt fog test is not often included and may be safely eliminated from the test plan by applying good design technique.

When this test is deemed necessary due to the introduction of new materials and/or technique, the procedure included in MIL-Std-810 (USAF) Method 509 may be applied.

HUMIDITY TEST

The humidity test is conducted to determine the resistance of equipment to the effects of exposure to warm, highly humid atmosphere such as is encountered in tropical areas. This is an accelerated environmental test, accomplished by the continuous exposure of the equipment to high relative humidity at an elevated temperature. These conditions impose a vapor pressure on the equipment under test which constitutes the force behind the moisture migration and penetration. Corrosion is one of the principle effects of humidity.

Hygroscopic materials are sensitive to moisture and deteriorate rapidly under humid conditions. Absorption of moisture by many materials results in swelling, which destroys their functional utility and causes loss of physical strength and changes in other important mechanical properties.

Sealed containers having satisfactorily passed the low pressure test can be considered to be resistant to moisture penetration and consequently *need not be tested* unless the exterior finish is not impervious to this environment and qualification is considered necessary.

Containers equipped with *controlled breathing* mechanisms and desiccants *must be subjected* to the humidity test to establish the effectiveness of these protective devices and to verify the amount of desiccant required.

Free breathing containers offer no resistance to humidity penetration. If the outer shell and suspension materials are certified as moisture resistant, the *test need not be conducted.* It may be assumed that items housed in free-breathing containers are inherently protected or are inert to the effects of high humidity.

PROCEDURE

The test chamber and accessories shall be constructed and arranged in such a manner as to avoid condensate dropping on the equipment under test. The chamber shall be vented to the atmosphere to prevent the build-up of vapor pressure. Relative humidity shall be determined from the dry bulb-wet bulb thermometer comparison method. The wet bulb thermometer shall be installed at the internal mouth of the air inlet duct. The air velocity flowing across the wet bulb shall be not less than 900 feet per minute. Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall not exceed 150 feet per minute. Distilled or deionized water having a pH value between 6.5 and 7.5 at 25°C (77°F) shall be used to obtain the specified humidity.

The test item shall be placed into the test chamber in a manner simulating its storage position. Prior to starting the test the chamber temperature shall be between 20° and 38°C (68° and 100°F) with uncontrolled humidity. The temperature and relative humidity shall then be gradually raised to 71°C (160°F) and 95 percent respectively over a period of 2 hours. These conditions shall be maintained for a period of not less than 6 hours. With the relative humidity maintained at 95 percent, the chamber temperature shall then be gradually reduced to 20° to 38°C (68° to 100°F) over a period of not less than 16 hours. This constitutes 1 cycle. The number of continuous cycles shall be 10 for a total test time of not less than 240 hours. At the conclusion of the test, the test item shall be removed from the chamber and returned to room ambient conditions.

CRITERIA FOR REJECTION

Evidence of moisture penetration resulting in the accumulation of condensate within the interior of sealed containers shall be cause for rejection. Swelling or saturation of container components shall constitute a failure.

Any deterioration of the container or of any of its components shall reflect upon its ability to withstand the effects of a humid environment.

SUNSHINE TEST

The sunshine test is conducted to determine the effect of radiant energy on the container and its components. Exposure to sunshine will cause heating of equipment and photo degradation such as fading of fabric colors in addition to checking of paints, natural rubber, and plastics.

The sunshine test is applicable to any item of equipment which may be exposed to solar radiation during service or while in storage. Examples of container components which must be protected from or be inherently resistant to the deleterious effects of sunshine are:

a. Exterior finishes

b. Exposed seals and gaskets

c. Wooden skids

d. Plastics

e. Rubber bumpers and externally mounted elastomers

f. Web straps and tie-down devices

g. Decals and markings

Those components housed within the container and not normally exposed to sunlight need not be resistant to solar radiation. In addition, many of the materials and finishes common to container construction are usually resistant to solar radiation and qualify for use by compliance with approved specifications. Consequently, the sunshine test is *not often included* in test programs unless the design introduces new and untested materials and/or finishes.

PROCEDURE

The test specimen shall be placed within the test chamber and exposed to radiant energy at the rate of 100 to 140 watts per square foot.

Fifty to eighty-four watts per square foot shall be in wavelengths above 3,800 angstrom units and 4 to 8 watts per square foot shall be in wavelengths below 3,800 angstrom units. The test chamber temperature shall be maintained at 45°C (113°F) for a period of not less than 48 hours. The test item shall then be returned to room temperature and inspected.

CRITERIA FOR REJECTION

Deterioration of any component which could in any manner contribute to or prevent the equipment from meeting functional, maintenance, and service requirements shall be cause for rejection.

FUNGUS TEST

The fungus test is conducted to determine the resistance of containers to fungi. Fungi secrete enzymes which can destroy most organic substances and many of their derivatives. They can also destroy many minerals.

The majority of today's packaging materials are either inert to attack by enzymes or can be conveniently treated to resist fungi growth. *Consequently, containers are rarely subject to fungus test.*

In those instances where new materials or finishes are utilized and require qualification, the test procedure delineated in MIL-Std-810 (USAF) is applicable.

CHAPTER V

MECHANICAL SUSPENSION SYSTEMS

GENERAL

Mechanical suspension systems for rocket and missiles are grouped for convenience into three general categories:

I. Helical Springs
II. Torsion Bars
III. Other types of Mechanical Suspensions

The first category, *helical springs*, will receive a more detailed analysis than the others because of its *wider use* and the greater amount of readily available material defining its application and performance. The procedure to be followed in designing a spring suspension system will be given; formulae, damping and mathematical examples will be included.

Torsion bar suspension systems are not recommended for rocket and missile component containers. The designer should give serious consideration to the inherent problems of this type of suspension system before entering into its formal design and construction. Section II gives a discussion of the problems associated with torsion bar suspension systems. The complexity of torsion bar calculations preclude their inclusion in this limited study. A description of the torsion bar system used in the Army Corporal M351 Missile Container is included for general orientation.

The third category includes such suspension systems as *cable isolators, Jarret-type springs* and *single use energy dissipators.* This section reflects the time alloted to it; its brevity should not be interpreted as a condemnation of these suspension systems. Indeed time and further development may prove one of these systems superior to elastomeric mounts or helical springs; two topics covered in detail by this study.

I. HELICAL SPRINGS

Only *helical, round wire compression or extension springs are considered* in this section. Formulas found in Machinery's Handbook show that fiber stress for a given shock load will be greater in a spring made from a square bar than in one made from a round bar; the side of the square bar being equal to the diameter of the round bar. *Square wire springs should not be used* in containers as round wire springs are more economical in applications involving shock loading.

Conical compression springs are used as a means for decreasing the solid height by telescoping action; as this requirement will in all probability never arise in container design, *conical springs have been excluded from this study.*

Elliptical or leaf springs are not included because these types of uniaxial springs do not lend themselves to the triaxial deflections necessary in rocket and missile containers.

GENERAL DESIGN PROCEDURE

The design of a Helical Spring Suspension System for Rocket and Missile Containers may include

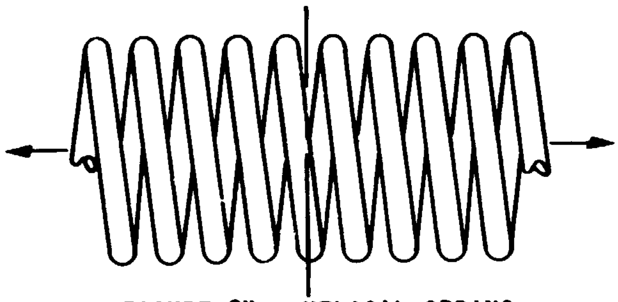


FIGURE 24. HELICAL SPRING

A. Loads and Required Deflections

The first and obvious step is to determine the weight, location of center of gravity, possible attachment points, and shipping attitude of the component or item to be contained.

From the fragility factor, Gm, of the item, the minimum deflection and minimum time through which this deflection occurs can be determined (see Chapter I).

It is interesting to note that when triaxial protection is provided to an item by its suspension system, assuming the items' fragility factor equal in all directions, varying levels of protection and therefore varying deflections will be required in the three axes as the severity of the tests, which simulate the hazards to be encountered, will often vary in the three axes. For example: a container may be required to withstand a 30" end drop and a rollover test (see Chapter IV). This will result in a much larger shock input in the vertical direction than in the lateral direction. The suspension system must therefore provide a greater level of protection in the vertical direction.

Knowing the fragility factor and the tests required to simulate the hazards the container will encounter, the designer can determine the deflection and pulse time required of the suspension system in each of the three pertinent axes. See Chapter I for deflections and Chapters III and IV for Hazards and Tests.

B. Body Types and Spring Locations

The body type concept of the container must be established (see Chapter VIII). Spring suspension systems can be designed for either top or end opening containers. The location of the springs cannot be divorced from and are interrelated to the configuration of the container. The springs should be located about the center of gravity of the packaged item such that each spring carries an equal load. If this arrangement is not possible then the spring rate should be adjusted to compensate for the unequal loading. Illustrated below are several containers with spring suspension systems.

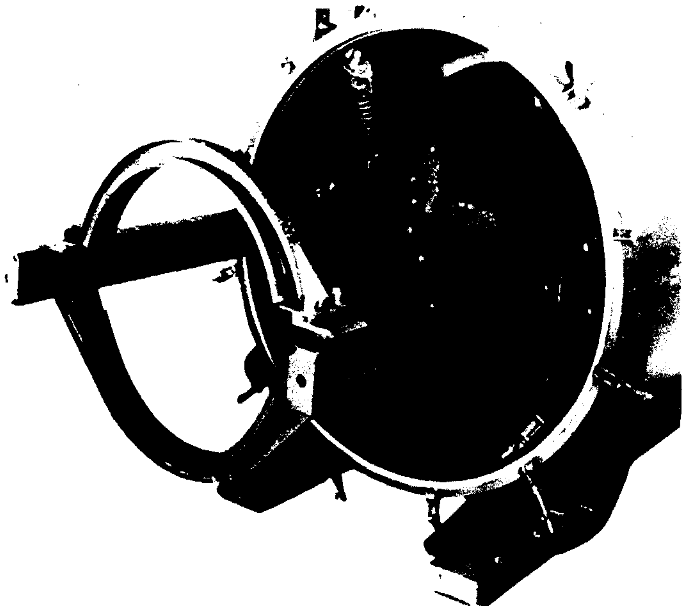


FIGURE 25. END VIEW OF NIKE-HERCULES CONTAINER SHOWING SPRING SUSPENSION SYSTEM AND ROLLOUT MECHANISM. DAMPING IS PROVIDED BY TUBULAR-TYPE SHOCK ABSORBERS MOUNTED INSIDE THE COIL SPRINGS

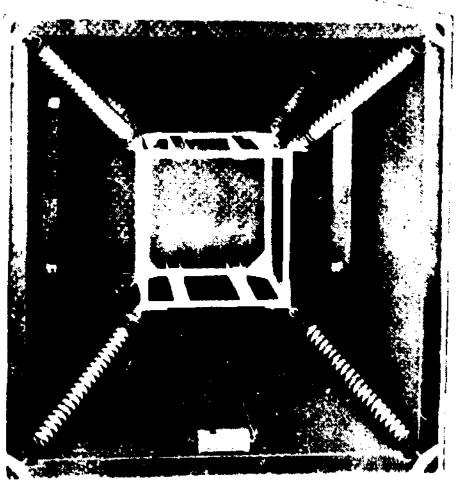


FIGURE 26. THREE DIMENSIONAL PROTECTION PROVIDED TO MISSILE COMPONENT BY HELICAL SPRINGS WITH STAINLESS STEEL SPRING CUSHIONS INSIDE THE SPRINGS USED FOR DAMPING. SPRING RATE IS IDENTICAL IN ALL PLANES ASSURING EQUAL PERFORMANCE REGARDLESS OF THE ATTITUDE AT THE TIME OF IMPACT.

The spring(s) necessary to satisfy the application requirements can be designed once the body type and its configuration, the number and location of the spring(s), and the deflection they must provide have been established.

C. Calculation of the Spring Rate

One of the first steps in designing a spring is the calculation of the spring rate, K. The spring rate, sometimes called stiffness, is the force required to produce unit deflection. The units of K are pounds per inch. It can be found from the following formula:

For *slowly* applied loads:

$$K = \frac{P}{S} = \frac{E_t \, d^4}{8 \, D^3 N} \quad \frac{lb}{in} \tag{1}$$

For *suddenly* applied loads:

$$K = \frac{2P}{S} = \frac{E_t \, d^4}{4 \, D^3 \, N} \quad \frac{lb}{in} \tag{2}$$

Where:

K = Spring rate; $\frac{lb}{in}$
P = Load on spring; lb
S = Spring deflection; in.
d = Wire diameter; in.
D = Mean coil diameter = outside dia. of spring - wire dia.; in.
N = Number of active coils in the spring
E_t = Torsional modulus of elasticity or modulus of rigidity; $\frac{lb}{in^2}$

The spring rate can be found knowing the load P, and deflection S, or the spring dimensions such as d, D, N and E_t. However, as the spring rate is used to determine the spring dimensions, the procedure following will be to first find K utilizing P and S, then to determine the spring dimensions. The deflection S, that the spring must provide is dictated by the fragility factor, G_m, and the container qualification tests required. The deflection, load P, and the resulting spring rate can be found as shown in the following illustrative problem:

Given: Item weight, W = 1,000 lb.
Item fragility factor, G_m = 20
Test required, 30 inch flat drop

Object: To find the spring rate K, required for adequate protection.

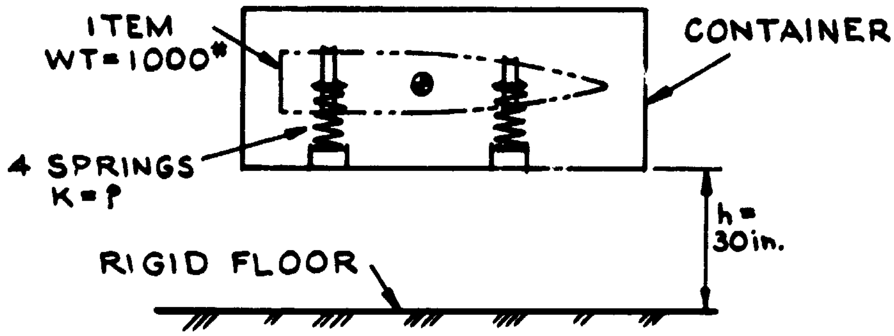


FIGURE 27. EXAMPLE OF SPRING SUSPENSION SYSTEM - USING 4 PARALLEL SPRINGS

If the container is dropped 30" it attains a *velocity*, V_t at impact of:

$$V_t^2 = V_o^2 \pm 2\ ah \tag{3}$$

Where:

V_t = velocity at impact, ft/sec

V_o = initial velocity, ft/sec

h = drop height, ft.

a = 32.0 ft/sec^2, acceleration due to gravity

Substituting into Equation 3, and using the + sign because the acceleration is increasing, gives:

$$V_t^2 = 0 + 2\ (32.0)\ \frac{ft}{sec^2}\ \ \frac{(30)\,ft}{12}$$

$$V_t^2 = 160\ \frac{ft^2}{sec^2}$$

$$V_t = 12.65\ \frac{ft}{sec}$$

Both the container and the item will have a velocity of $12.65\ \frac{ft}{sec}$ at impact.

With the fragility factor G_m = 20 and the 30" drop height enter Table 4, Chapter I, of Deflection for Linear Systems. The table for linear systems is used because an undamped spring is essentially linear, i.e. the spring rate is constant throughout the range of its use. The required deflection will be found to be 3.3 inches. Therefore, the item which is moving at 12.65 ft/sec at impact must be brought to rest in a distance of 3.3 inches in order to prevent damage to the item.

Equation 3 can be used to calculate the retarding *acceleration* that must be provided by the springs.

Now:

$$h = 3.3 \text{ in} = \frac{3.3}{12} \text{ ft.}$$

V_t = Final velocity = 0 ft/sec because the item will come to rest.

V_o = Initial velocity, i.e. the velocity of the item as the container strikes the ground, = 12.65 ft/sec.

a' = Unknown retarding acceleration in ft/sec^2.

NOTE: Assume that the container and the ground are rigid.

Substituting:

$$V_t^2 = V_o^2 \pm 2\,a'$$

$$0 = (12.65)^2 - \frac{(2)\ (3.3)}{12}\,a'$$

The minus sign is used because the acceleration is decreasing.

$$a' = \frac{(12.65)^2\ (12)}{(2)\ \ (3.3)}$$

$$a' = 290.9 \text{ ft/sec}^2$$

The mean *force*, F, at impact follows Newton's Law:

$$F = ma = \frac{W}{g}\,a \qquad (4)$$

Where:

m = Mass of the item, lb/ft sec^2
W = Weight of item, lb
g = Acceleration of gravity = 32 ft/sec^2
a = Acceleration of item, ft/sec^2
F = Mean force at impact, lb

Substituting:

$$F = \frac{1000 \text{ lb } (290.9) \text{ ft/sec}^2}{32.0 \text{ ft/sec}^2}$$

$$F = 9091 \text{ lb}$$

This force will be used in finding the spring rate and also the stresses developed in the spring.

The *time*, t, through which the deceleration takes place is:

$$V_t = at \tag{5}$$

$$t = \frac{V_t}{a} = \frac{12.65 \text{ ft/sec}}{291 \text{ ft/sec}^2}$$

$$t = 0.0435 \text{ sec, or } 43.5 \text{ milliseconds}$$

Having found the deflection, S, and the force, F, the total *spring rate*, K_t, can be found with Equation 2.

$$K_t = \frac{2F}{S}$$

$$K_t = \frac{(2)(9091) \text{ lb.}}{3.3 \text{ in.}}$$

$$K_t = 5510 \text{ lb/in}$$

When springs are placed in parallel the total spring rate is the sum of the individual spring rates.

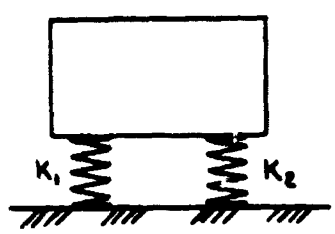


FIGURE 28. SPRINGS IN PARALLEL

$$K_t = K_1 + K_2 + \ldots \tag{6}$$

If K_t = 5510 lb/in and four identical springs each carrying an equal weight are used then:

$$K_t = 4K \tag{7}$$

$$K = \frac{K_t}{4} = \frac{5510}{4} \text{ lb/in}$$

$$K = 1378 \text{ lb/in}$$

Each of the four springs must then have a spring rate of 1378 lb/in.

An alternate and less complex method for arriving at the spring rate in the above problem can be found in "Dynamics of Package Cushioning," by Mindlin. This solution is given below.

$$K_t = \frac{2hW}{S^2} \tag{8}$$

Where: The terms are the same as those defined above:

$$K_t = \frac{(2)\ (30)\ \text{in}\ (1000)\ \text{lb.}}{(3.3)^2\ \text{in}^2}$$

$$K_t = 5510 \text{ lb/in}$$

Division by 4 gives the same spring rate, K, of 1378 lb/in.

Equation 8 can be used for cushioning with a linear load-displacement relation and suddenly applied load. When the load is slowly applied, the following equation applies:

$$K = \frac{hW}{S^2} \tag{9}$$

D. Calculation of Total Deflection

When calculating the deflection of springs used in containers, it should be noted that the springs undergo a static loading due to the weight of the item upon which is superimposed a dynamic load resulting from shock and/or vibration.

The total deflection of the springs must be found in order to calculate the physical dimensions of the springs. The total deflection, S_t, will be the deflection due to impact plus that resulting from the static load:

$$S_t = S \text{ impact} + S \text{ static} \tag{10}$$

Using the foregoing problem as an example:

$$S_t = S_i + S_s = 3.3 + \frac{P}{K}$$

$$S_t = 3.3 + \frac{250}{1378}$$

$$S_t = 3.3 + 0.18$$

Where P here equals the load carried by each spring, i.e. $\frac{1000}{4}$

$$S_t = 3.48 \text{ in.}$$

E. Vibration and Damping

In the preceding sections the spring rate and spring deflections have been found. These values will have a direct bearing on the vibrational response of the suspension system and the forces transmitted to the item.

A container in transit will undergo forced vibrations. The vibrational response of the suspension system must be determined in order to exclude the possibility of (1) excessive and damaging oscillations at resonance, and (2) the failure of the springs due to fatigue.

A spring contains virtually no internal damping, therefore, in order to reduce excessive displacements at resonance to a tolerable level, several damping methods are employed. There exists three types of damping:

1. Dry or coulomb friction - between rigid bodies.
2. Fluid friction - a rigid body moving in a fluid.
3. Internal friction - between the molecules of seemingly inelastic bodies.

In the first two types of damping, the frictional force developed is directly proportional to the speed of the moving body. The coulomb type of shock absorber, illustrated in Figures 30 and 31, follows the formula $F = \mu N$. Where F = frictional force; N = normal force; μ = coefficient of friction.

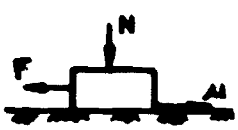


FIGURE 29. FORCES ON A BODY IN MOTION

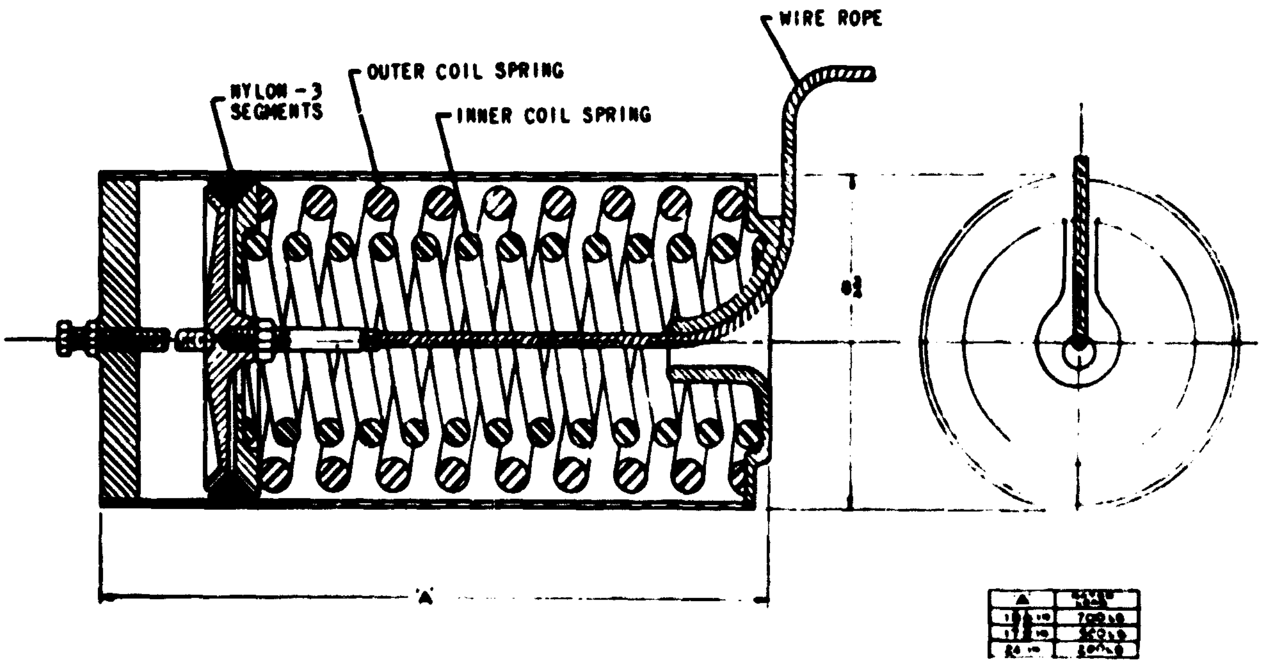


FIGURE 30. METAL SHOCK MOUNT UTILIZING FRICTION DAMPING

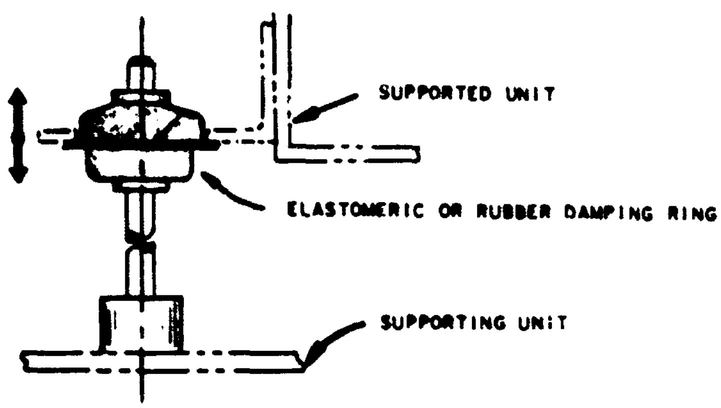


FIGURE 31. FRICTION DAMPER ASSEMBLY

A shock absorber operating on the fluid friction principle is the automotive tubular-type shock absorber. This absorber is available in a wide variety of sizes, capacities and end configurations. The fluids normally used in this type of shock absorber, tend to stiffen at -65°F, therefore, if such operating temperatures are anticipated, a silicone oil or comparable fluid should be specified to prevent the loss of performance. The amount of damping c, for a given shock absorber can be obtained from its manufacturer.

Stainless steel wire mesh has also been used successfully to dampen unwanted vibrations. The claimed advantages of this type of damping when used in conjunction with metal springs, is that it provides an all metal mount virtually impervious to temperature, oil, water, ice, ozone, fungus, etc. Figures 32 and 33 illustrate this type of mount.

FIGURE 32. TYPICAL RESILIENT WIRE MESH CUSHION

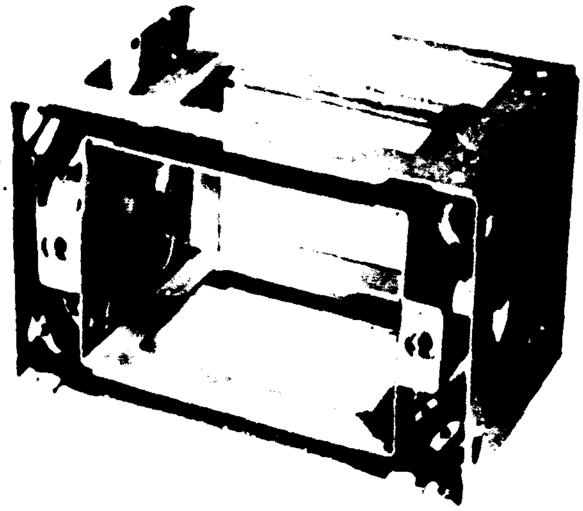


FIGURE 33. MOUNTING SYSTEM UTILIZING SPRINGS WITH WIRE MESH DAMPING

The spring rate and deflection found in sections C and D will be used in an illustrative example to show the calculations which must be performed in order to determine the vibratory response of a suspension system.

F. Vibration and Damping Calculations

Using the example given in section C with the addition of four tubular-type shock absorbers the following shall be found: the *natural frequency* f_n and w_n; the *disturbing* or impressed *force*, P_o; the *amplitude* at resonance, X_o; the *transmissibility*, TR; and the % *of critical damping*.

Given: Item weight, W = 1,000 lb.; static deflection, S_{st} = 0.18 in.; acceleration due to gravity, g = 386 in/sec^2; four shock absorbers with a damping coefficient, c = 7 lb/in sec.; impressed amplitude, a_o = 0.032 in. (This value can be determined for any given condition from Chapters III and IV, Hazards and Tests.)

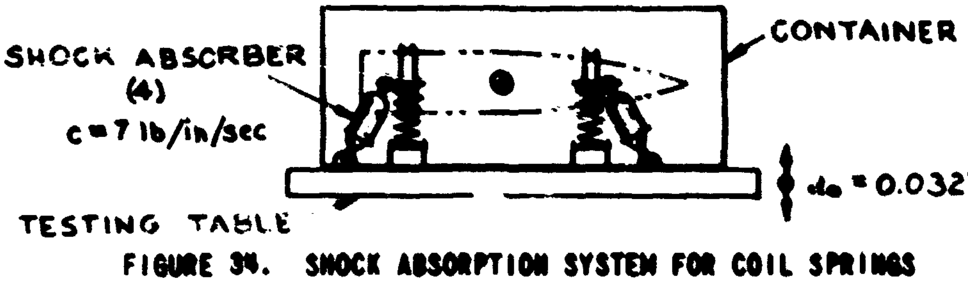


FIGURE 34. SHOCK ABSORPTION SYSTEM FOR COIL SPRINGS

The *natural frequency* of the system f_n is:

$$f_n = \frac{w_n}{2\pi} \text{ cycles/sec} \qquad (11)$$

Where w_n is the natural frequency in radians/sec

For springs

$$w_n = \sqrt{\frac{g}{S_{st}}} \qquad (12)$$

$$w_n = \sqrt{\frac{386}{0.18}}$$

$$w_n = 46.3 \text{ rad/sec}$$

$$f_n = \frac{w_n}{2\pi} = \frac{46.3}{2\pi}$$

$$f_n = 7.37 \text{ cycles/sec}$$

The natural frequency of a suspension system is calculated to determine if it coincides with the natural frequency of the transportation medium to which it is subjected. Chapters III and IV will provide guidance on the magnitude of the imposed vibrational frequencies for the pertinent modes of transportation. Generally the natural frequency of container suspension systems should be above 7 cycles per second. The natural frequency of 7.37 cps calculated in the example is somewhat low; this value can be raised by decreasing the static deflection of the springs. This will increase the stiffness of the springs, therefore, care must be taken when raising the natural frequency in order not to compromise the protection provided by the system.

Excessive vibrations can be reduced by increasing the damping. It should be noted that damping will not affect the magnitude of the natural frequency because for spring suspension systems the natural frequency is dependent solely on the static deflection. As a result the natural frequency is calculated without taking into account the effects of damping.

The *disturbing force*, P_o, for spring suspension systems at resonance is derived by Hartog as:

$$P_o = \sqrt{\left[(K)(a_o)\right]^2 + \left[(C_t)(a_o)(w)\right]^2} \qquad (13)$$

Where:

$$K = \text{Spring constant of complete system} = \frac{W}{S_{st}}$$

$$K = \frac{1000 \text{ lb}}{0.18 \text{ in}} = 5556 \frac{\text{lb}}{\text{in}}$$

a_o = Impressed amplitude = 0.032 in.

C_t = The total damping of the system = (4)(c) = (4)(7) lb/in/sec = 28 lb/in/sec

w = Natural frequency, w_n, = 46.3 rad/sec.

Substituting:

$$P_o = \sqrt{\left[(5556)(.032)\right]^2 + \left[(28)(.032)(46.3)\right]^2}$$

Solving for the disturbing force:

$$P_o = 182.6 \text{ lb.}$$

The *amplitude*, X_o, of the item at resonance can now be found:

$$X_o = \frac{P_o}{C_t w_n} \tag{14}$$

$$X_o = \frac{182.6 \text{ lb}}{(28) \text{ lb/in sec } (463) \text{ rad/sec}}$$

$$X_o = 0.14 \text{ in.}$$

The *transmissibility*, TR, is the ratio of the disturbing force to the impressed force.

$$TR = \frac{0.14}{0.032} \tag{15}$$

$$TR = 4.37$$

The *critical damping* C_c is:

$$C_c = \frac{2k}{w_n} \tag{16}$$

$$C_c = \frac{(2)(5556)\ \text{lb}}{46.2\ \text{rad/sec in}}$$

$$C_c = 240.0\ \text{lb/in/sec}$$

Percent of critical damping is:

$$\%\ C_c = \frac{C_t}{C_c}\ (100)$$

$$\%\ C_c = \frac{28(100)}{240}$$

$$\%\ C_c = 11.7$$

This value is somewhat low; it can be raised by increasing the damping or changing the spring rate. In container applications, a damping of 15 to 20% of critical damping at resonance is desired in order to prevent excessive oscillations. Figure 35 illustrates various degrees of damping; the damped vibration curve being the desired condition. The shaded curve in Figure 36 shows the results of the proper percentage of critical damping.

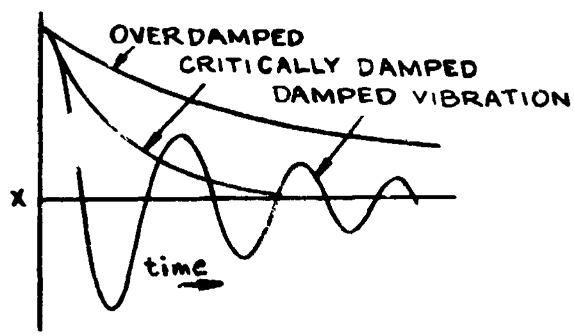
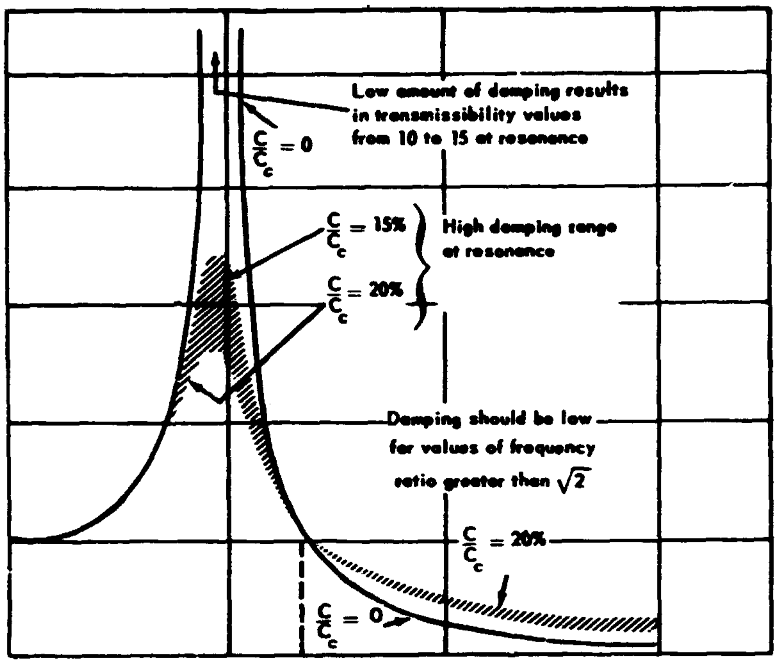


FIGURE 35. DEGREES OF DAMPING

In the preceding sections the performance requirements of the spring suspension system have been calculated. First the spring rate was calculated utilizing the impact or shock loading involved; then the effects of vibration were considered. There remains the determination of the spring(s) dimensions. This will require the choice of a material and the calculation of the stresses developed in the spring(s).



$$\text{Frequency ratio} = \frac{\text{Forcing frequency}}{\text{Undamped Natural frequency}}$$

FIGURE 36. MOUNTING SYSTEMS POSSESSING 15-20% OF CRITICAL DAMPING AT RESONANCE ARE DESIRABLE. THIS VALUE SHOULD NOT BE AFFECTED BY ANY OPERATING ENVIRONMENTAL CHANGES SUCH AS PRESSURE, TEMPERATURE OR HUMIDITY. TO REDUCE THE TRANSMISSIBILITY TO A MINIMUM, THE DAMPING RATIO SHOULD DECREASE IN VALUE FOR A FREQUENCY RATIO GREATER THAN $\sqrt{2}$.

G. *Spring Design*

1. *General*

For a complete treatment of spring design refer to authoritative texts such as Wahl, "Mechanical Springs," and MIL-Std-29. The scope of this publication permits only an outline of the many factors involved in the design of helical springs.

2. *Fatigue*

A container in transit will be subjected to vibrations which will continually deflect its suspension system. When springs are subject to fatigue, the allowable stress used in their design, should be based on the endurance limit. This is the highest stress, or range of stress that can be repeated indefinitely without failure of the spring. Ten million cycles of deflection is generally accepted as an infinite life. The severity of service is listed below.

Light Service - Includes springs subjected only to static loads, having small deflections with low stress ranges. Subject to less than 1,000 and seldom more than 10,000 deflection cycles in a lifetime.

Average Service - Subject to average use without shock loading. One hundred thousand to one million deflection cycles in a lifetime.

Severe Service - Subject to rapid deflections over long periods of time. One million to ten million deflection cycles in a lifetime. When designing springs for severe service, the endurance limit should be used in the calculation of stress.

Safe working stresses will of course differ for each material; these values should be obtained from the manufacturer of the material or from a reliable text.

Fatigue simultaneous with even slight corrosion, is very effective in causing failure under comparatively small stresses. For example, spring steels subjected to stresses while in contact with fresh water fail at a stress range only 1/4 to 1/9 the normal endurance limit. The reason for such premature failure is that in a spring the torsional fiber stress is a maximum at the surface of the wire. Any surface defect accelerates the start of a crack which then continues through the wire causing complete failure.

Fatigue failures can be reduced by improving spring surface and by preventing corrosion of this surface. Shot-peening, which consists of propelling steel shot at high velocity against the spring surface, will improve this surface. This tends to increase the endurance strength by, a.) cold working the surface where the stress is highest and, b.) prestressing the surface layer under compression. As fatigue failures are due to tension stresses, superimposing compressive stresses where tension stresses occur enable the spring to carry a greater load.

Steel springs can be protected from corrosion by plating; however, the endurance limit will be reduced. Painting has been found unsuccessful for container springs. It is recommended that a thermally fused epoxy plastic coating be applied to steel springs to prevent corrosion. This process has been used with success on Nike Hercules containers. (See Rock Island Arsenal Purchase Description RIAPD-636 Coating Protective, Thermally Fused Epoxy Plastic.)

3. *Temperature*

Most common spring materials will perform satisfactorily at -65°F under static loads; however, often problems arise with the ability of a material to absorb impact loads at -65°F. Many materials become brittle at low temperatures with carbon steels showing a dramatic loss of impact strength at even moderately low temperatures (0°F). Nickel alloys will show little loss of impact strength at -65°F.

For compression and extension springs subjected to shear loads and stresses, the stress calculations will be based on the torsional properties of the material. The torsional modulus of elasticity, E_t, a factor in determining the relation between the load and deflection of a spring, will vary with temperature. As E_t increases, so does the spring stiffness. This variation is shown below for several spring materials.

TABLE 14

VARIATION OF TORSIONAL MODULUS OF ELASTICITY (E_t) WITH TEMPERATURE

Material	Temperature		
	$-100^{\circ}F$ (psi)	$0^{\circ}F$ (psi)	$+200^{\circ}F$ (psi)
Hard Drawn Steel	11,550,000	11,200,000	11,240,000
Si - Mn Steel	11,450,000	11,200,000	10,600,000
Chrome Vanadium Steel	11,400,000	11,250,000	10,600,000
Stainless Steel (18/8)	10,100,000	10,300,000	9,750,000
'Monel'	9,100,000	9,100,000	9,050,000

After the selection of a material has been made and using the information calculated in previous sections, the physical dimensions of the spring can be determined.

4. *Spring Dimensions*

The procedure followed in finding the spring dimensions is one of trial and error. An example utilizing the deflections and loads found in previous sections will illustrate this procedure. Choosing a material, a convenient outside diameter and estimating the wire diameter, we will find the free length of the spring required.

Given: Total deflection, S_t = 3.48 in.
Total load (includes impact and static load on one spring)
P = 2523 lb.

Select: Material - Chrome Vanadium Steel with $E_t = 11.5 \times 10^6$ psi
Outside coil diameter = 4 in.
Wire diameter, d = 0.625 in.
∴Mean coil diameter, D = 4-0.625 = 3.375 in.

To Find: Number of active coils, n; pitch, p; and free length, L.

Use Equations:

$$n = \frac{S_t\ E_t d^4}{8\ P\ D^3} \tag{17}$$

$$p = B + f + d \tag{18}$$

$$L = np + 2d \tag{19}$$

Solving for n:

$$n = \frac{S_t\ E_t d^4}{8P\ D^4}$$

$$n = \frac{(3.38)\ in\ (11.5 \times 10^6)\, lb.\ (0.625)^4 in^4}{(8)(2523)\ lb \qquad in^2\ (3.375)^3 in^3}$$

Number of active coils, n = 7.87

Solving for p:

$$p = B + f + d$$

Where:

p = pitch or lead of free or unloaded spring

B = the clearance space between each coil, in inches, when spring is supporting some load P. Calculate B by using 25% of the deflection per active coil.

f = deflection, in inches, per active coil for a given load P.

d = wire diameter in inches

$$p = \frac{(0.25)(3.48)in}{7.87} + \frac{3.48}{7.87} + 0.625\ in.$$

p = 1.17 in.

Solving for L:

The given formula is for springs with squared and ground ends. For springs with other type ends, consult a reliable text on spring design.

$$L = np + 2d \tag{20}$$

$$L = (7.87)(1.17)\ in + (2)(0.625)\ in$$

$$L = 10.46\ in.$$

These calculations provide a tentative spring design, if it does not fit the available space a new design can be found by choosing different values of wire diameter, outside diameter, material, etc. When a suitable size spring is found, the stresses developed from impact and fatigue loading must be checked.

The methods used for finding loading due to impact and fatigue, have been delineated in the preceding sections. Formulas which can be used for finding the stresses developed in springs follow in the next section.

5. *Calculation of Stresses*

The following equations can be used to find the stresses induced by impact and fatigue loading.

$$T_c = \frac{8PDK_w}{d^3} = \frac{SGdK_w}{D^2n} \tag{21}$$

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C} \tag{22}$$

$$C = \frac{D}{d} \tag{23}$$

Where:

P = load on spring

D = Mean coil diameter = Outside diameter - Wire diameter

d = Wire diameter

K_w = Wahl factor - Correction factor for curvature

n = Number of active coils in spring

C = Spring index

T_c = Corrected shear stress

With fatigue loading and a cyclic load variation between P_{max} and P_{min} the corrected shear stress range T_r can be calculated:

$$T_r = K_w 8 \frac{(P_{max} - P_{min})D}{d^3} \tag{24}$$

When designing for -65°F and severe impact and fatigue loading, spring design calculations consider lower stresses than would be used at ambient temperatures. Studies have indicated that a 25% to 30% reduction in published values for allowable stress, when designing steel springs, would be a reasonable figure to use under these conditions.

Where allowable stress values are given for statically loaded springs at ambient temperatures, the following allowances can be made.

a. Compression springs that are preset and shot-peened increase values 10 to 15%.

b. For extension springs reduce values 10 to 20%.

c. For suddenly applied loads, reduce values by 50%.

The *springs should also be checked for stresses* developed at *solid compression, eccentric loading, buckling, lateral loading, spring index, effects of vibrations* and *resonance*.

The above calculations are a simplification of the actual forces a container will undergo. The base mounted system illustrated represents the least complex application. However, troublesome coupled response can result because the center of gravity is above elastic center of the mounting system. Further calculations are necessary to fully describe the motions of this system.

The advantages and disadvantages of spring suspension systems for rocket and missile containers are listed in the following table.

TABLE 15
ADVANTAGES AND DISADVANTAGES OF SPRING SUSPENSION SYSTEMS

ADVANTAGES	DISADVANTAGES
Reliable.	Requires damping.
Not adversely affected by: Temperature, Oil, Water, Chemicals, Aging	Possible large amplitudes when passing thru resonance.
	Frequency of suspension system difficult to determine at right angles to springs.
Isolates low frequencies better than rubber.	Linear spring deflection rate.
Does not drift.	
Capable of providing identical protection in all directions.	

Spring suspension systems should be considered for:

1. Items having considerable weight, 250 pounds and up.

2. Items having low fragility factor, i.e. 10 - 20 g's, regardless of weight.

3. Items requiring chemically inert suspension systems.

4. Items requiring a high degree of triaxial protection. It is recommended that tension spring packages be used in such cases. See Figure 26 for photo, Mindlin, "Dynamics of Package Cushioning" for description of required calculations.

II. TORSION BARS

Torsion bar springs have found a wide number of uses in recent years; however, they are not recommended for missile container suspension systems for numerous reasons. A torsion bar is essentially a uniaxial spring; therefore, in order for it to provide the triaxial protection required in container designs the packaged item must be suspended from the torsion bar lever arms by cables or some other similar system (see Figure 37).

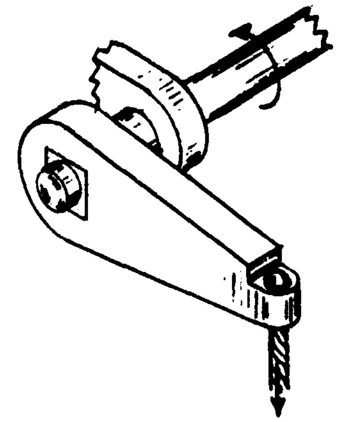


FIGURE 37. TORSION BAR-CABLE

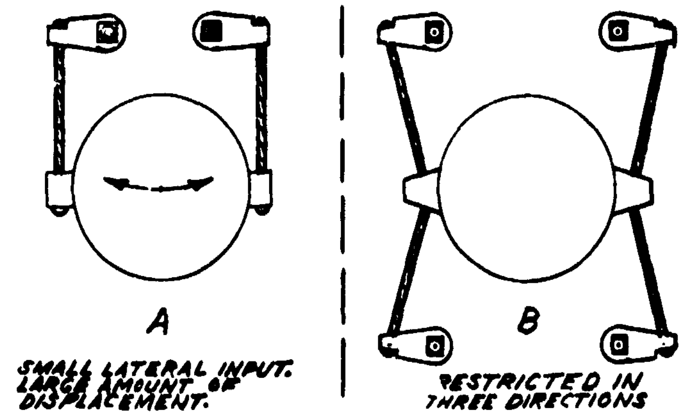


FIGURE 38. TYPICAL TORSION BAR-CABLE ARRANGEMENT

To properly restrain the item four (4) or more torsion bars are generally required (see Figure 38).

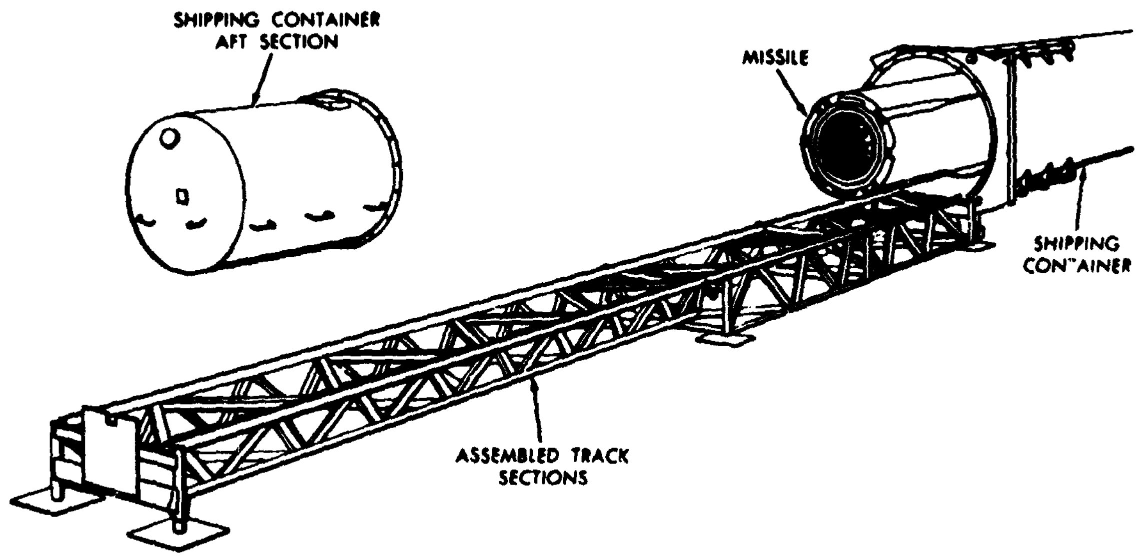
The arrangement illustrated in Figure 38-A does not easily lend itself to a top opening container, which is the preferred type of opening, excepting very small or very large containers (see Chapter VIII). If an end opening container is chosen, the item cannot be removed quickly.

Although a torsion bar is an efficient energy storing device it is an expensive one. It is also a potentially dangerous one should the bar break during presetting; proper safeguards must be provided for personnel.

No calculations for a torsion bar suspension system are given because of their complexity and limited application. See "Design and Manufacture of Torsion Bar Springs" by the S.A.E. for guidance in the design of torsion bars.

In spite of disadvantages a torsion bar suspension system has been used with success on the Corporal M351 Missile Body Container. The extreme size of the missile and the state-of-the-art of suspension systems at its time of design, made this system a logical choice. Figures 39 through 44 illustrate the M351 container and its suspension system.

There are eight cables attached to the missile which lead from eight torsion bars in cylinders located on the exterior of the container. Each torsion bar is twisted initially 40 to 60 degrees to provide a preload in excess of 30,000 inch pounds. Although this system works well, it is difficult to connect the cables to the missile inside the container, especially at the closed end where it is necessary to work through access holes.



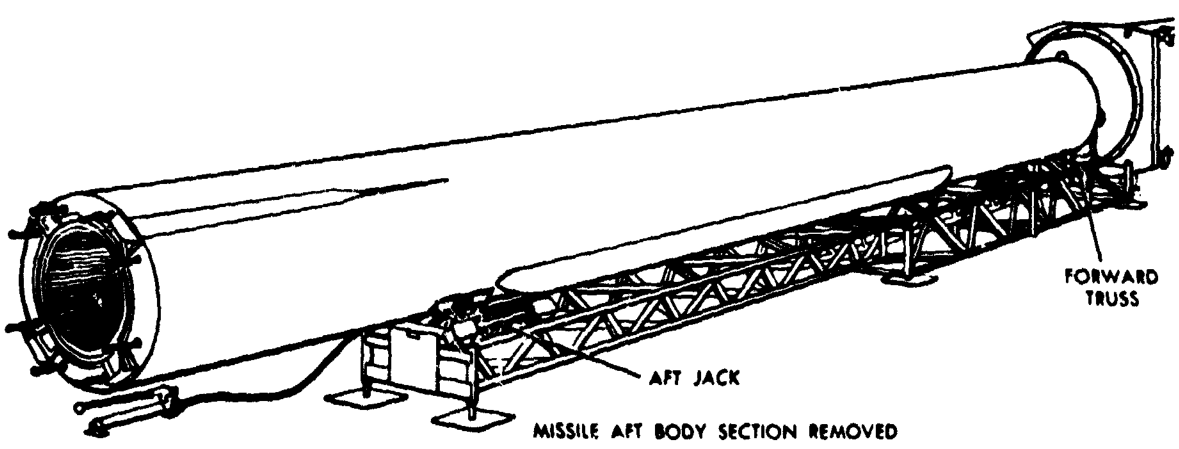


FIGURE 39. CORPORAL CONTAINER TRACK SECTIONS

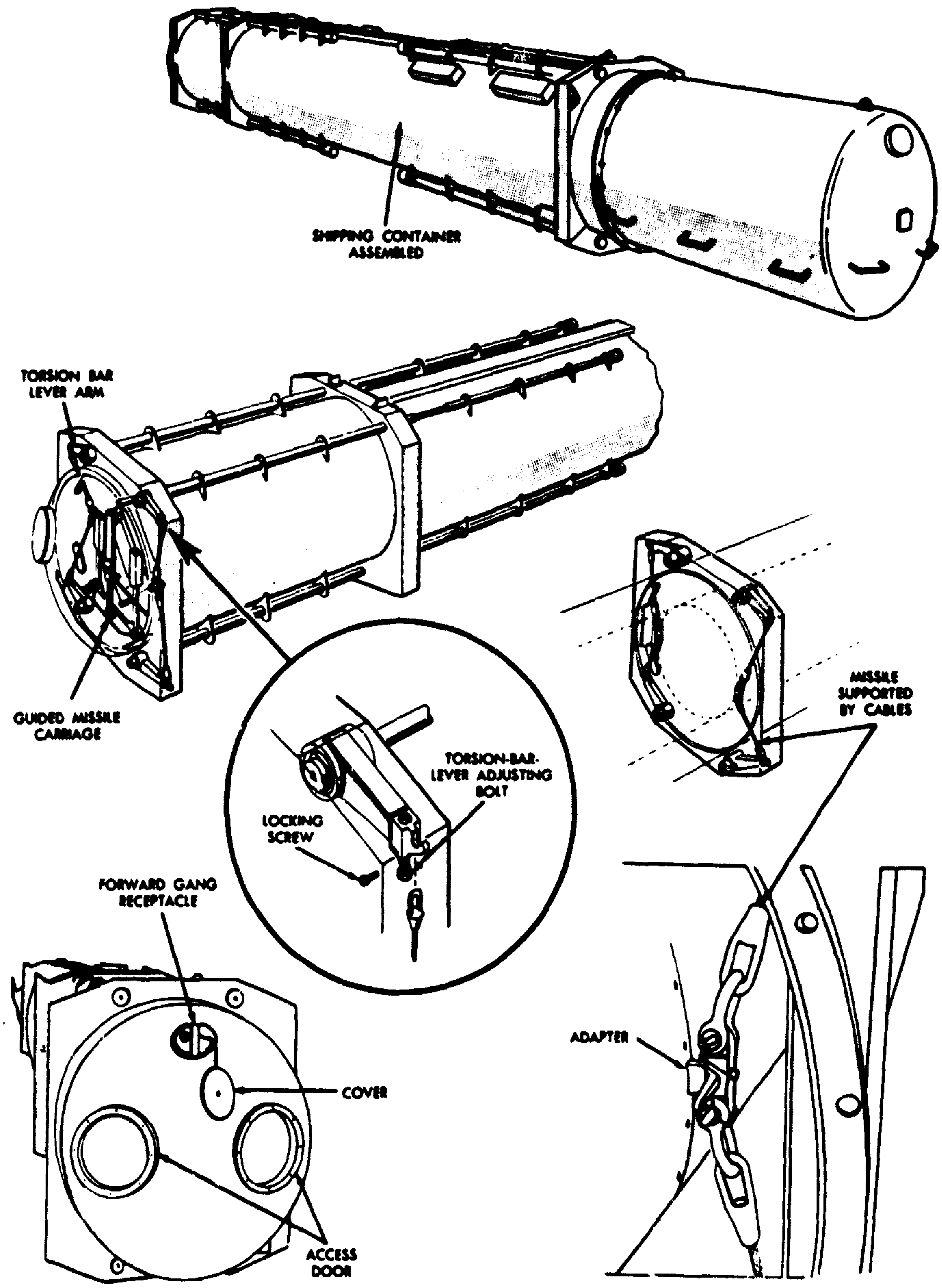
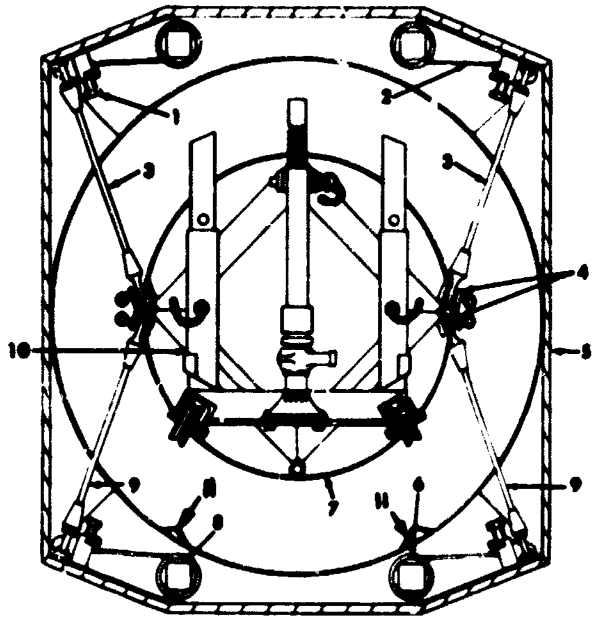
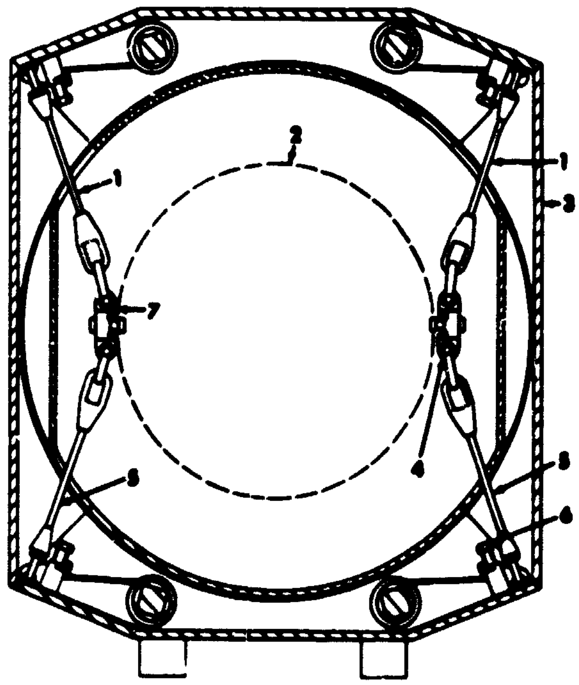


FIGURE 40. CORPORAL MISSILE SHIPPING CONTAINER - PARTIALLY EXPLODED VIEW



1-Adjusting screw
2-Torsion bar lever
3-Wire rope
4-Shackles
5-Container(stiffener)
6-Torsion bar bearing
7-Missile
8-Torsion bar
9-Wire rope
10-Carriage assembly
11-Rails

FIGURE 41. FORWARD SUSPENSION SYSTEM AND CARRIAGE ASSEMBLY



1-Wire Rope
2-Missile
3-Container
4-Shackle
5-Wire rope
6-Adjusting bolt
7-Adapter

FIGURE 42. AFT SUSPENSION SYSTEM

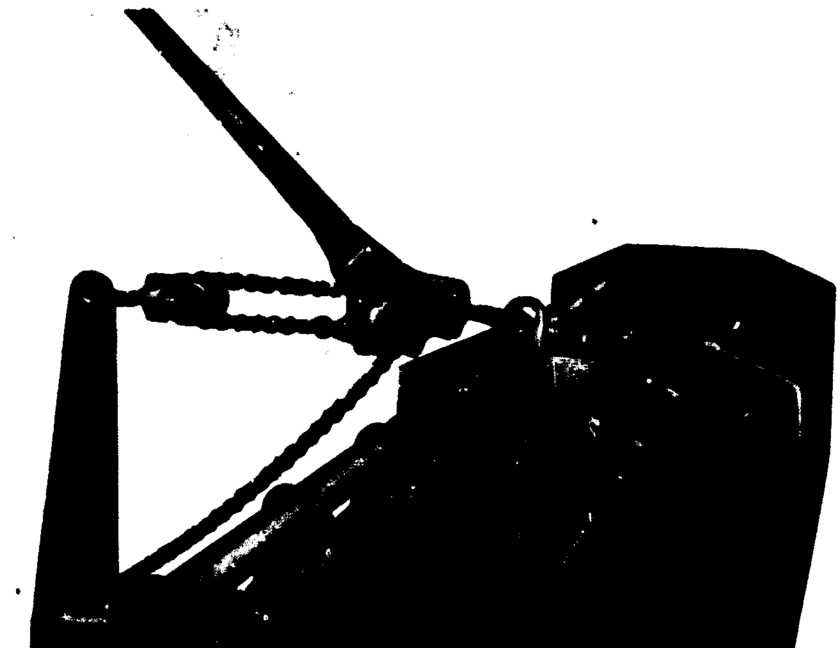


FIGURE 43. APPLYING PRELOAD TENSION TO TORSION BARS

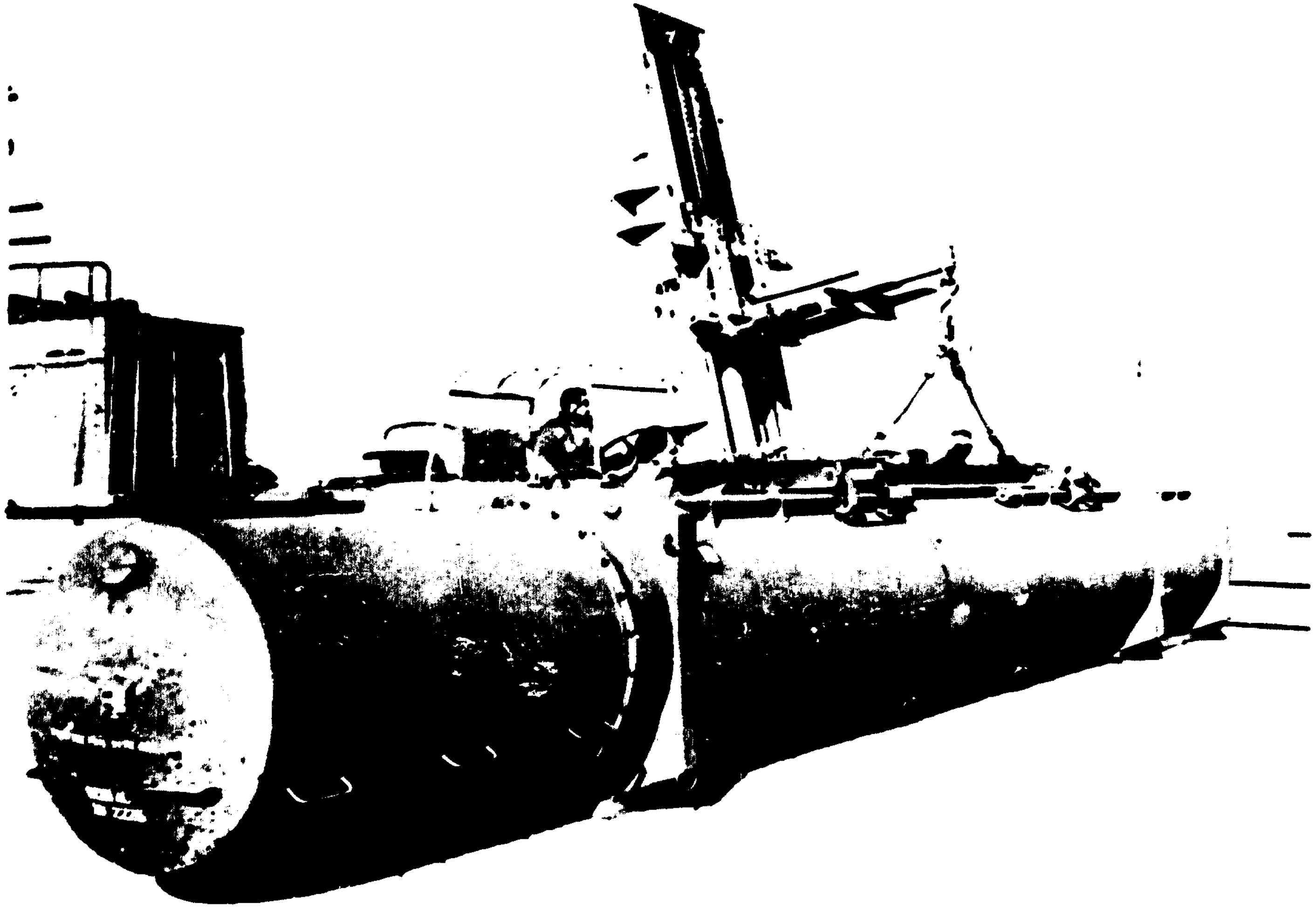


FIGURE 44. CORPORAL M351 MISSILE BODY CONTAINER

III. OTHER TYPES OF MECHANICAL SUSPENSION SYSTEMS

A. *Cable Isolators*

A relatively new type of suspension system is one employing stranded steel cable interlaced between two metal retainer strips. One end of the assembly is attached to the item and the other to the supporting structure. An assembled pair of these isolators will provide triaxial shock and vibration protection to the item.

Suspension systems commonly include four cable isolator assemblies which can be attached to the item at the corners, sides, top or bottom in order to provide equal isolation in all directions. Figure 45 illustrates some typical cable isolator systems.

Cable isolators can provide shock and vibration protection in all directions with an equal spring rate which can be easily varied. The spring rate is nonlinear. The natural frequency which is normally in the 15 to 20 cps range can also be easily shifted.

B. *Single Use Energy Dissipators*

Single-shot, sheet-type energy dissipators having mechanical properties similar to those of paper honeycomb find their use in the control of accelerations during an air drop impact. This type of suspension system is not recommended where repeated shock loads must be attenuated.

A complete dissertation on this subject will be found in "Design of Cushioning Systems for Air Drop," by Maurice P. Gionfriddo, published by Quartermaster Research and Engineering Command, U. S. Army, Natick, Mass, October 1961. Because of the thoroughness of Mr. Gionfriddo's study this subject will not be further discussed here.

C. *"S"-Type Jarret Mountings*

Jarret-type mountings consist basically of a steel tube in the shape of the letter "S" with locating pads top and bottom. The tube is filled with compressed elastomer. It operates without any solid friction using the internal flow of the elastomer as a damping medium. They should normally be used only in compression, as tensile forces might cause fracture of the metallic envelope containing the elastomer. Because of its design the Jarret "S"-type spring is essentially a unidirectional mounting. They are generally used as antivibration mountings. Figure 46 illustrates Jarret "S"-type springs.

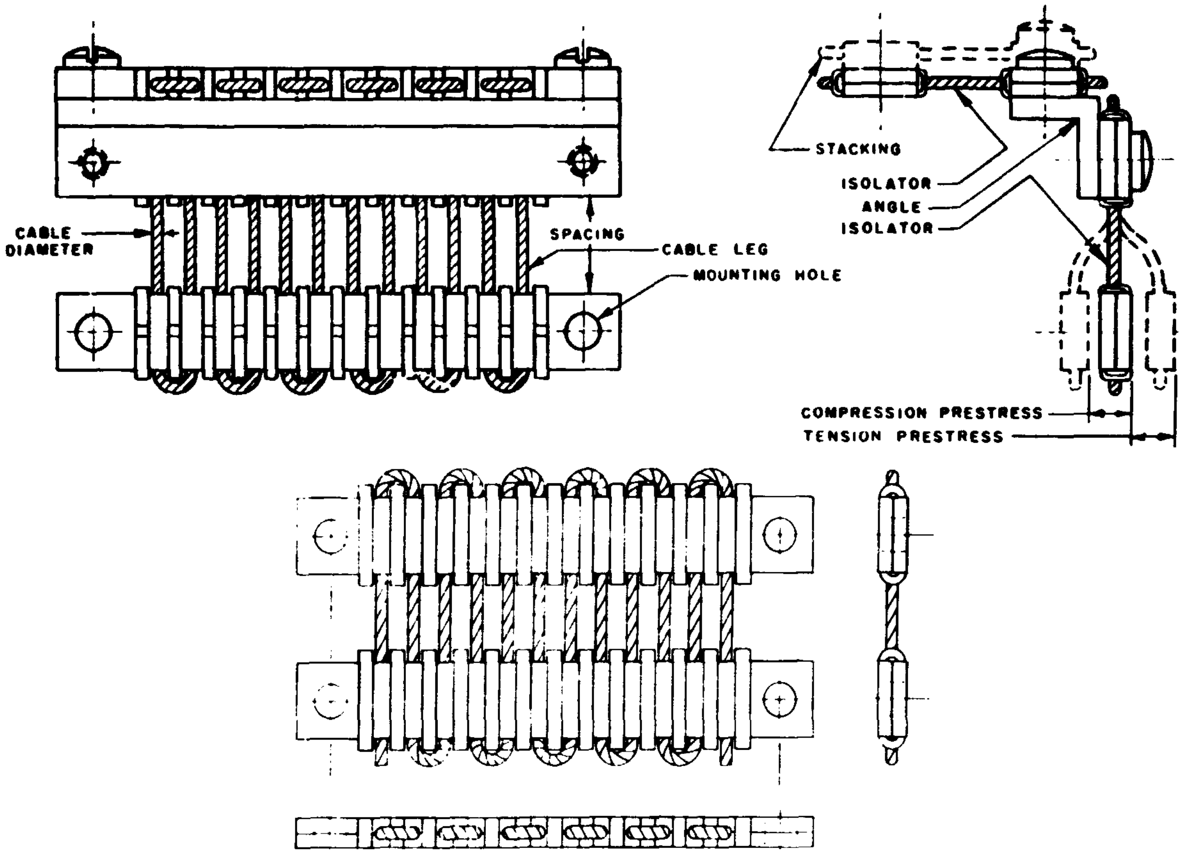


FIGURE 45. CABLE ISOLATOR ASSEMBLIES IN TWO TYPICAL MOUNTING ATTITUDES

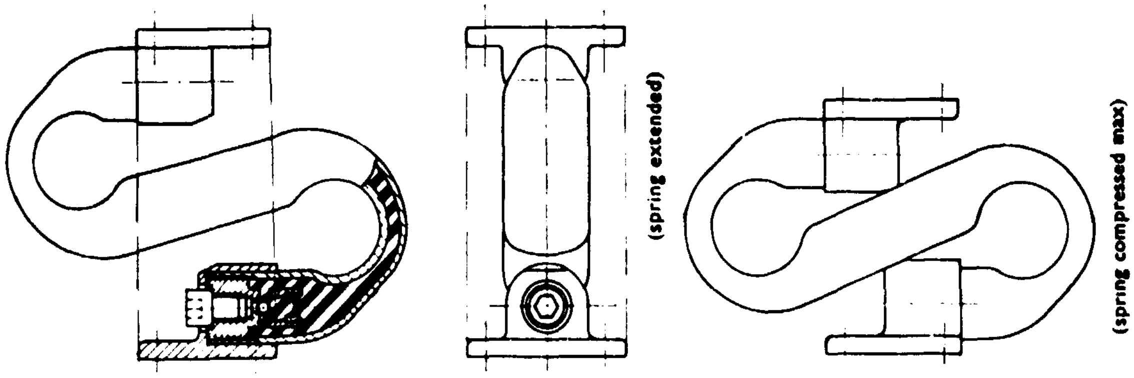


FIGURE 46. JARRET "S" - TYPE MOUNTING

THIS TYPE OF MOUNTING IS AVAILABLE COMMERCIALLY IN THE FOLLOWING LOAD RANGES:

VERTICAL	TRANSVERSE	LONGITUDINAL
20 to 18,000 lb.	15 to 14,000 lb.	15 to 10,000 lb.

Deflections are 1 to 2 inches

CHAPTER VI

ELASTOMERIC SUSPENSIONS

INTRODUCTION

Elastomeric, shear type sandwich mounts were first developed during World War II to protect aircraft engines. As more fragile and sophisticated weaponry was introduced, the need for protecting these mechanisms became critical. The favorable performance of elastomeric mounts led to their wide acceptance and use in the field of protective packaging and container suspension engineering.

The elastomeric mount offered several advantages. The shear configuration provided sufficient travel to mitigate high shock inputs; it provided equal protection in two planes; its configuration was simple and compact and the cost to install was low. Shear mounts have a proven record of reliability; they resist handling abuse and adapt to equipment complexity.

During the past two decades, the impetus in container development has made available a wide assortment of shear mounts, each of which has been specifically tailored to the peculiar requirements of its application.

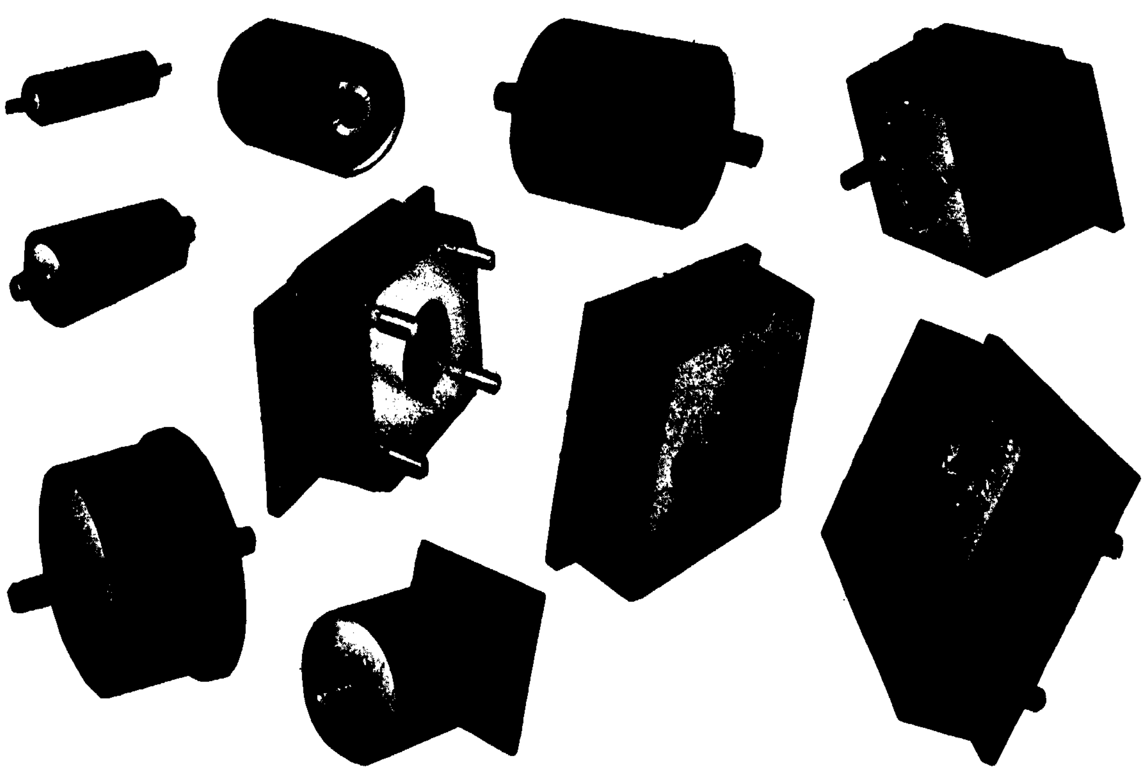


FIGURE 47. SHEAR MOUNTINGS - SANDWICH CONSTRUCTION

Unfortunately, the design technique applied in the development of shear mounts has not been documented nor has the data generated by this effort been consolidated. Consequently, the state-of-the-art is such that each and every application must be analyzed and a mount tailored to satisfy its particular demands. It is probable that an existing design may be identified as capable of satisfying the requirements of a proposed application; however, the performance and physical characteristics of these existing mounts has never been consolidated and the data is not available to provide the container designer with these basic tools to permit general application.

Existing designs encompass a spring rate range of from 10 to 5000 pounds per inch and dynamic shear deflection capabilities up to 22 inches. Figure 48 illustrates the deflection capability of elastomeric sandwich mounts.

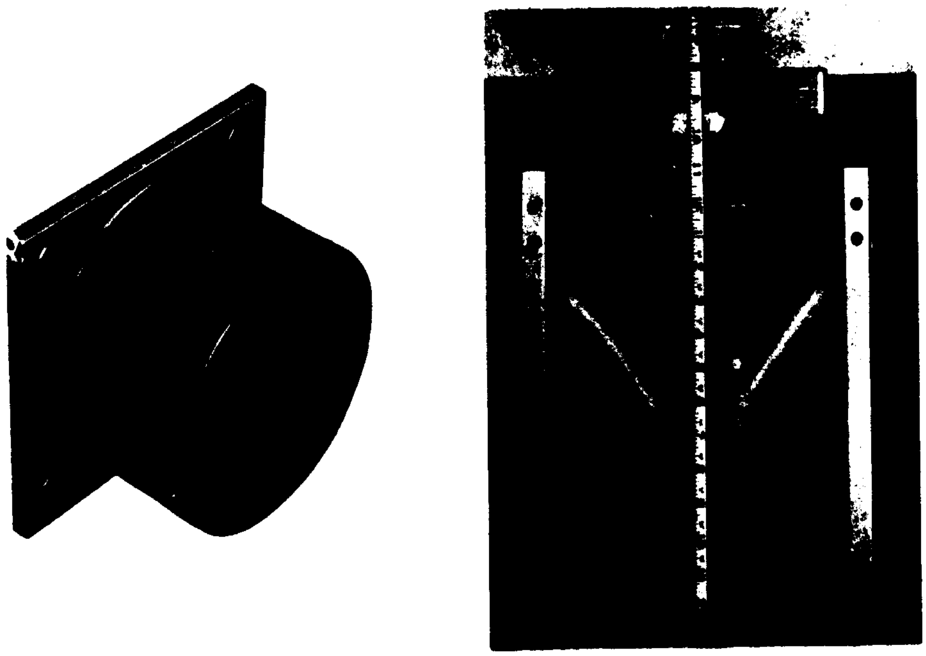


FIGURE 48. ELASTOMERIC MOUNT SHOWN ON LEFT. AT RIGHT, A TEST DEMONSTRATES LARGE DEFLECTION CAPABILITY AND HIGH STRENGTH BOND OF ELASTOMERIC MOUNTINGS

The characteristic of sandwich shear mounts to provide linear displacement and the ability to provide large deflections permit wide design latitude. Shear mounts function to minimize the acceleration of the mounted mass while absorbing and dissipating large amounts of energy introduced by the operating environment. The favorable characteristic of the elastomeric shear mount is graphically depicted in the load deflection curve of Figure 49. This curve is typical of elastomeric mounts in general; however, for a specific mount, the particular performance curve must be developed by test, or provided by the manufacturer.

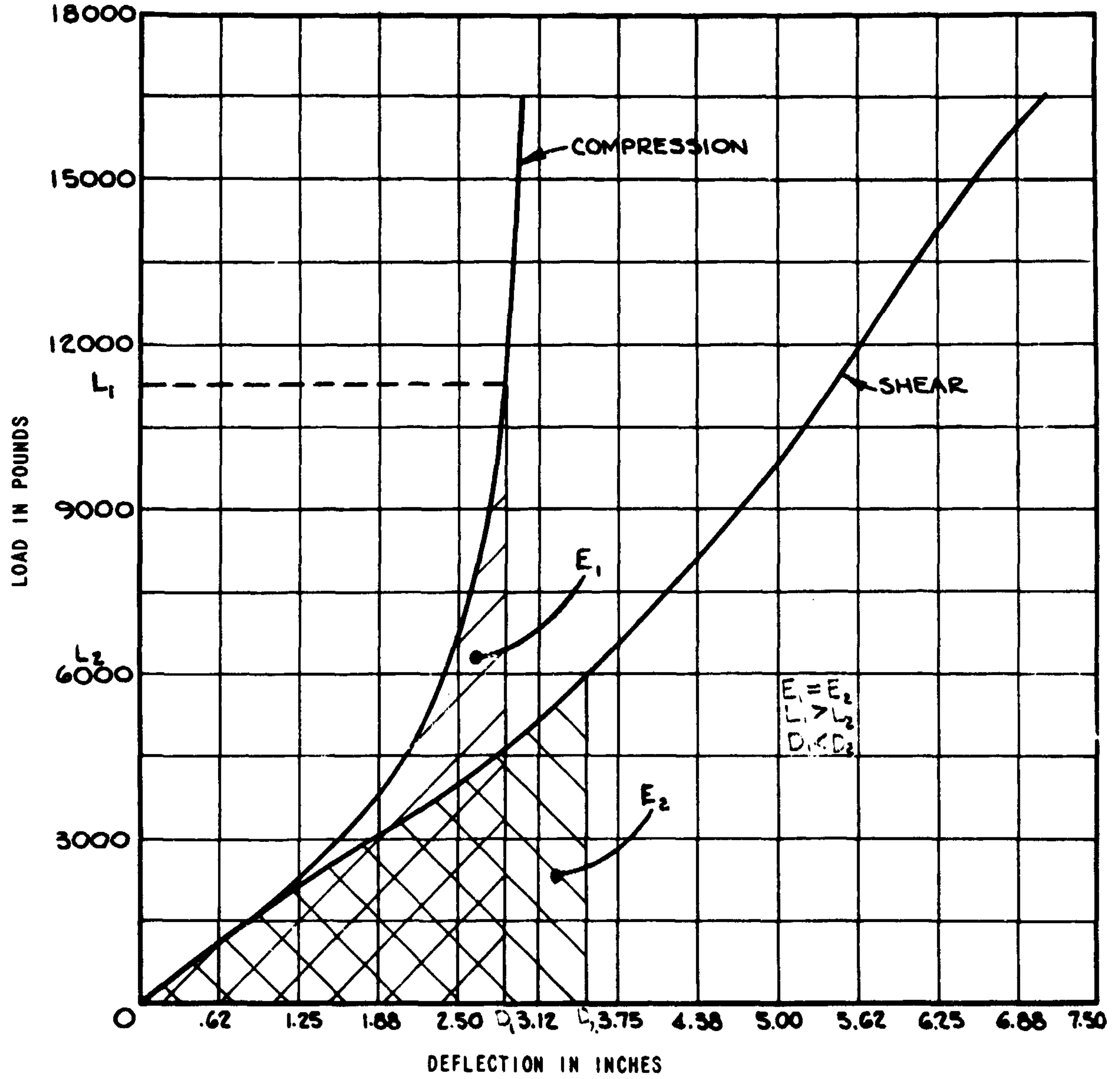


FIGURE 49. TYPICAL LOAD DEFLECTION CURVE FOR ELASTOMERIC MOUNTS

The area below the load deflection curve is representative of the capacity for energy absorption. The area under the compression curve E_1 is equal to the area under the shear curve E_2. It can be seen that the load and therefore the force needed to develop equal energy absorption is much higher for the compression mounting than for the shear mounting. For this reason the shear mount with a nearly linear load deflection curve, is more efficient than the compression mount whose performance follows a more expotential path.

In addition to the favorable performance cited, many elastomeric mounts usually provide inherent vibration damping characteristics and may, under certain conditions, obviate the need for additional auxiliary damping devices. There are also an assortment of elastomers available which will satisfy the temperature range requirements of the "worldwide distribution" environment.

A review of military containers demonstrates the technical feasibility of shear mount suspension systems. Economic feasibility is generally limited to reusable containers or those subject to selective salvage (see Chapter VIII).

GENERAL

The preferred approach in the process of container design is to develop the suspension system first. When the sway space, as determined by the required spatial displacement has been calculated; the proper mounts have been selected and their location established; then, the container can be designed.

Unfortunately, the present state-of-the-art does not provide sufficient data to permit the designer to make a mount selection. Consequently, elastomeric shear mounts cannot be considered as standard off-the-shelf hardware; they must be tailored to the application by the mount supplier.. As inconvenient as this may be, the designer must resort to this procedure; he must consult and collaborate with the mount supplier in the selection of a suitable shear mount suspension. As application data are not available, this design guide can only provide a suggested approach to the problem; one which will result in expeditious resolution of the mount selection. The designer must however, retain control of all aspects of design and/or application and not permit the supplier to introduce characteristics or restrictions favoring one product or source of supply. As the result of this necessary marriage-of-convenience between the container designer and the mount supplier the initiating agency should request and expect from the mount supplier assurance and certification of performance.

Mount Design

As previously mentioned, the design and/or selection of a particular shear mount must be the result of collaboration with the mount supplier. The container designer must orient the mount supplier in the details of the proposed application and provide sufficient data to permit for a comprehensive analysis and subsequent mount recommendation.

The many factors affecting mount performance cannot be mathematically expressed in any simple or series of simple formulae. The design and application of elastomeric shear mounts has yet to attain the status of a pure technology and the technique involved cannot be conveniently conveyed. Until this deficiency has been satisfied by the development of a practical analytical design procedure the selection and/or design of a specific shear mount must remain within the domain of specialists, usually found in the employ of mount suppliers.

Problem Definition

Consequently the container designer must establish the performance criteria and convey these data to the mount supplier early in the program to expedite the container development. The information required by the mount supplier is tabulated below and should be as complete and accurate as possible:

a. Identification and description of the item to be protected. (The name and description of the item are important since they provide a reference designation for the particular application and give the suspension system designer an idea of what he is working on.)

b. Weight of the item.

c. Weight of the cradle or fixture used to support the item.

d. A sketch of the item showing overall envelope dimensions; permissible points of attachment or support; and the center of gravity. (The purpose of b, c, and d is to establish the total suspended weight or the weight the mountings will support. It has been found desirable to list the weight of the cradle separately to bring attention to it, since cradle weight is frequently ignored. A sketch of the unit, the attachment points, and the location of the center of gravity are all necessary to establish the reaction load on each of the mountings; however, when cradles are used, it is not necessary to restrict the location of the mountings to the attachment points. Also, if there is a reason why the mountings should be located in one particular place, this should be noted, since it will influence the selection of the mountings.)

e. The fragility factor of the item and the temperature, direction and location at which it shall be measured and/or tested. (Fragility factor information is frequently passed over without enough consideration. Since some of the container applications require protection down to -65°F and others require protection to room temperature conditions only, it is important to know the temperature at which the G load will be measured. Some units also have different fragility levels or different axes for directions of impact. When subjecting the unit to an edgewise rotational drop test, it is important to know where on the unit the G's will be measured.)

f. The shock imposed upon the item; the type of drop and drop height or the magnitude of G input; and the pulse time and its shape. (If the shock input is expressed in terms of G's, it is essential that the time duration of the pulse and the pulse shape be included, since G's input by itself does not define the amount of energy going into the container.)

g. The testing procedure, the number of drops, and the temperature at which testing will be conducted. (The above requests a definition of the testing procedure, since on occasion the number of drops and the temperatures at which the drops are conducted will actually represent a fatigue test that will control the selection of the mountings.)

h. The vibration inputs imposed upon the test item. (Some military specifications include vibration test and resonant dwell requirements that exceed the normal mounting requirements of the shock protection--in other words, the mountings are selected primarily to meet the vibration test requirements, since the vibration tests are more severe than the shock protection requirements. The allowable vibration output or the vibration tolerance of the unit is frequently different than the fragility factor, since the fragility factor applies to a shock input whereas the vibration tolerance will refer to the ability of the unit to withstand a steady state vibration. This information is not generally available and can be quite complicated, since the vibration tolerance would have to be defined in G's as well as in frequency in most instances.)

i. The allowable vibration limits to be experienced by the suspended item.

j. The normal shipping attitude of the item.

k. The moment of inertia of the protected item. (Moment of inertia data is important if the shock requirements include an edgewise rotational drop or end impact testing. If this form of testing is included, moment of inertia data is essential and must be approximated before an analysis can be made.)

l. The moment of inertia of the cradle support. (This can have the same affect as the weight of the cradle, as far as distorting the actual suspended weight. Mounting space limitations are important if the designer wishes to limit the thickness or width into which the mounting must be installed. This applies especially in cases where an existing container is being used for new applications. The container dimensions, as requested in question p, would apply in those instances where an existing container is being used.)

m. Applicable restrictions peculiar to the item or the application.

n. A description of the transit environment.

o. A description of the climatic environment affecting mount performance.

p. Description of the container and its dimensions.

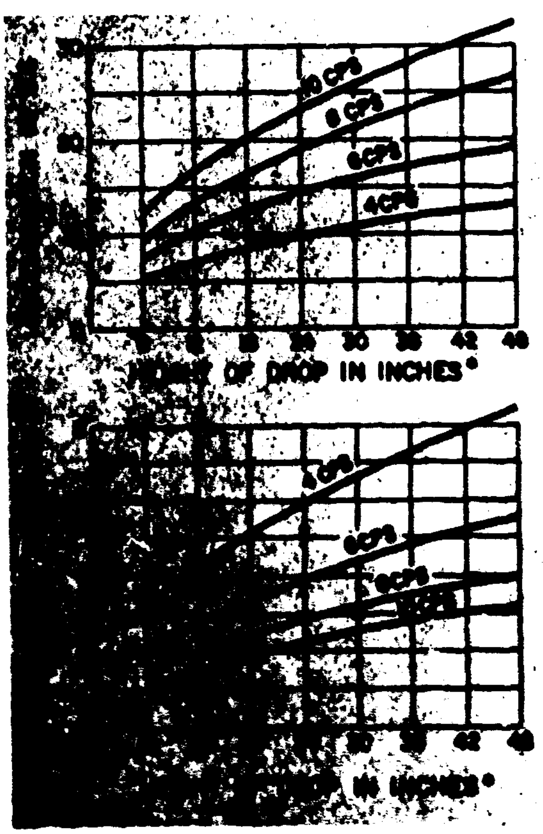
q. Special testing requirements.

r. Other pertinent data.

Preliminary Design

Having defined the problem and submitted the required data to the mount supplier, the container designer may proceed to apply several rules of thumb to provide an indication as to the size of the container and the affect the suspension system will have on the container design. All "ball-park" figures generated by these rules-of-thumb shall be modified upon receipt of specific data and recommendations from the mount supplier.

The following data sets forth very useful information concerning the relationship between drop height, natural frequency, acceleration, and deflection. The designer can determine, simply on the basis of drop height and fragility factor, what natural frequency the system will have and approximately how much deflection will result from the drop tests. By adding an inch or two to the deflection figure, the designer can approximate the sway space between the unit and the inside of the container and, thus, the size of the container.



* adjusted to include deflection across mountings

DESIGN GUIDE

This useful guide has been developed by Lord* to show the relationship of drop height (h), deflection (d), fragility factor (G_m) and natural frequency of a suspension system (f_n).

Designers and packaging engineers will find this guide valuable in two ways.

1. *Gain a rapid understanding of the factors involved in a suspension system.*

For example, note that G and d are inversely proportional; as the fragility factor is lowered, larger deflections must be provided. And d determines the sway space that must be provided within the container.

The guide also shows whether the proposed system has compatible shock and vibration requirements. Certain G_m limits will place the f_n in the critical 2 to 7 c.p.s. range. In this instance, either a stiffer suspension must be adopted (which raises the G_m limits), a lower drop height must be accepted or damping must be introduced to control motion under the resonant conditions.

2. *Get a quick approximation of h, d, G_m and f_n.*

The guide permits you to:

a) find f_n and d when h and G_m are known. This is the usual case since most specifications call out the drop height and G_m limits.

b) find G_m for various suspension stiffnesses (expressed as f_n) after assuming h. Stiffness affects d and ultimate choice of mounting.

c) find h when you know G_m by assuming f_n.

d) find h for various f_n when you know d. This is the case when it is necessary to use an existing container. The available sway space determines the maximum permissible d. Note that h will be limited by the G_m which the equipment can withstand.

*Lord Mfg. Co.-Erie, Pa.

FIGURE 50. RELATIONSHIP OF DROP HEIGHT, DEFLECTION, FRAGILITY FACTOR AND NATURAL FREQUENCY OF A SUSPENSION SYSTEM

Various factors affect the design of a shipping container mounting system: shock requirements, natural frequency, size, stability and others. To arrive at a practical system, these must be balanced. If shock requirements will permit, the natural frequency should be higher than 7 cps.

Sample Problem: Selection of mountings

An object 36" long x 24" wide x 15" high, weighing 125 pounds must be protected against a 30" flat drop. Its center of gravity is at its geometric center. There are a number of convenient attaching points along its lower sides on the long axis. Its fragility factor is 25 G.

Using this information, the first step is to determine the spring rate (K) and deflection (d) of a suitable mounting system.

The following formula is used:

$$d = \frac{2h}{G - 2}$$

Deflection of the mounting system would be:

$$d = \frac{2x30}{25 - 2} = 2.6 \text{ inches}$$

(For ball-park figure of sway space required, add 2".)

NOTE: The calculations shown here are simplified for purposes of clarity. In order to design and select a mounting system that is satisfactory for all conditions, end impacts, side drops, end drops, rollover tests and natural frequencies in all modes must also be considered (see Chapter I).

Mount Location

Having established an approximate value for the required sway space the designer may then approximate the dimensions of the container. The internal dimensions of the container must provide for the unrestricted movement of the suspended item. The sway space or amount of clearance shall be provided both below and above the suspended mass and at both ends to provide for both deflection and rebound experienced when subjected to shock loading.

The following rules are applicable and are provided as guidance in the development of the concept and subsequent design of the container.

The mounts should be placed as far apart as practical for stability. The center-to-center spacing of the mountings in the lateral direction should be about three times or more the distance the center of gravity is about the mounting plane. This dimensional relationship will generally avoid serious coupling problems that result in instability. In the longitudinal direction, the spacing of the mounting should be about five times or greater the distance of the center of gravity above the mounting plane. In all cases, the mountings should be spread as far apart as possible, as mentioned previously. There are installations in which the above rules cannot be applied; however, special attention must be given to the applications to be sure the coupled natural frequencies will not cause a vibration problem.

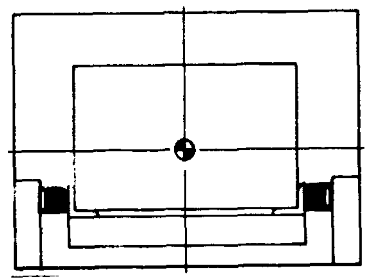


FIGURE 51. LATERAL VIEW OF TYPICAL SUSPENSION SYSTEM

In the plan view, the mounts should be symmetrical with respect to the center of gravity, or, if this is not possible, the mountings should be selected and located so they will have the same static deflection. It is conceivable that the mountings would also have to be selected in different sizes to produce the same stress on each mounting. Generally speaking, however, it is possible to locate the mountings symmetrically about the center of gravity to avoid using two different types of mountings in the same container.

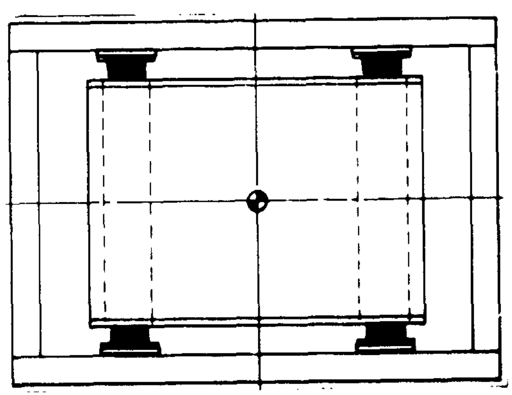


FIGURE 52. PLAN VIEW OF TYPICAL SUSPENSION SYSTEM

When multiples of mountings are used, they should be clustered at the extremities of the unit in preference to spacing them along the structure.

This technique will avoid an excessively low natural frequency in the pitch mode.

Be sure to avoid interferences that will contact the mountings when they deflect and either abrade them or possibly tear them.

Allow several inches of sway space on all sides as well as the top and bottom of the mounted unit. The amount of such space depends on the size and shape of the equipment and on the rough handling anticipated.

Mount Orientation

Conventional shear mount applications position the assembly with its shear plane vertical, at right angles to and parallel with the longitudinal axis of the suspended item to be protected. In this position, shear mounts provide excellent protection in both the vertical and longitudinal directions.

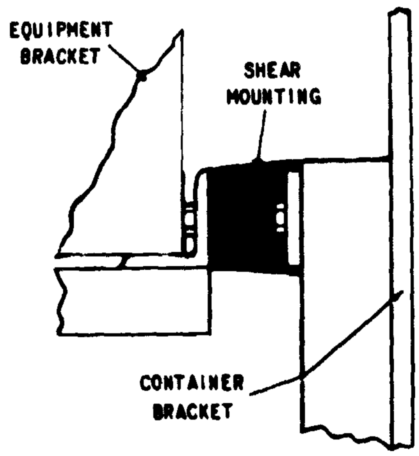


FIGURE 53. CONVENTIONAL SHEAR MOUNT ORIENTATION

Side drops subject the conventional suspension scheme to compressive forces negating the excellent shear performance of sandwich mounts. Due to their physical configuration and inability to provide any appreciable compressive deflection, the shear mount can be considered to provide little or no shock mitigation when subjected to compressive loading. However, the logistic environment normally subjects the container to vertical and longitudinal impacts; lateral impact loading is most infrequent. The usual configuration of the container and its normal shipping attitude preclude the necessity for maximum lateral protection as the container will either roll or tip-over transmitting to the suspended mass only a fraction of the imposed shock of impact. Suspension system design technique usually positions the shear mounts below the center of gravity of the suspended load introducing a couple which functions to further mitigate the effects of the imposed shock.

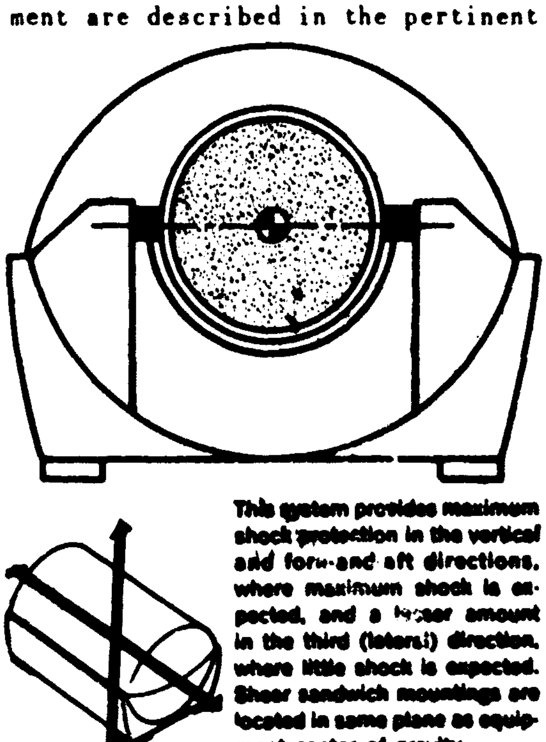
In considering the location of the elastomeric mountings, it should be noted that a typical missile container system may have two pairs of shock and vibration isolators spaced symmetrically about the spring mass center of gravity in side elevation. With a symmetrical spacing of isolators, the spring rate for each can be the same. The longitudinal spacing of isolators is based on pitching frequencies and on deflection of the isolators. The further apart the isolators are longitudinally, the greater the pitching frequencies and the larger the deflection of the isolators for a given acceleration.

Since isolators have a definite deflection range, such range often dictates the longitudinal spacing of the isolators.

The spring rate for each pair of isolators in a system need not be the same provided their static deflections are the same. In a system where the missile attachment points are such that the missile can be made to work structurally, as a link in the suspension system, a simpler system results with the elimination of longitudinal rails and the use of two pairs of isolators which have different spring rates.

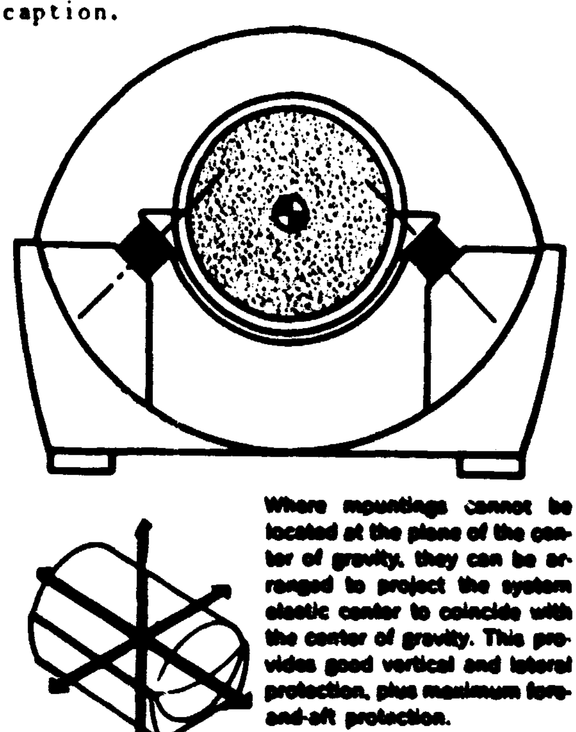
Suspension Schemes

The position of sandwich mounts and their location with respect to the center of gravity of the suspended mass can either enhance or degrade the performance of the suspension system. Common suspension schemes are depicted in the following illustrations; the advantages of each arrangement are described in the pertinent caption.



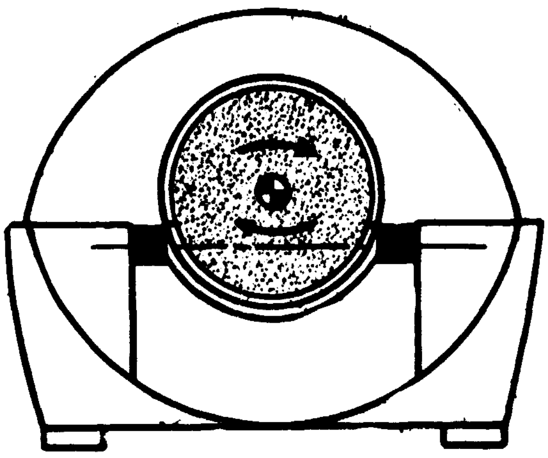
This system provides maximum shock protection in the vertical and fore-and-aft directions, where maximum shock is expected, and a lesser amount in the third (lateral) direction, where little shock is expected. Shear sandwich mountings are located in same plane as equipment center of gravity.

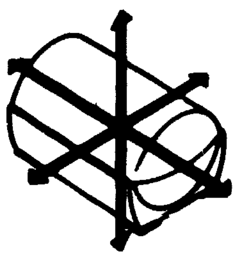
FIGURE 54. VERTICAL SYSTEM



Where mountings cannot be located at the plane of the center of gravity, they can be arranged to project the system elastic center to coincide with the center of gravity. This provides good vertical and lateral protection, plus maximum fore-and-aft protection.

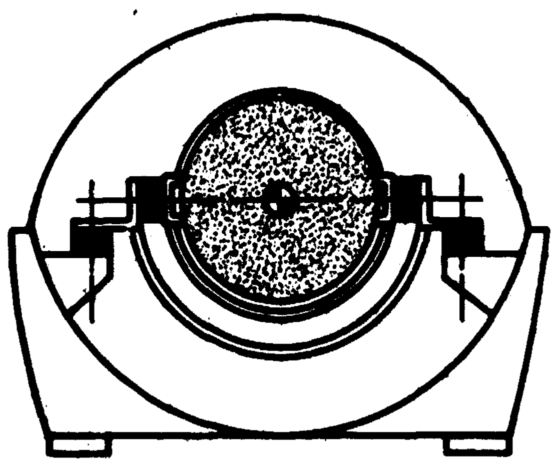
FIGURE 55. FOCALIZED SYSTEM

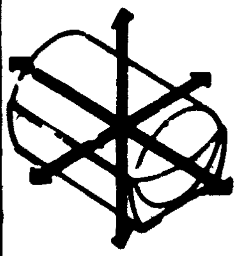




Protection in 3 directions can also be achieved by locating the mountings in a plane below the center of gravity so that lateral inputs will result in controlled rotation of the unit about its elastic center. This provides good lateral protection plus maximum vertical and fore-and-aft protection.

FIGURE 56. 3 - DIRECTION SYSTEM





(RARELY USED)

This type of system provides the needed protection in all directions for equipment that has low fragility factors along the 3 principal axes, and is susceptible to maximum shock along these same axes. The arrangement uses 2 shear sandwich mountings at each attachment point at right angles to provide large deflection capabilities vertically, fore-and-aft, and laterally. This assures maximum all-attitude protection.

FIGURE 57. GIMBAL SYSTEM

OTHER AVAILABLE ELASTOMERIC MOUNTS

typical system design alternatives

Where extremely unusual requirements exist, such as severe space limitations or exceptionally low fragility factors, other elastomeric mounting designs may be employed:

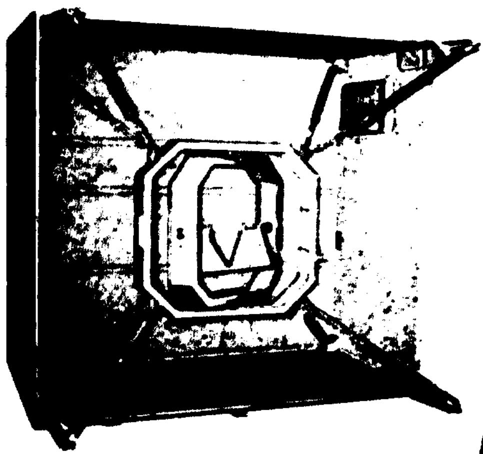


FIGURE 58. SPECIAL ALL-ATTITUDE SYSTEM

This 8-corner mounting arrangement combines the principle of rubber-in-shear with tension and compression. It is especially effective for ultra-sensitive equipment, provides low fragility protection, withstands severe abuse, and insures all-attitude protection.

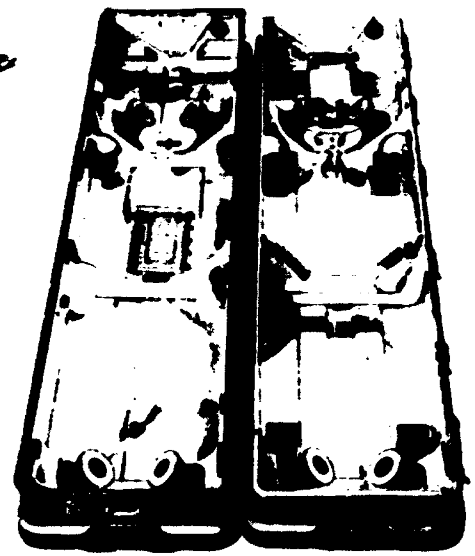


FIGURE 59. BUCKLING COLUMN SYSTEM

Systems incorporating the buckling column principle of shock control may be used for maximum protection with minimum deflection and sway space inside the container. Under shock, the elastomeric section buckles and provides high energy absorption for a given deflection.

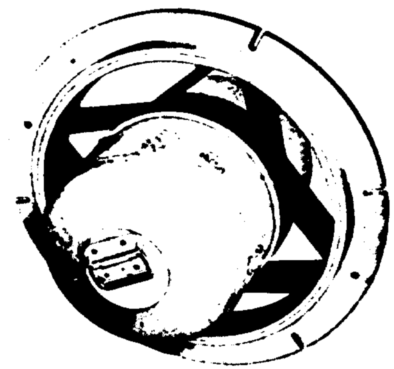


FIGURE 60. ELASTOMERIC RING MOUNTING

This unit is a special adaptation of the buckling column principle. The design is suitable for cylindrical objects of any diameter, and provides approximately equal protection in all directions.

NOTE: The information contained in this chapter is based on data furnished by Lord Manufacturing Co., Erie, Pennsylvania.

CHAPTER VII

BULK CUSHIONING

INTRODUCTION

The object of this chapter is to provide an orderly, concise cushioning design procedure for the solution of bulk cushioning problems. The material included was drawn in large part from "*Design Criteria for Plastic Package-Cushioning Materials*," Picatinny Arsenal and "*Package Cushioning Design Handbook*," Air Force Packaging Laboratory, Brookley Air Force Base, Alabama. The content of these reports has been adapted and expanded where necessary to meet the needs of Army Rocket and Missile Containers.

Discussed are the more common cushioning materials such as rubberized hair, urethane foam, foamed polystyrene, foamed polyethylene and fibrous glass.

Recent investigations have produced sufficient data to enable the packaging designer to estimate cushioning requirements in most problems with reasonable accuracy. However, some aspects of cushioning design are still too intangible for practical solution by analytical methods. Therefore, efficient cushioning design requires a blend of both scientific design principles and data, together with a liberal amount of sound judgment.

To facilitate cushioning design on both a scientific and practical basis, this document presents a discussion of the available analytical data and practical considerations that must be understood and used by the package designer in solving cushioning problems.

GENERAL

Progress in materials research has made available to the packaging engineer an assortment of bulk cushion materials having favorable protective properties. These have virtually replaced the classic excelsior, shredded paper and sawdust.

Due to the nature of these new materials and the many factors affecting their performance, it is practically impossible to correlate their characteristics into one mathematical expression capable of general application. Consequently, the application becomes quasi-scientific and the analytical designs must be subsequently subjected to laboratory test to verify the calculated performance.

Bulk cushion functions to allow the item being protected to continue its motion after the container has halted; gradually decelerating the motion of the contained item. The depth of the cushion pad and the compressive characteristics of the cushioning material determine the amount of shock to which the item will be subjected. The material's resistance to compression determines the rate of deceleration of the item within the container and the thickness of the pad is determined by the distance through which the item must decelerate before coming to rest (see Chapter I). The ability to satisfy these physical requirements as governed by the weight, weight distribution and fragility of the item to be protected, influence the selection of the cushion material.

Quite often there will be several materials having the required characteristics (density, elasticity and loading values)' and the choice will then be influenced by cost factors, availability of material and the physical limitations imposed upon the container.

Compressibility is the most important value in bulk cushion selection as it represents a measure of its deflection under load. As this characteristic differs with different materials and even among different densities and thicknesses of the same type of material, each one must be tested under similar loading. Plotting the loading data results in a stress-strain or a load-deflection curve with the loading expressed in pounds per square inch (psi) and the deflection in inches or a percentage of the measured thickness. As these data can be developed with comparative ease, they are normally all the data available to the designer and are presented by the cushion manufacturer in graph form to promote the application of his product. These data, based on static loading, provide a comparison of the relative efficiency of the various materials used as bulk cushion; however, as shock loading in service is of a variable dynamic nature, the use of only static compressive-displacement (stress-strain) curves is not recommended for missile container design.

The general classification of bulk cushion is based on the manner in which it performs and responds under loading as reflected by the shape of its force-displacement curve. The manner in which cushion materials respond to loading is depicted in Figure 61 and categorizes these materials into types.

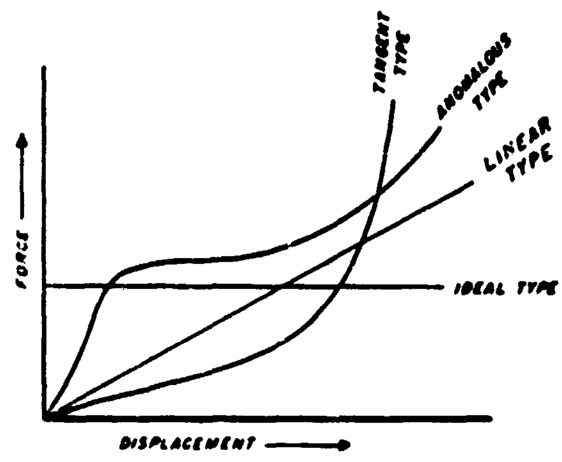


FIGURE 61. FORCE-DISPLACEMENT CURVES FOR VARIOUS TYPES OF CUSHIONS

A review of the plotted data indicates that as the displacement increases, the force necessary to produce each additional increment of displacement also increases. Of significance, is the rate and manner in which this force increases.

As the material compresses, it becomes more dense and its resistance to compression increases; consequently, the force necessary to result in further compression (deflection) must necessarily increase. This characteristic is peculiar to all conventional cushioning materials and their performance varies only in the manner and rate in which they respond.

The type performing most favorably is that designated as anomalous which provides a range of cushion performance comparable to that of the ideal. The tangential type is applicable only within a certain range beyond which, the cushion attains a density approaching that of nonresiliency and its cushioning effects become nil. This condition is referred to as "bottoming" and the full force of impact is transmitted to the container contents. The linear type is limited in application by the displacement required to attenuate shock and the spatial limitations placed upon the container.

The most common cushion materials and those of any significance are listed below and classified according to the manner in which they perform.

Tangential Type:
- a. Fibrous glass.
- b. Natural latex foam.
- c. Expanded resilient polystyrene.
- d. Rubberized hair (flat-wise loading).

Anomalous Type:
- a. Urethane foam.
- b. Polyethlene foam.
- c. Rubberized hair (edge loading).

It has been found that a more accurate prediction of cushion performance can be made by applying the relationship between peak acceleration G experienced by an impacting mass and the static stress produced by this same mass upon a sample of the cushion material. The compilation of these data is a long, tedious and costly process which must be conducted for all materials; and within this family of materials, all compounds, densities, grades and thicknesses.

The magnitude of endeavor necessary to compile these data is further compounded by the need to drop the impacting mass from various heights peculiar to the proposed environment of "worldwide distribution." Unfortunately, such data is often not available and must be developed by the user; however, the use of this design technique is recommended and the development of data expansion is encouraged as a contribution to the state-of-the-art.

Drop test data introduces the dynamic aspects of impact and better simulates the cushion response when operating in a realistic transit environment. Consequently, this guide advocates and will present design procedures based on methods applying "peak acceleration versus static stress" curves.

In many instances, a military container will be subjected to repetitive abuse and the ability of the cushion to recover is of prime import. Many of the common cushioning materials are resilient and will recover upon removal of the applied load. This characteristic if required by the proposed application must be included within the material selection criteria.

Nonresilient cushions, when subject to a dynamic impact, experience a displacement resulting in permanent set, with no recovery. Unless this set is external the effect of impact results in loss of restraint and the item to be protected is free to vibrate within the confines of the container. This loss of restraint introduces a condition detrimental to the protective function of the container. When exposed to a vibratory environment, the unrestrained item may not necessarily vibrate in phase with its container and will produce a hammering action tending to pulverize its protective cushion. Unless deflection can be localized and restricted to those surfaces not affecting physical restraint of the protected item, it is recommended that a resilient cushion be used.

The resiliency of the material and its ability to recover results in rebound and introduces harmonic vibrations which if resonant with the natural frequency of the cushion system, will result in damage to the contents of the container.

At present, much additional research is needed to develop quantitative data relating to the vibrational aspects of bulk cushioning and until this deficiency is satisfied, empirical testing of the developed prototype is necessary.

CUSHIONING MATERIALS

Many of the materials classified as cushioning agents are not suited to missile container application and will be mentioned only briefly together with some of their liabilities. More extensive treatment is afforded those considered compatible with the proposed application.

Excelsior, shredded paper, sawdust and other similar substances are not considered to be suitable for the protection of missiles and rockets due to their high moisture absorption rate, their tendency to disintegrate and decay, and their vulnerability to permanent set. Mention is made only for the historical significance of these materials as they have been used in military packaging applications.

Materials in current use and which are considered capable of providing the protection required include:

a. Rubberized hair.
b. Expanded polystyrene.
c. Polyethlene foam.
d. Urethane foam.
e. Fibrous glass.

A. *Rubberized Hair*

Rubberized hair is classified as a bound fiber cushioning material and is comprised of latex treated animal fibers, vulcanized to provide a bonded assembly commercially available in either sheet form or as a contoured mold.

MIL-C-7769 establishes the requirements of bound fiber cushioning materials and qualifies their use for applications intended "to protect against vibrational and impact shocks where a resilient and water-resistant cushion is required. The flat sheets are intended for general cushioning applications and are cut to size as needed. Molded forms are intended for specific articles and are molded to fit the contours of the article."

MIL-C-26861A classifies bound fiber cushion into five types and establishes the optimum unit load to which the material may be subjected. "The following unit load (weight of article divided by the load-bearing area in contact with the cushion) designations are for guide purposes only and may vary, depending upon the fragility of the packaged article, the magnitude of shock, and the amount of fiber used."

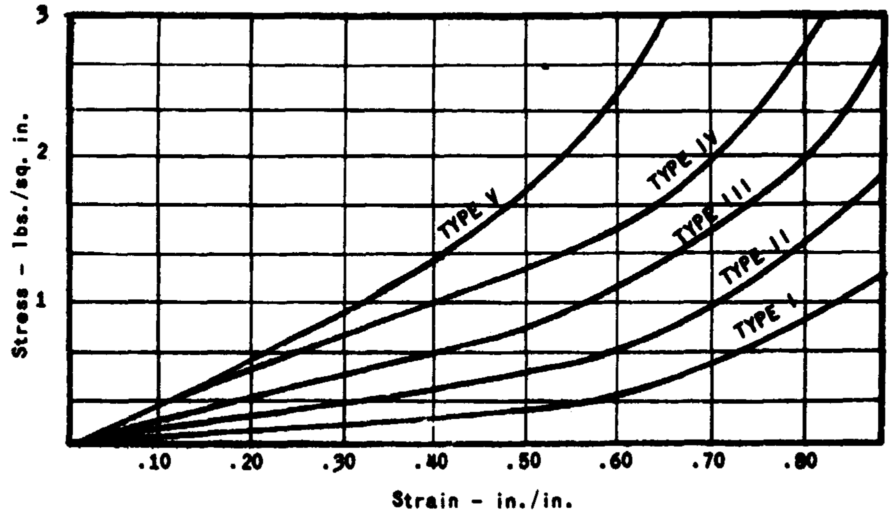
Type I - Soft - for loads up to 0.10 psi.
Type II - Medium Soft - for loads up to 0.30 psi.
Type III - Medium Firm - for loads up to 0.70 psi.
Type IV - Firm - for loads up to 1.30 psi.
Type V - Very Heavy - for loads up to 1.5 psi.

It should be noted that latex treated animal fibers acquire a pronounced sulphuric property during the vulcanization process which may affect the integrity of silver soldered joints. Other liabilities introduced by the latex which limit the application of rubberized hair include:

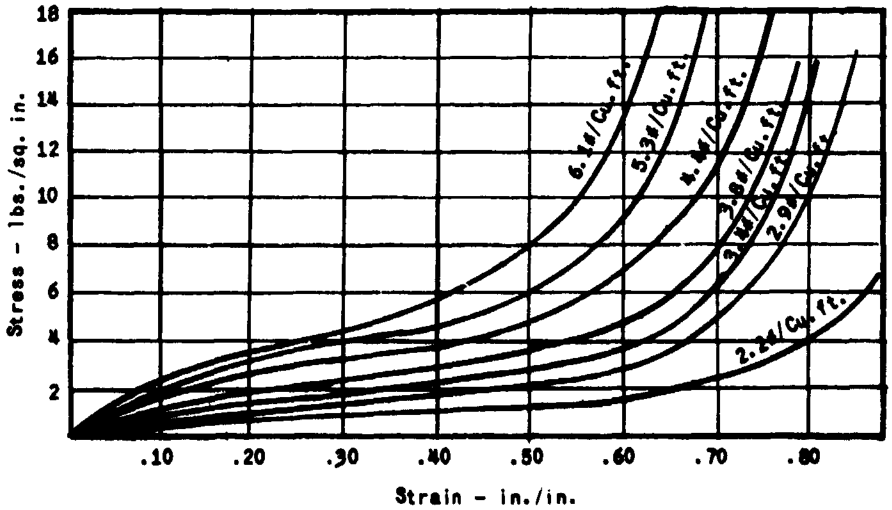
1. Tend to adopt a definite set of extended duration under shock load.
2. Sulphur in the latex combines with silver solder to form an oxide inducing failure in missile components.
3. Reliability below 32°F not yet established.
4. Experience swelling after exposure to petroleum base substances.
5. Develop a hard, brittle texture when exposed to prolonged direct sunlight.
6. Become unreliable in the presence of certain oxidizers.
7. Possess unsatisfactory flame resistance.
8. Suffer loss in resiliency with age.
9. Damping ability questionable within temperature range required for "worldwide distribution."

Figure 62 depicts the static stress-strain curves for various types of rubberized hair. These curves function to convey to the designer the physical characteristics of the standard types available. It becomes evident that for a 1 psi load factor, the cushion will experience a reduction in thickness of 32% for Type V; a 40% for Type IV; a 58% for Type III; a 71% for Type II and an 84% for Type I. This in essence is a measure of the materials elasticity and provides an indication of relative density. The application of these data to container design is limited to establishing the deflection experienced by the cushion when subjected to a static load. The amount of static deflection experienced by a cushion is one factor which must be considered in the selection of an adequate cushion thickness to provide sufficient preload to result in a snug unit pack.

The dynamic performance of both forms of rubberized hair are depicted in Figures 63 and 64. These data are used in the design process and account for the dynamic response experienced in practice. It should be noted that the data is based on a 30" flat-drop; however, pending further expansion of data, current design technique may assume the 30" height as typical of the "worldwide distribution" environment.



(a)



(b)

FIGURE 62. STATIC STRESS-STRAIN CURVES FOR VARIOUS TYPES OF RUBBERIZED HAIR

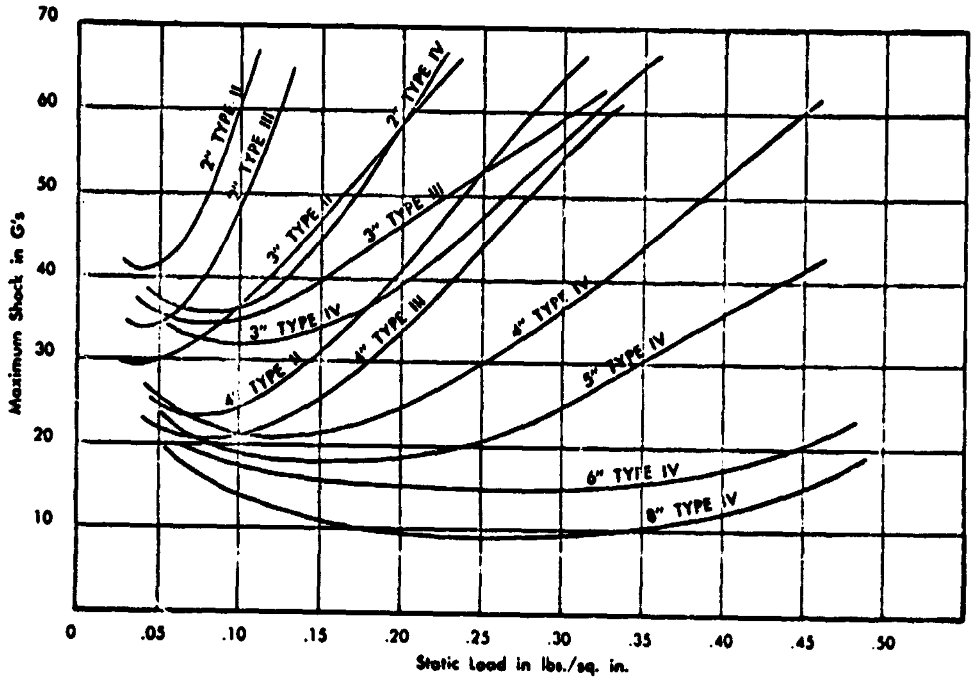


FIGURE 63. G VERSUS STATIC STRESS
RUBBERIZED CURLED HAIR SHEET FORM PER MIL-C-7769 - 30" FLAT DROP

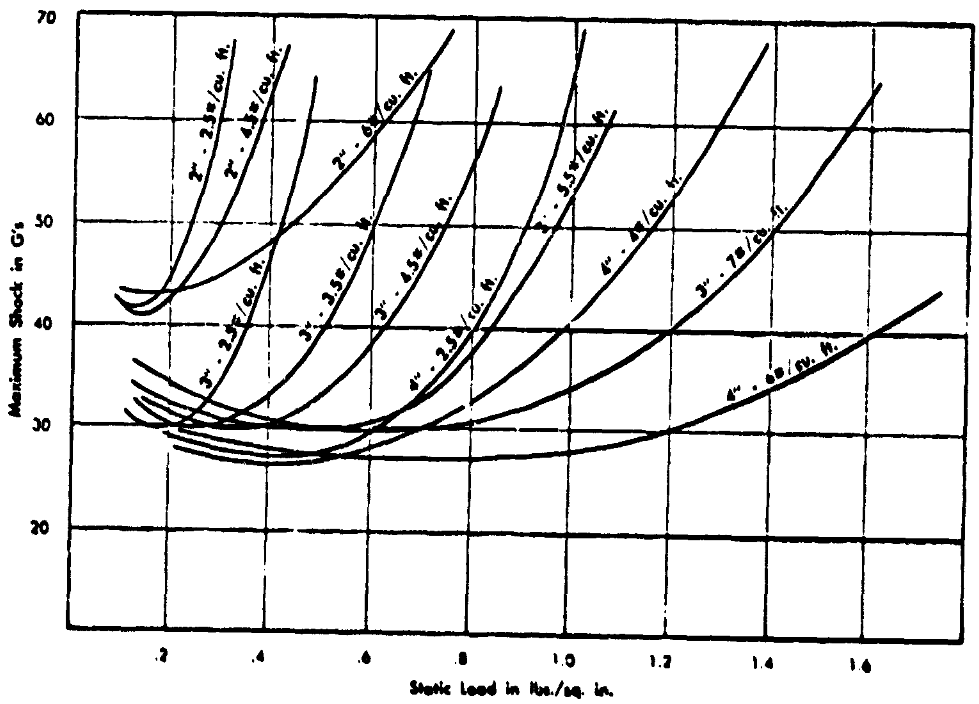
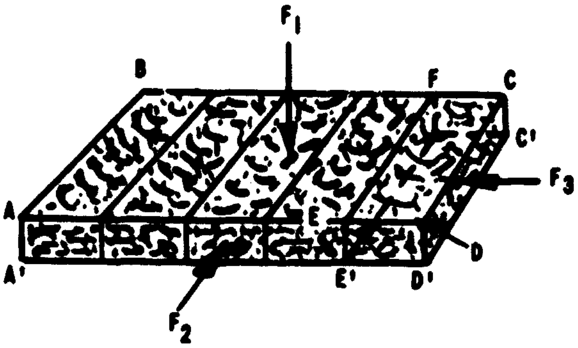


FIGURE 64. G VERSUS STATIC STRESS
MOLDED RUBBERIZED CURLED HAIR - 30" FLAT DROP

Though not readily apparent, the curled hairs of conventional sheet stock rubberized hair pads are oriented to occur in planes that are parallel to those of the top and bottom of the sheet (symbolized by planes A, B, C, D and A', B', C', D' of Figure 65). Consequently, the load-bearing characteristics of a unit volume of this material vary with the direction of applied load.

Resistance to force F_1, Figure 65, would differ markedly from that met by F_2 and F_3, which symbolizes edgewise loading. Little difference would be observed in the resistive force of the cushion to forces F_2 and F_3.



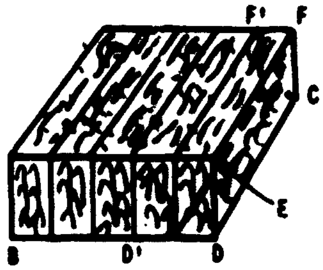


FIGURE 65. CONSTRUCTION OF "HAIR-ON-EDGE" PAD

A - CONVENTIONAL PAD CUT INTO EQUAL SECTIONS

B - "HAIR-ON-EDGE" PAD MADE OF BONDED SECTION

In general, the dynamic compression characteristics of sheet stock rubberized hair may be improved substantially by loading the pad in an edgewise direction as indicated by the data for 2 inch rubberized hair in Figure 66. The data shown represents tests conducted with an impact velocity equivalent to a 30 inch drop. Pads can be constructed with strips equal to the desired thickness of the hair-on-edge pad, see Figure 65. The strips are joined together with a latex binder.

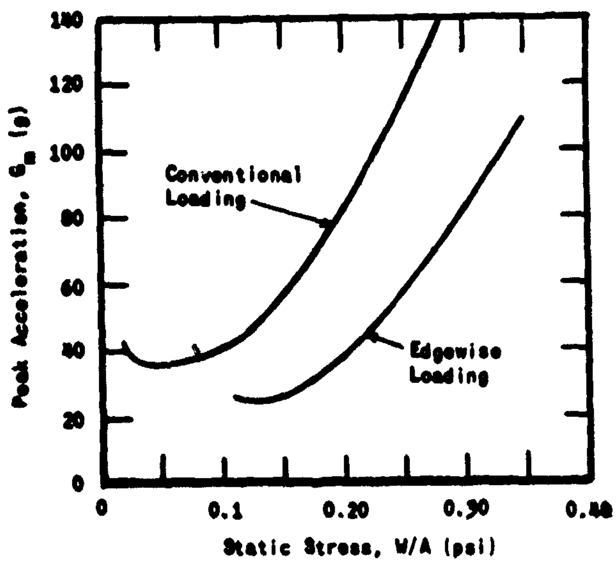


FIGURE 66. EFFECTS OF LOADING ORIENTATION UPON THE DYNAMIC COMPRESSION CHARACTERISTICS OF RUBBERIZED HAIR (2 INCH, 2.0 LB/FT^3, MIL-C-7769)

The increased efficiency of hair-on-edge pads tends to offset their higher cost. They should be considered for certain applications, especially when a range of static stress of about 0.10 to 0.25 psi is involved.

In addition to latex, additional chemicals are normally included which provide resistance to mold, rot and fungus. Because of its porosity, rubberized hair provides for maximum air circulation and minimum moisture retention. Certain commercial grades of molded rubberized hair have functioned at -80°F and at +180°F with a maximum loss of 20% cushion efficiency.

B. Expanded Polystyrene

Expanded polystyrene is classified under the general heading of foamed plastic and is basically an expanded resinous material with a cellular sponge-like structure. The material consists of a dispersion of normally liquid hydrocarbons in a polymer matrix. Expansion of the polystyrene into its sponge-like form is accomplished by the introduction and dispersal of gas in the liquid resin and subsequent curing of the expanded mass.

Polystyrene is basically a rigid plastic foam whose characteristic and performance requirements are specified in MIL-P-19644A. There are available polystyrene compounds which are both flexible and resilient. The fabrication of this grade of polystyrene subjects the rigid foam to a crushing process which imparts to the material a degree of resiliency often desirable in protective cushioning applications. The performance requirements for resilient polystyrene are documented in Federal Specification PPP-C-850b.

Expanded polystyrene foam may be purchased in the form of boards or logs in various types, classes, and grades or as pure polystyrene beads containing an expanding agent. The application of heat will cause the beads to expand to more than 40 times their original volume to form a strong fused close-cell structure. Boards and logs can be fabricated with common wood-working equipment contributing to the versatility of their application. For complex contours and large volume production, expandable polystyrene beads can be charged directly into a mold, expanded and fused in the mold cavity to provide the required contoured cushion pad. Both the expanded and expandable types have essentially the same physical properties. Their cellular structure is closed-cell and they have a high capacity for energy absorption, low thermal conductivity, low water absorption. They are relatively tough, are resistant to attack by fungi and do not support bacterial growth and are dimensionally stable within the temperature range of a "world-wide distribution" environment.

Based on the recommended design technique, the following dynamic response data are presented to assist in the selection of a suitable cushion. There are numerous commercial compounds available satisfying the specifications regulating the application of polystyrene to military packaging. Data describing the static and dynamic response of these compounds is presented as developed by the supplier; its validity has not been established. Consequently, empirical testing of any prototype suspension is required to qualify the container for the intended use in the pertinent military environment.

The following curves have been prepared to depict the response of various grades and types of expanded polystyrene to static loads. Those prepared by Koppers relate stress (dead load in psi) to compression in inches. Those developed by Dow are the stress-strain type and present the deflection experienced as a percentage of the thickness of the cushion. These data will permit the designer to provide for static deflection in his selection of cushion thickness.

Pending the availability of additional data, the response of each type shown may be considered as typical and the same for any compound having the same density regardless of the source of manufacturer.

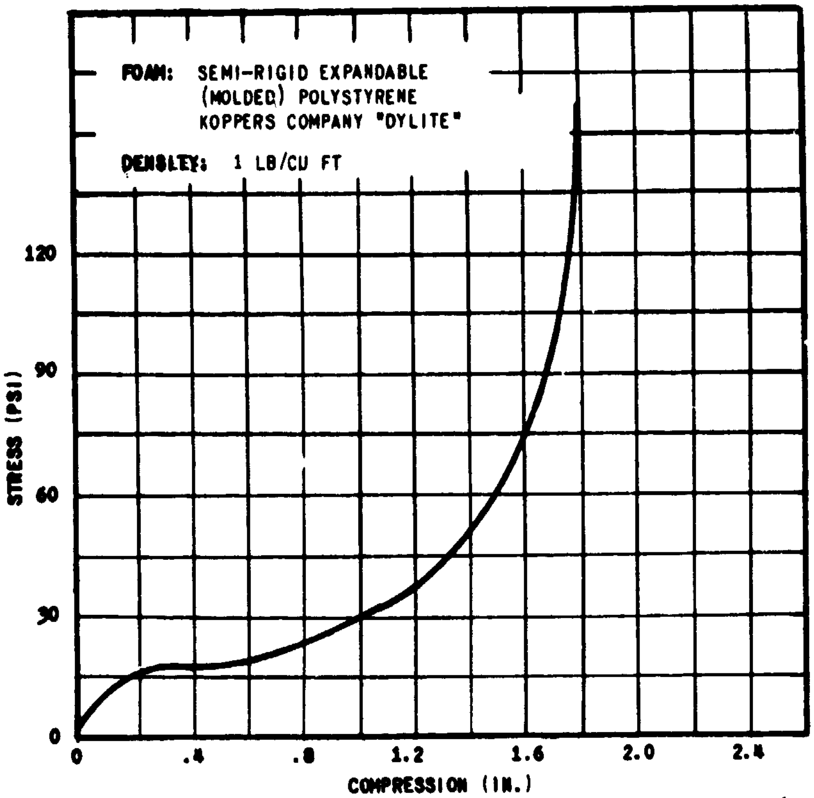


FIGURE 67. STATIC STRESS VERSUS COMPRESSION CURVES FOR EXPANDABLE (MOLDED) POLYSTYRENE FOAM AT AMBIENT TEMPERATURE

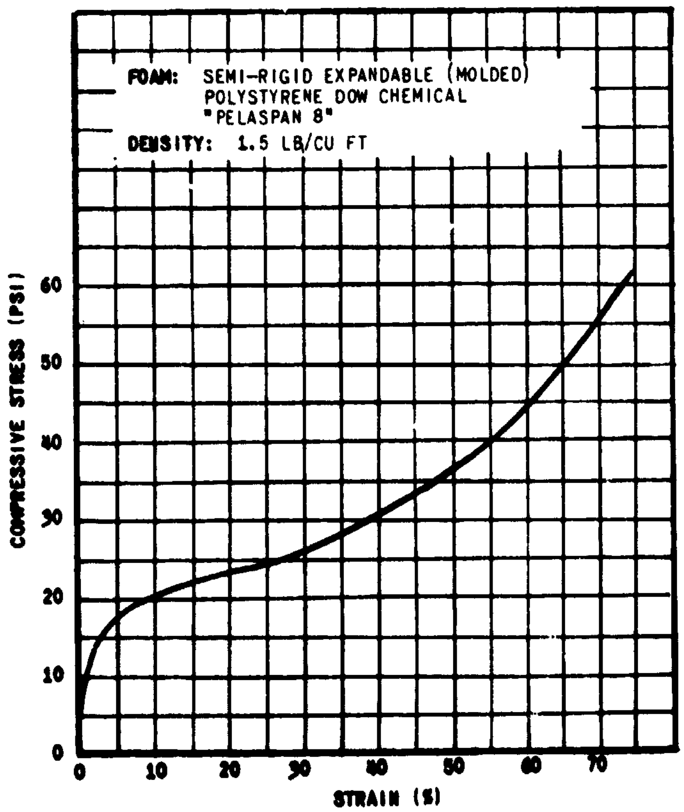


FIGURE 68. STATIC STRESS VERSUS STRAIN CURVES FOR EXPANDABLE (MOLDED) POLYSTYRENE FOAM AT AMBIENT TEMPERATURE

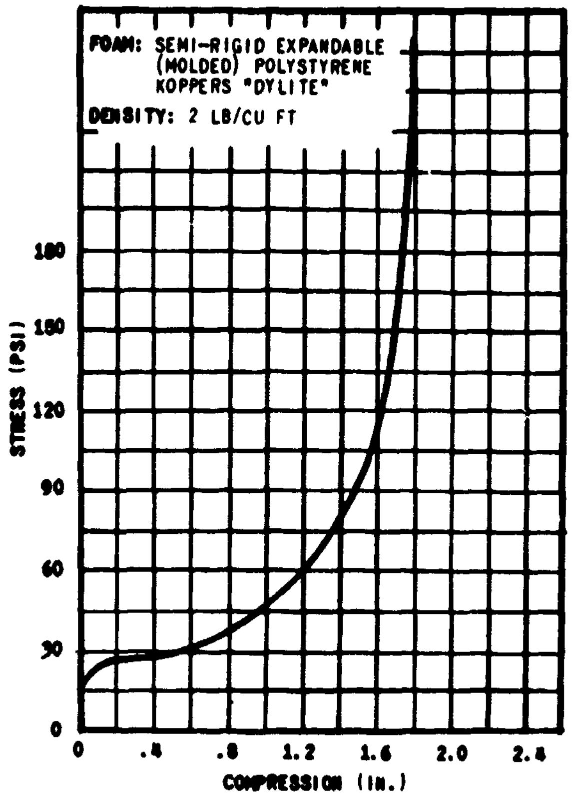


FIGURE 69. STATIC STRESS VERSUS COMPRESSION CURVE FOR EXPANDABLE (MOLDED) POLYSTREME FOAM AT ROOM TEMPERATURE (2 lb/cu ft density)

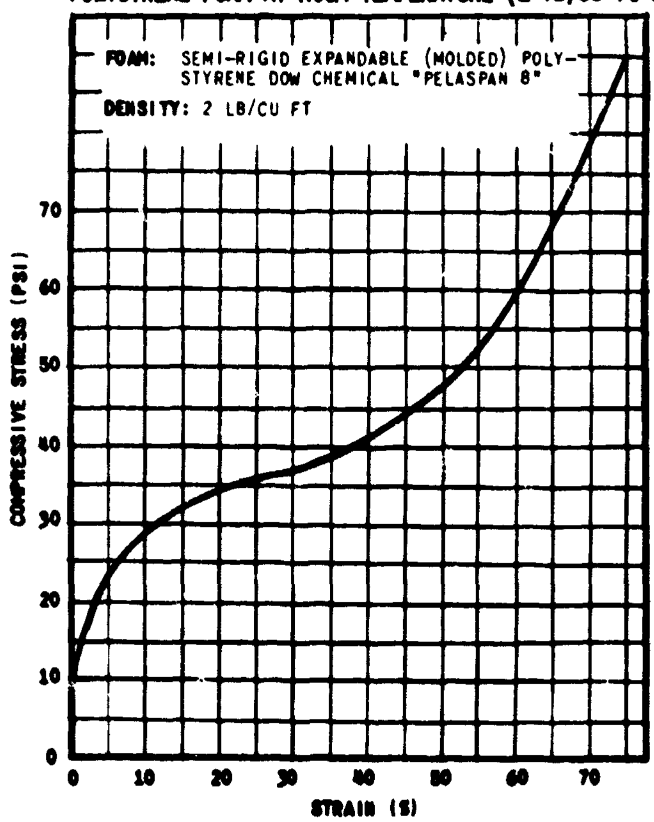


FIGURE 70. STATIC STRESS VERSUS STRAIN CURVE FOR EXPANDABLE (MOLDED) POLYSTYRENE FOAM AT ROOM TEMPERATURE (2 lb/cu ft density)

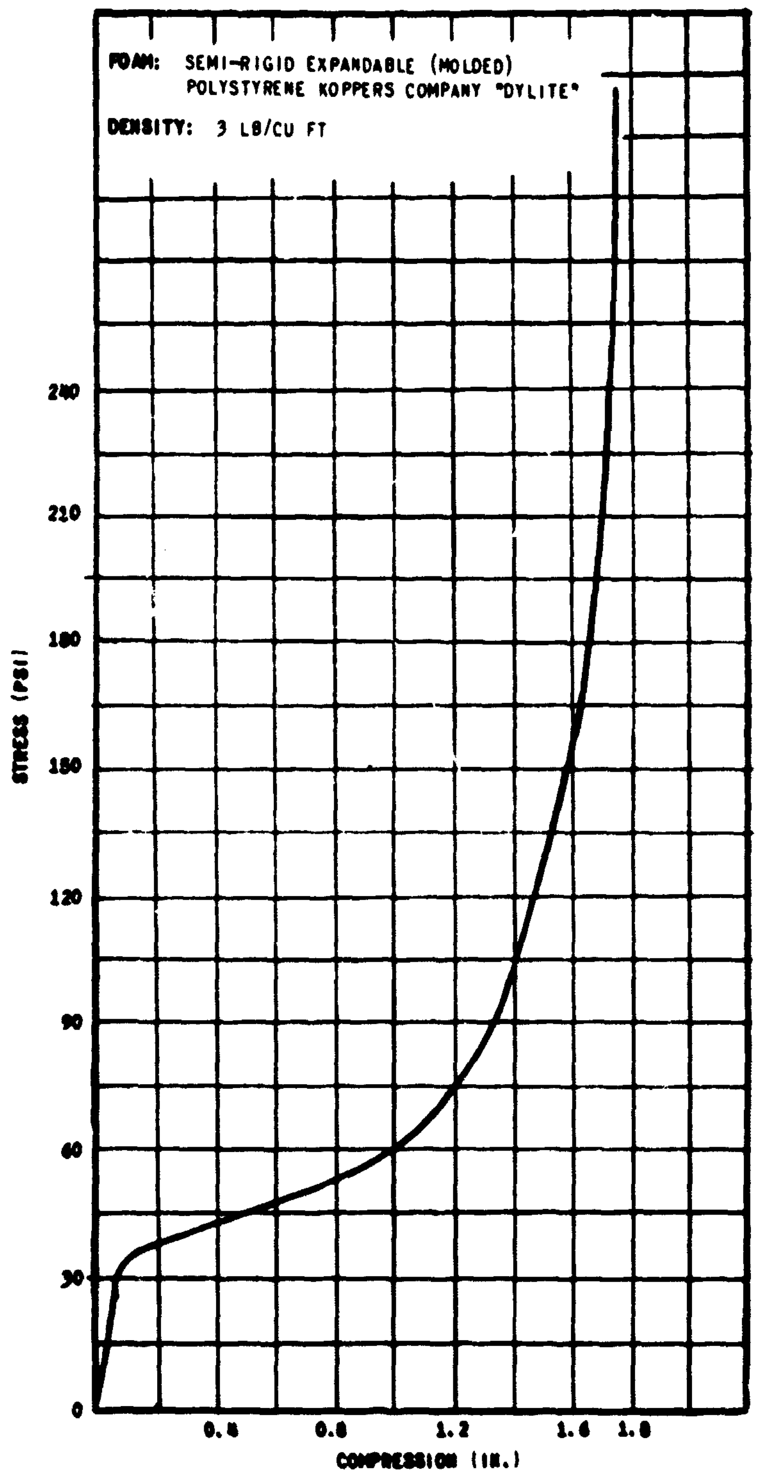


FIGURE 71. STATIC STRESS VERSUS COMPRESSION CURVE FOR EXPANDABLE (MOLDED) POLYSTYRENE FOAM AT ROOM TEMPERATURE (3 lb/cu ft density)

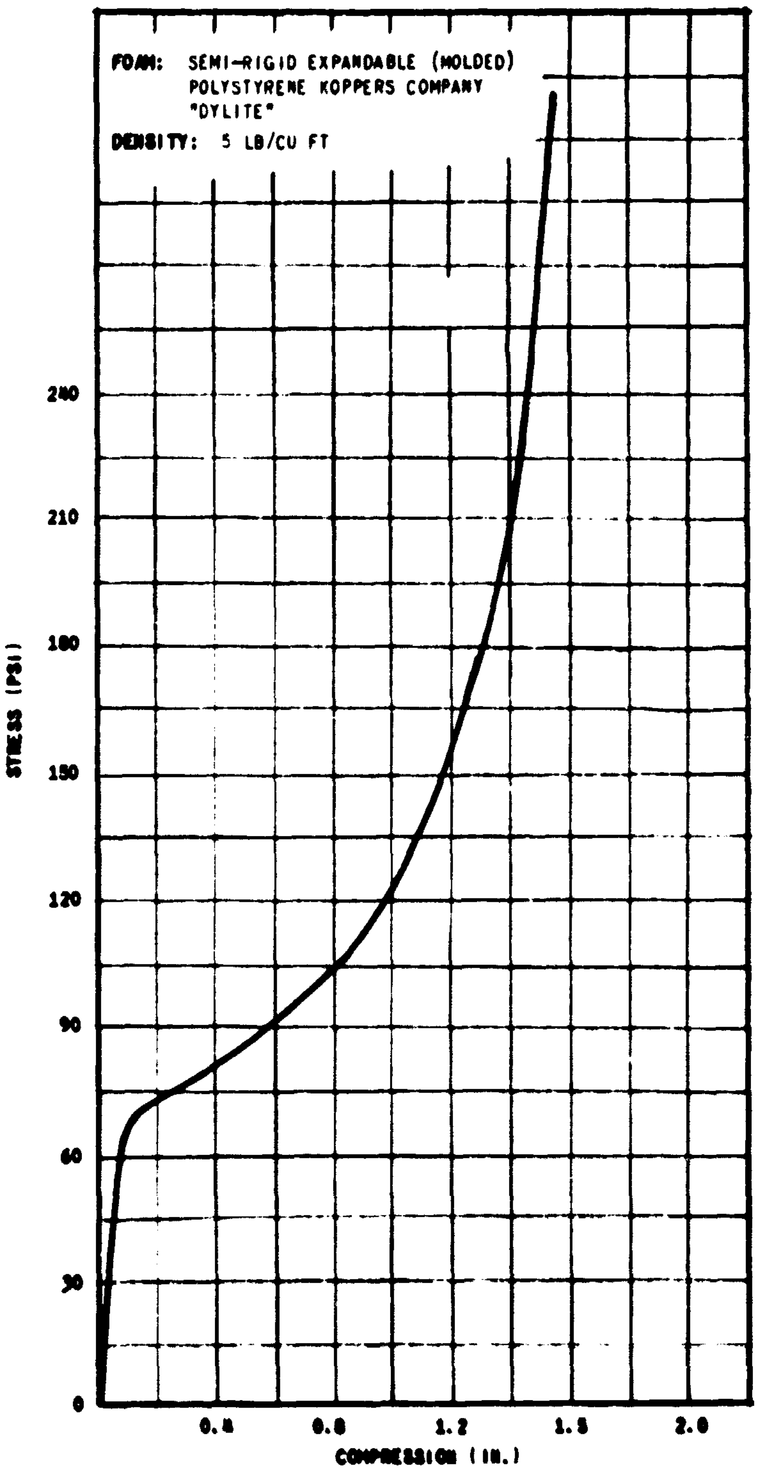


FIGURE 72. STATIC STRESS VERSUS COMPRESSION CURVE FOR EXPANDABLE (MOLDED) POLYSTYRENE FOAM AT ROOM TEMPERATURE (5 lb/cu ft density)

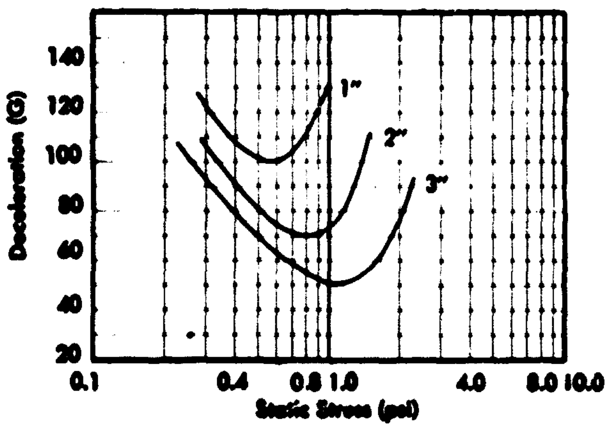


FIGURE 73. DYNAMIC CUSHIONING OF SAMPLES MOLDED OF PELASPAN (1.5 lbs. Density) FOR A 30" DROP HEIGHT AT A TEMPERATURE OF 73°F

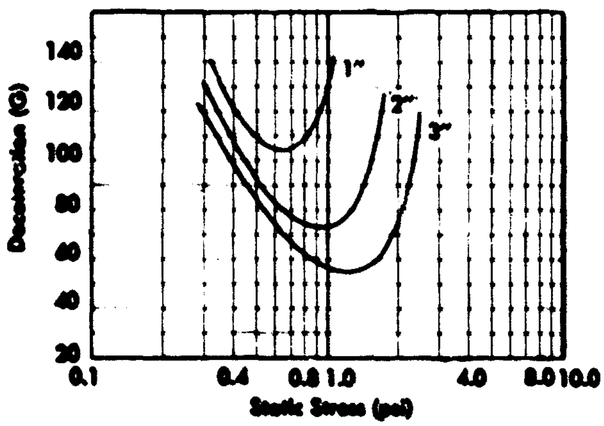


FIGURE 74. DYNAMIC CUSHIONING OF SAMPLES MOLDED OF PELASPAN (2.0 lbs. Density) FOR A 30" DROP HEIGHT AT A TEMPERATURE OF 73°F

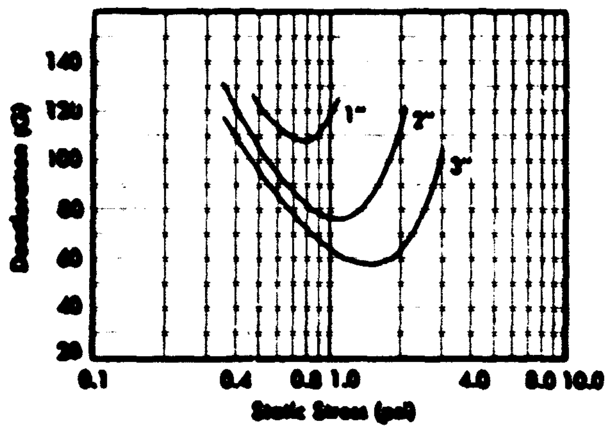


FIGURE 75. DYNAMIC CUSHIONING OF SAMPLES MOLDED OF PELASPAN (2.5 lbs. Density) FOR A 30" DROP HEIGHT AT A TEMPERATURE OF 73°F

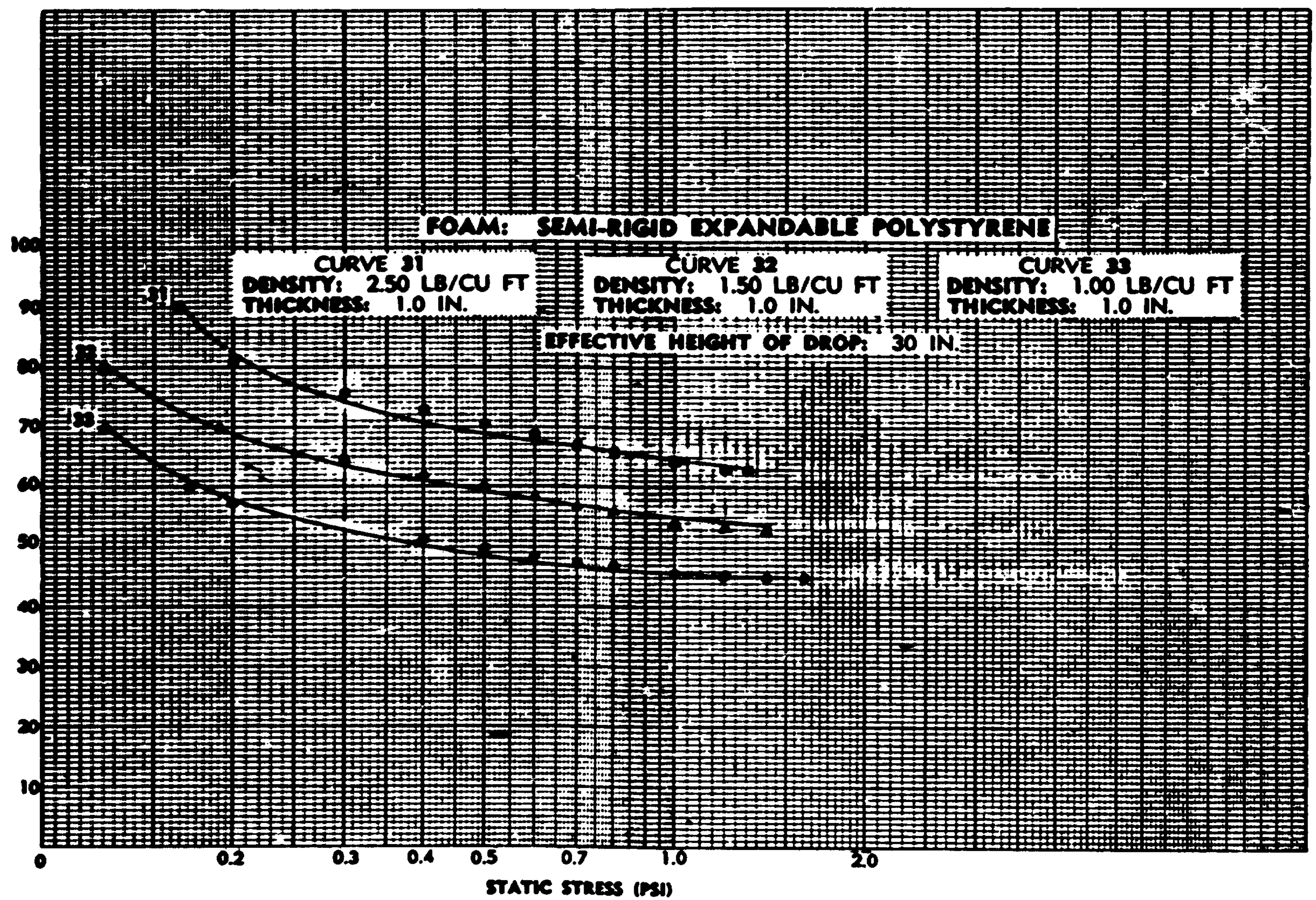


FIGURE 78. DYNAMIC COMPRESSION DATA (ACCELERATION VERSUS STATIC STRESS CURVES - 31, 32, 33) FOR SEMI-RIGID EXPANDABLE POLYSTYRENE FOAMS AT ROOM TEMPERATURE (Derived by Kopper Co. and Michigan State University Laboratories)

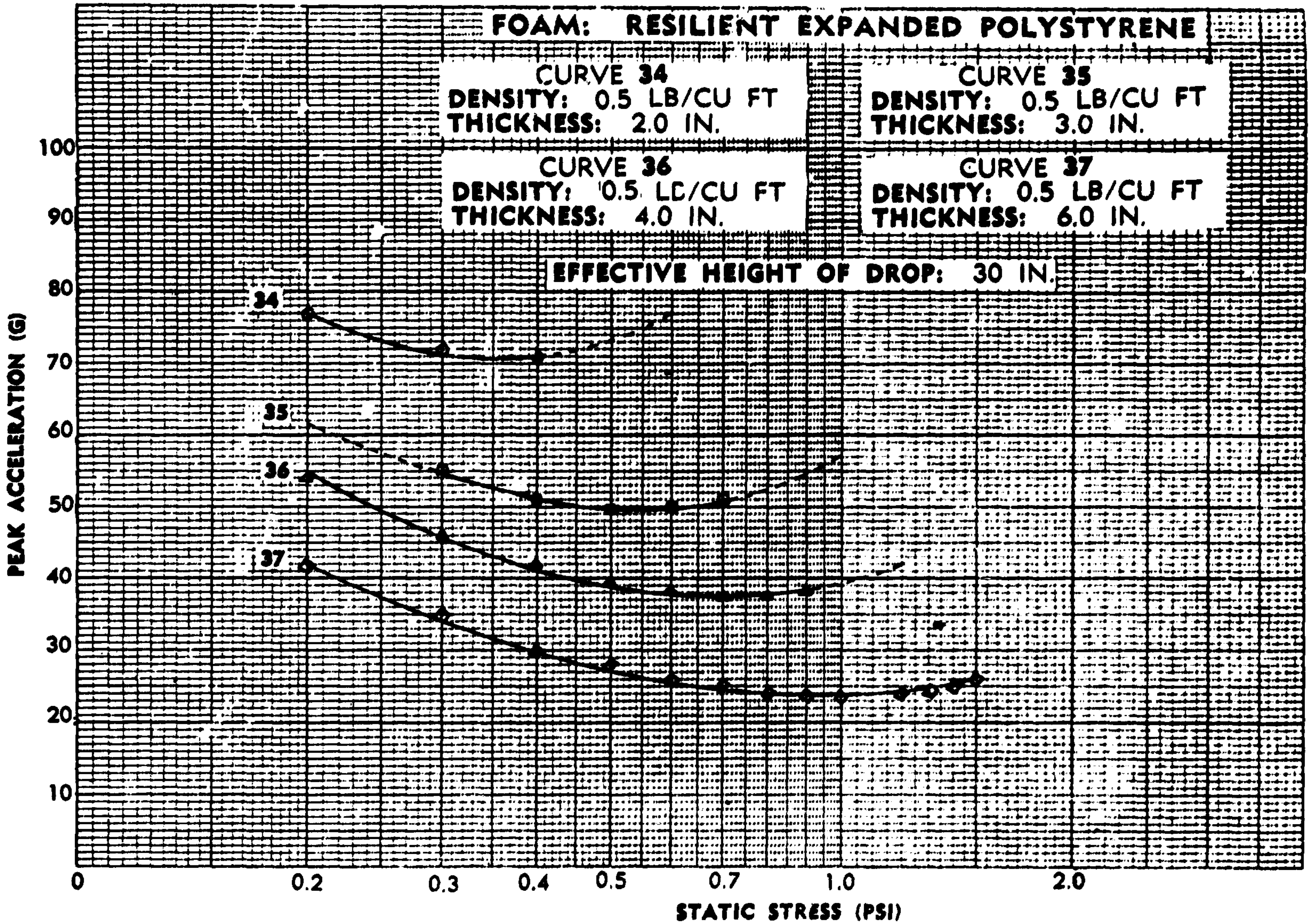


FIGURE 77. DYNAMIC COMPRESSION DATA (ACCELERATION VERSUS STATIC STRESS CURVES - 34,35,36,37) FOR RESILIENT EXPANDED POLYSTYRENE FOAMS AT ROOM TEMPERATURE (Derived by Armstrong Cork Company)

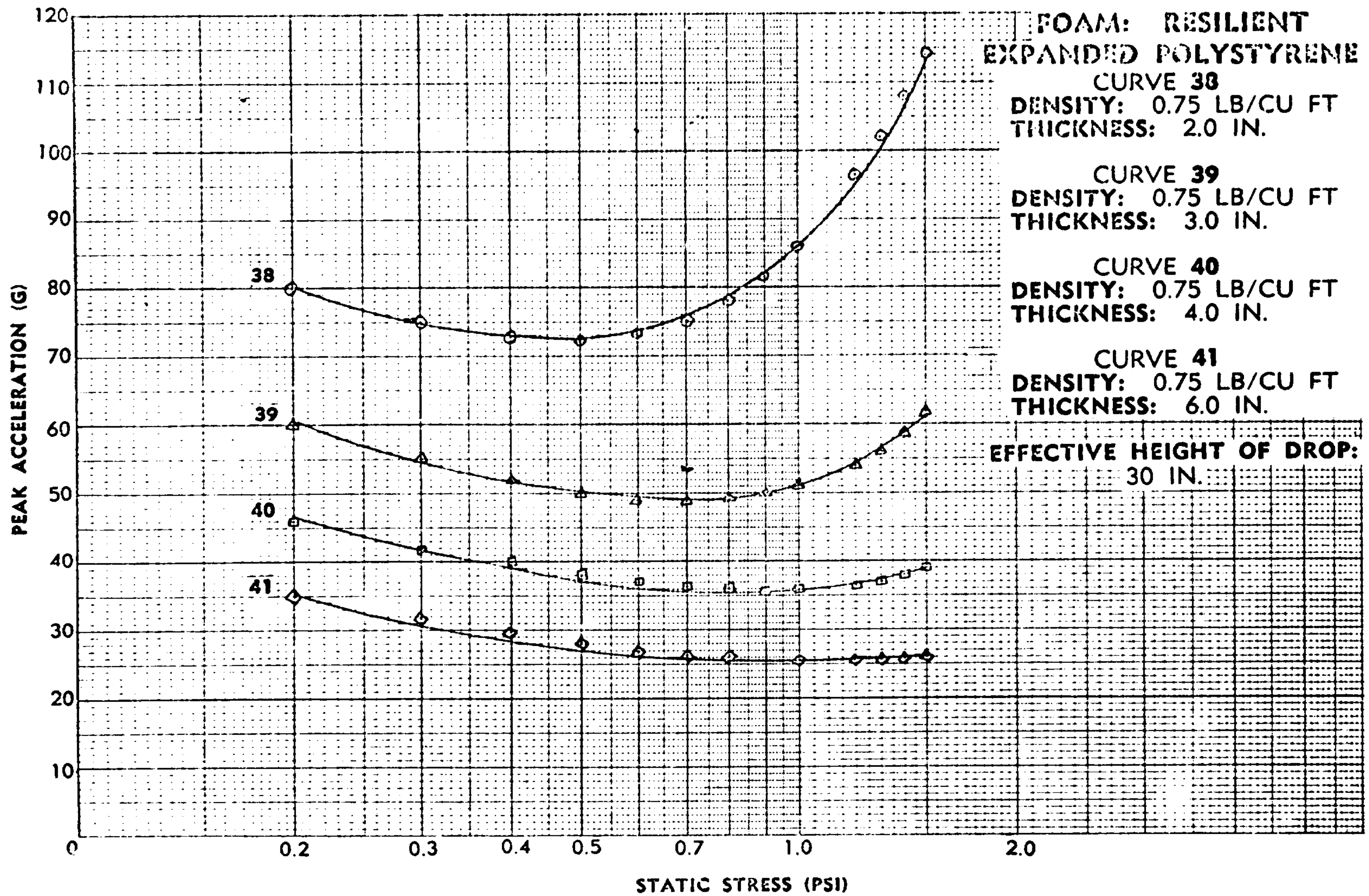


FIGURE 78. DYNAMIC COMPRESSION DATA (ACCELERATION VERSUS STATIC STRESS CURVES - 38,39,40,41) FOR RESILIENT EXPANDED POLYSTYRENE FOAMS AT ROOM TEMPERATURE (Derived by Armstrong Cork Company)

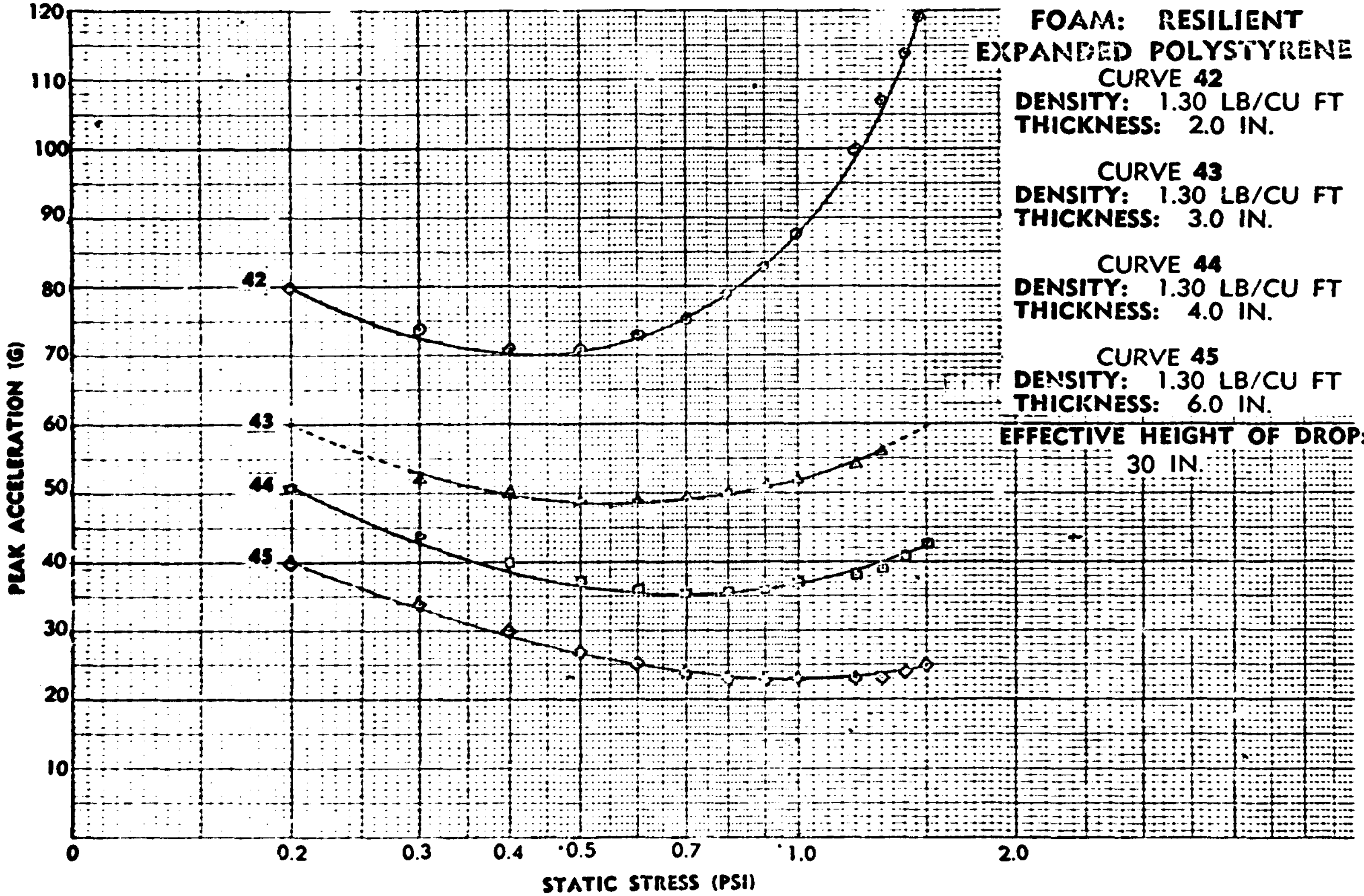


FIGURE 79. DYNAMIC COMPRESSION DATA (ACCELERATION VERSUS STATIC STRESS CURVES - 42,43,44,45) FOR RESILIENT EXPANDED POLYSTYRENE FOAMS AT ROOM TEMPERATURE (Derived by Armstrong Cork Company)

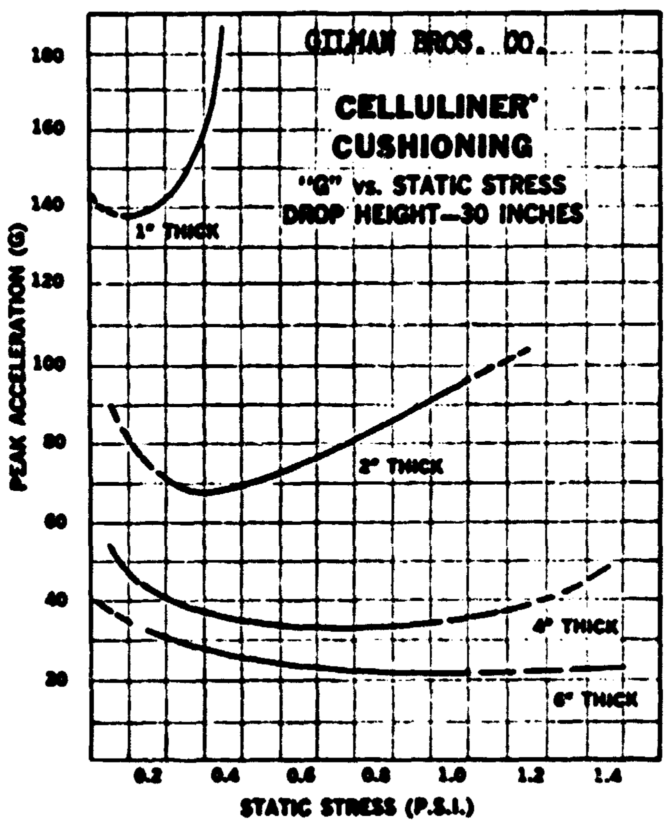


FIGURE 80. CELLULINER CUSHIONING "G" VERSUS STATIC STRAIN

C. *Polyethlene Foam*

Expanded polyethlene is a foamed closed-cell, flexible plastic possessing physical response characteristics suitable for protective cushioning applications. The outstanding advantages of foamed polyethlene include:

1. Excellent energy absorption.
2. Excellent chemical stability.
3. Flexibility over a wide temperature range.
4. Excellent strength and toughness.
5. Low water absorption.
6. Low moisture vapor transmission.
7. Lightweight
8. Good insulation value.
9. No odor.
10. No toxicological effects.
11. Easily fabricated.

The nominal density of foamed polyethlene is 2.0 lb/cu.ft; however, production tolerances range from 1.8 to 2.6 lb/cu.ft. It is available in various sizes and shapes or may be shaped in contoured molds. Polyethlene has the ability to withstand temperatures of from -60°F to +160°F; however, being a thermoplastic compound it is subject to dimensional distortion and degradation of performance when exposed to changes in temperature.

The effects of static loading is depicted in Figure 81 and relates the strain resulting from the applied stress to the temperature extremes of the projected environment. The drastic change in performance due to the effects of thermal change distinguish polyethlene and require the introduction of the temperature factor.

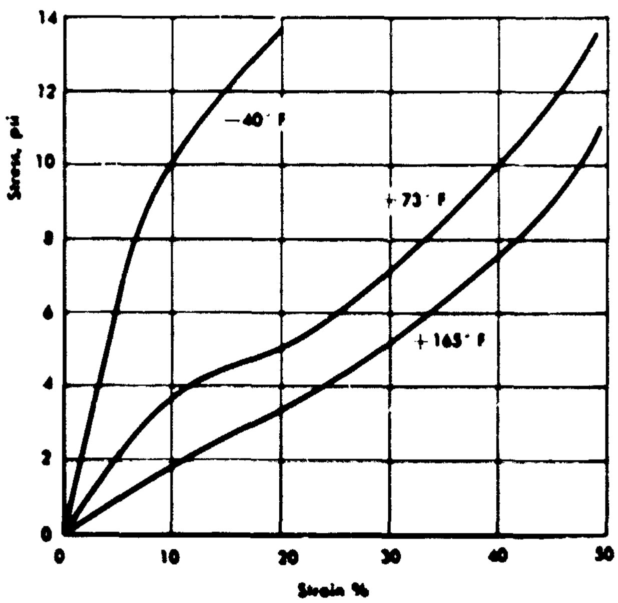


FIGURE 81. COMPRESSIVE STRESS STRAIN OF ETHAFOAM

The dynamic response of polyethlene functioning as a cushion is shown in Figures 82, 83 and 84, again introducing the operating temperature to compensate for the appreciable change in performance experienced by thermal exposure. The data is limited to the 30 inch free-fall height previously established as typical of the "worldwide distribution" environment.

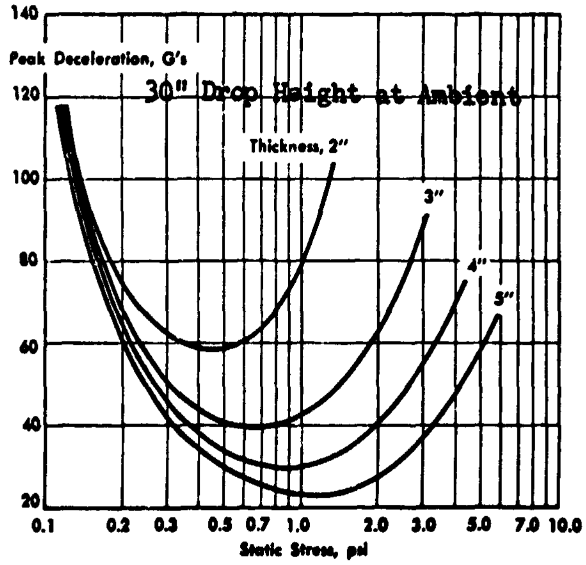


FIGURE 82. DYNAMIC CUSHIONING OF POLYETHLENE FOR A 30" DROP

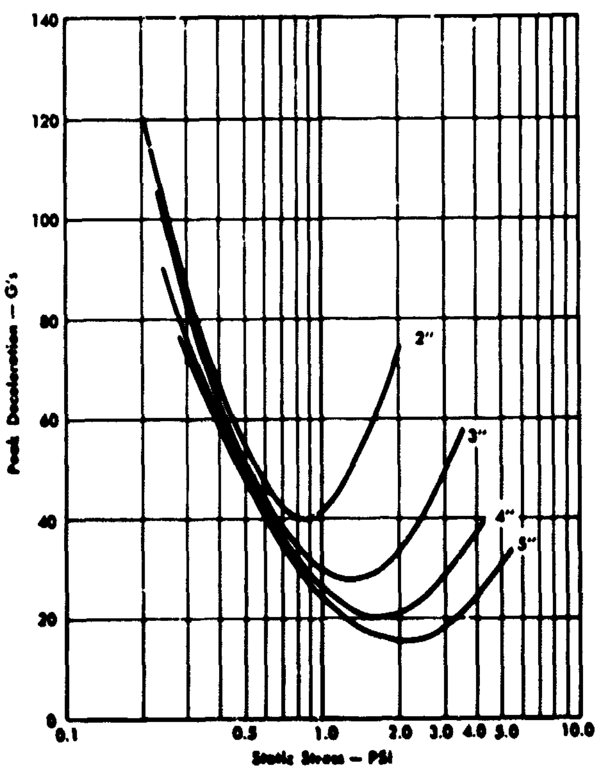


FIGURE 83. DYNAMIC CUSHIONING OF ETHAFOAM FOR A 30" DROP HEIGHT AT -65°F

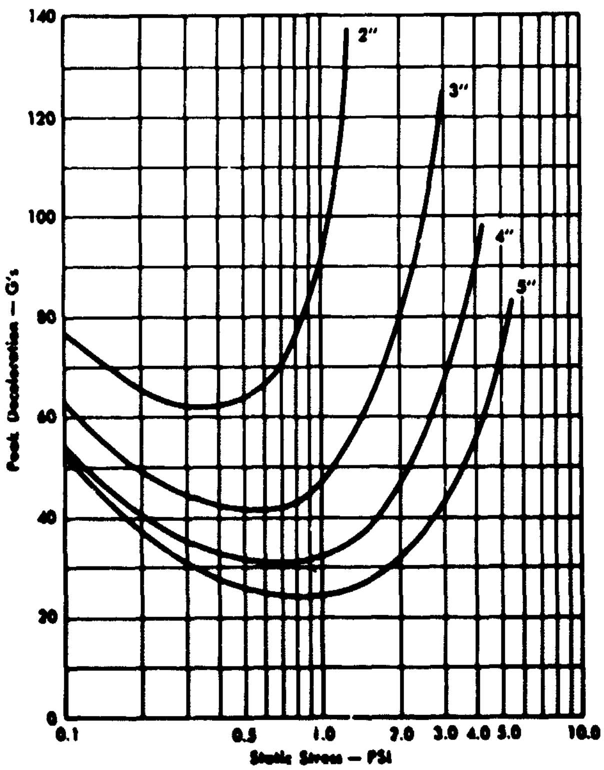


FIGURE 84. DYNAMIC CUSHIONING OF ETHAFOAM FOR A 30" DROP HEIGHT AT 155°F

D. Urethane Foam

Urethane foams are basically chemically expanded reaction products of a polyol and a polyisocyanate. Among the available types of urethane foam are the preferred polyethers, offering better cushioning properties and generally lower costs.

Urethane is an extremely versatile substance permitting wide density variation. Flexible polyurethane foam, expanded by the manufacturer, is commercially available in slabs and molded forms at densities of 1.5 'b/cu.ft. to 20 lb/cu.ft. In addition, both open- and closed-cell foams are available to meet the specific demands of the proposed application.

MIL-P-26514A (ASG) classifies and delineates the performance requirements of polyurethane foam. Only that designated as Class 2-Elastic is pertinent to the scope of this document.

A characteristic peculiar to polyurethane is its ability to be conveniently foamed-in-place to encapsulate items having a complex configuration.

The data shown in Figures 85 and 86 show that flexible polyether urethane foam cushion in the 3 - 5 lb/ft^3 density range is suitable in the static stress range of from 0.05 to 0.60 psi. The dynamic curves of Figure 86 are limited to only a 30 inch drop and are typical of the limited data pertaining to bulk cushion.

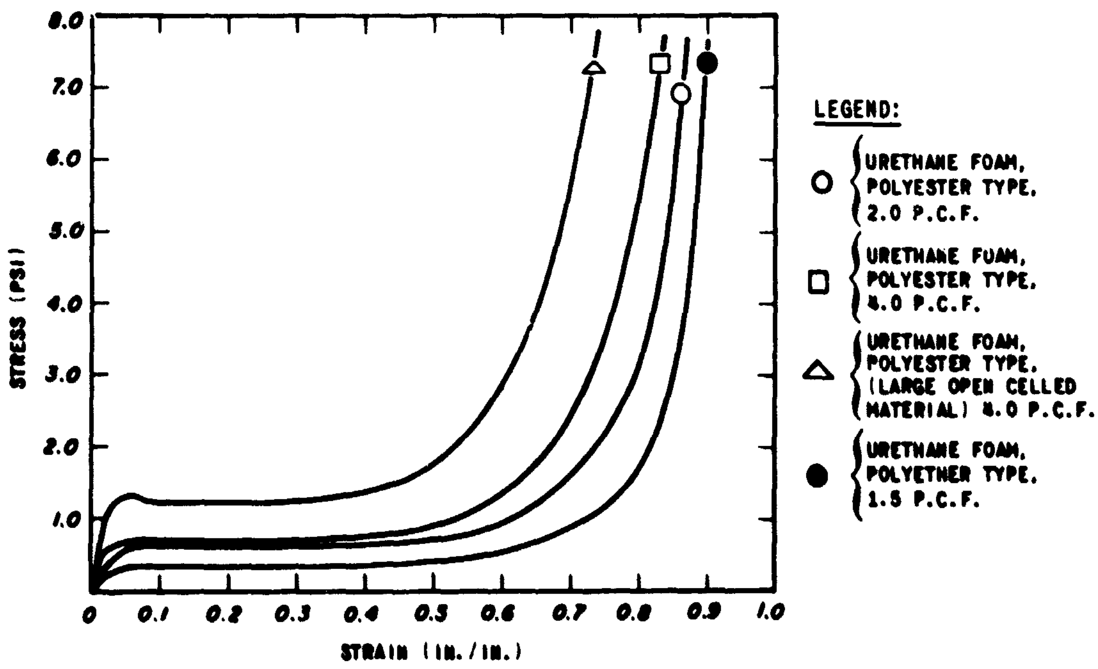


FIGURE 85. COMPRESSIVE STRESS-STRAIN RELATIONSHIP FOR DIFFERENT DENSITIES AND KINDS OF URETHANE FOAM

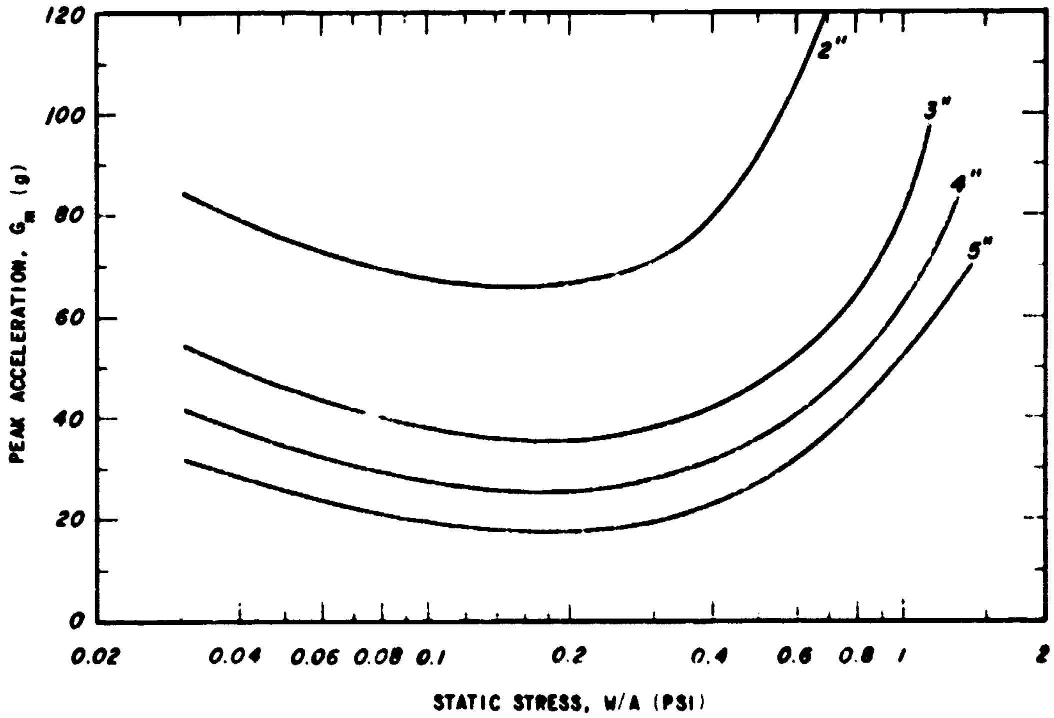


FIGURE 86. G_m VERSUS W/A CURVES FOR URETHANE FOAM (POLYETHER TYPE, 1.5 P.C.F.) FOR A 30 INCH DROP HEIGHT

E. Fibrous Glass

Fibrous glass cushioning material is made from fine glass fibers bonded with a variety of resins and formed into the desired shape by the application of heat and pressure. It is available commercially in blanket form or as custom molded pads.

The uniformity and cushion performance of fibrous glass cushioning material is regulated by MIL-C-17435. Some of the advantages of fibrous glass cushioning are:

1. Broad working range; -120°F to +250°F.
2. Variety of densities; fraction of lb/ft^3 to 12+ lb/ft^3.
3. No permanent set.
4. Resists:
   a. Growth of fungus
   b. Rot
   c. Fire
   d. Most acids and alkalies.

Among the disadvantages of fibrous glass are:

1. Highly abrasive in some grades.
2. High water adsorption.

These disadvantages often necessitate coating the cushion with a vapor barrier. Suitable materials for such a barrier would be: neoprene and hard drying resins. The thickness of coating must be controlled closely in order not to degrade the cushioning characteristics.

Little data has been generated on fibrous glass which is useful to the package designer. The primary use of this material is insulation and sound adsorption rather than shock mitigation. Figure 87 illustrates the stress-strain characteristics of fibrous glass; dynamic data is given in Figure 88.

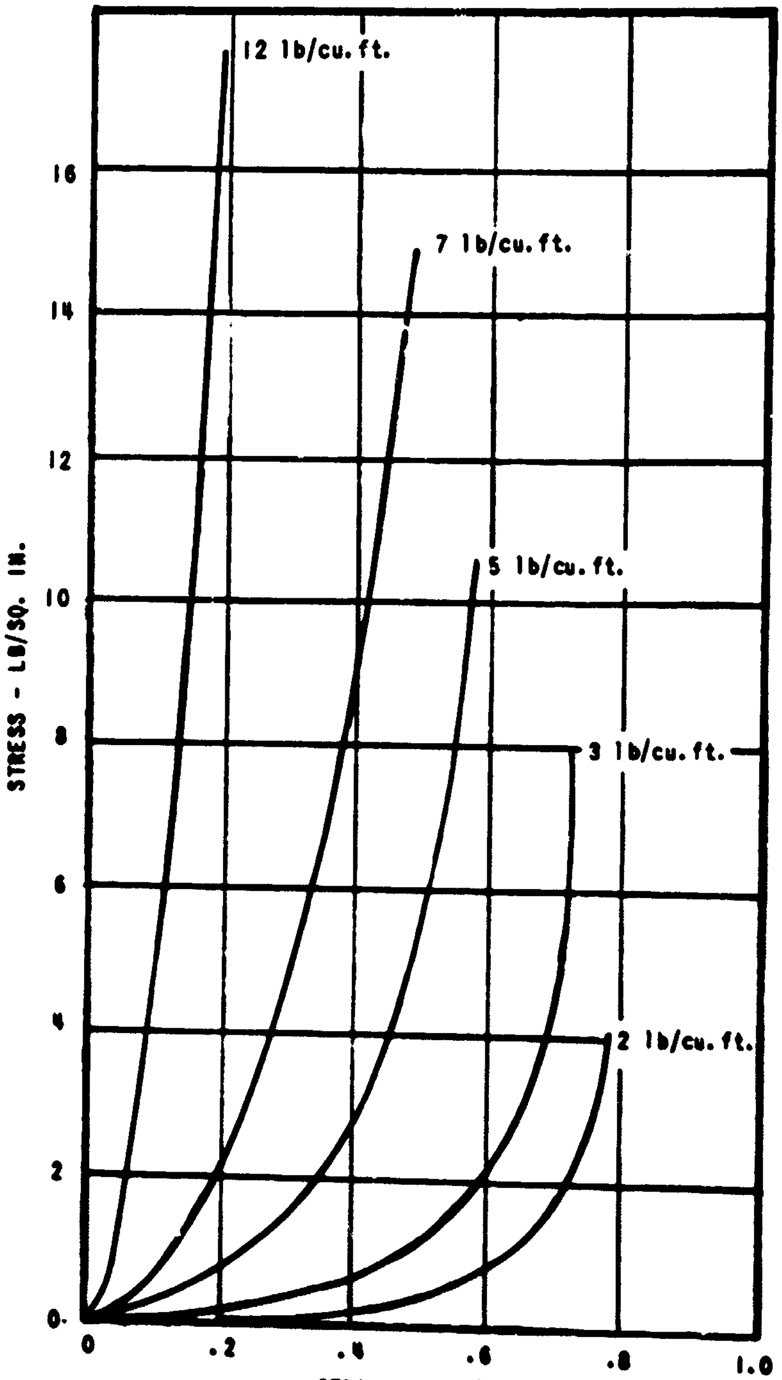


FIGURE 87. FRACTION DISPLACEMENT (IN/IN) STRESS VERSUS STRAIN VARIOUS DENSITIES GLASS FIBER CUSHIONS

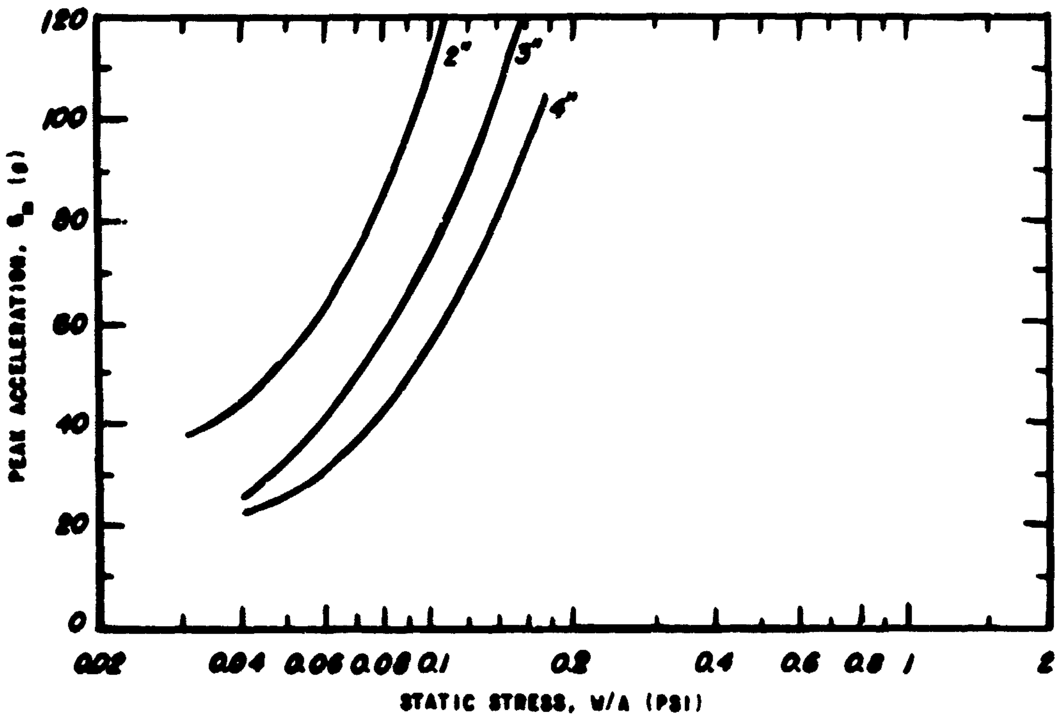


FIGURE 88. G_m VERSUS W/A CURVES FOR FIBROUS GLASS (1.1 P.C.F.) FOR A 30-INCH DROP HEIGHT

SELECTION OF THE OPTIMUM CUSHIONING MATERIAL

GENERAL

The selection of an optimum cushioning material for a specific application considers an assortment of interrelated factors. This section discusses those additional factors which must be considered after the ability to satisfy the shock and vibration criteria has been established.

TEMPERATURE AND HUMIDITY

The performance of most cushioning materials is adversely affected by exposure to high humidity and/or temperature extremes. Cushioning systems, whose design has been based on general dynamic response data will ultimately fail when exposed to environmental extremes. The designer must be cognizant of this degradation of performance and compensate for the possibility of exposure to conditions other than ambient.

Generally, low temperature exposure is considered to be the most severe of the extreme climatic conditions. At low temperatures, cushioning materials experience a loss of resiliency, become brittle, and subsequently fail.

Cushioning materials having the capacity to adsorb, absorb or retain moisture and/or water will, when exposed to such conditions experience degradation of physical response. Degradation of performance is further compounded should the relatively wet cushion be subsequently exposed to a sub-freezing temperature. Materials not resistant to moisture penetration must be contained within sealed barriers or coated to provide the required resistance.

The dimensional stability of thermoplastic compounds will be affected by exposure to high temperatures and through loss of restraint, degrade the protective characteristics of the cushion system.

The state-of-the-art does not as yet, provide comprehensive dynamic data for all materials at all temperature levels. Data is, however, available for those whose performance is drastically affected by temperature fluctuation and these specific data must be considered, when applicable, to assure adequate protective performance.

A recent study pertaining to the utility of ambient dynamic data has developed the "probable minimum safe temperature" for various cushioning materials. Based on this study, it is safe to say that the dynamic performance will not change appreciably until these limits are reached at which time peak acceleration values show a dramatic increase. Beyond these limits of "minimum-safe-temperature," the ambient data cannot be used and specific data must be developed or available data modified or extrapolated.

TABLE 16
PROBABLE MINIMUM SAFE TEMPERATURE FOR CUSHIONING MATERIALS

MATERIAL	"PROBABLE MINIMUM SAFE TEMPERATURE"
Urethane polyether foam	-22°F
Expanded resilient polystyrene	Below -60°F
Latex bonded fibrous glass	Below -60°F
Rubberized hair (4-6 pcf)	-40°F

COMPRESSION SET

Cushioning materials vary in their inherent ability to recover original thickness upon removal of an applied load. This deviation from perfect recovery (100% of original thickness) is referred to as "set" and when caused by compressive loads is expressed as "Compression Set." Loads peculiar to the environment of "worldwide distribution" subject cushioning to compressive forces resulting in "set." This dimensional deformation is the result of:

a. Long-term static storage.
b. Dynamic shock forces resulting from rough handling.
c. Forces generated by the transit media vibrational inputs.

Figure 89 illustrates a deformed cushion subjected to the impact force of shock and vibration tests.

FIGURE 89. LOSS OF CUSHION THICKNESS FROM SHOCK AND VIBRATION TESTING

Compression set is undesirable in cushioning material for two principal reasons: (1) Looseness (and the related increased likelihood of damage), and (2) with some cushioning materials it indicates that the compressive stress-strain behavior of the material has changed and the possibility of damage caused by "bottoming" has also increased.

Some effects of looseness in a package are depicted by Figure 90 where (a) represents a cushioned item being displaced normally from its original position during a drop against a flat rigid surface; (b) illustrates the same item in a different position due to jostling and looseness and thus receiving an impact on a point; and (c) represents a loosely packaged item moving in a direction opposite from that of the exterior container and cushioning. The instance of (c) could occur during vibration of the package as it rests on the bed of a truck or rail car; the vibration causes larger peak forces and accelerations to be developed and these, in turn, increase the likelihood of damage to the item.

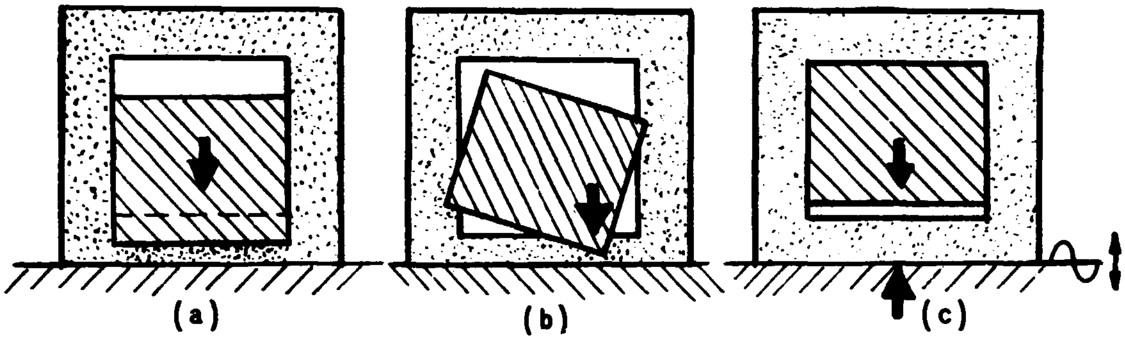


FIGURE 90. EFFECTS OF LOOSENESS IN A PACKAGE. (a) NORMAL DISPLACEMENT DURING IMPACT. (b) NONUNIFORM LOADING DURING IMPACT BY ITEM MISORIENTED BECAUSE OF LOOSENESS. (c) OUT-OF-PHASE MOTION OF ITEM AND CONTAINER DURING VIBRATION

Compensation for compression set is usually accomplished by: (1) Designing according to data that have involved a realistic amount of preworking prior to testing and repetition of impacts, or (2) applying an excess of cushioning material in precompressed condition (usually accomplished indirectly when such compensation is made for creep).

Creep - Virtually all cushioning materials, when subjected to a constant load for a period of time, tend to lose thickness; this phenomenon is called creep. The creep rate for all common package cushioning materials is greatest at initial loading and declines exponentially with elapsed time thereafter. After a load is removed, a cushion will regain most of its original thickness, but some permanent set will have been produced. Therefore, to prevent looseness in packages, it is desirable to apply extra thickness of cushioning material (in a precompressed state) in the package. However, because of the difficulty of closing a container after insertion of precompressed cushions, their use to offset creep is practicable only if relatively light precompression forces are required.

The amount of extra cushioning thickness required to offset creep can be estimated arbitrarily $T_c = T + 1/3(T)$ or, preferably, be calculated using available creep-time data. Creep-time curves are generally unavailable for the commonly used ranges of static stress; however, should they be or when they do become available, they should be used in preference to the arbitrary value of 1/3.

Regardless of the method used, it is customary to add extra thickness to either the top or bottom cushion - *but not both.*

Buckling

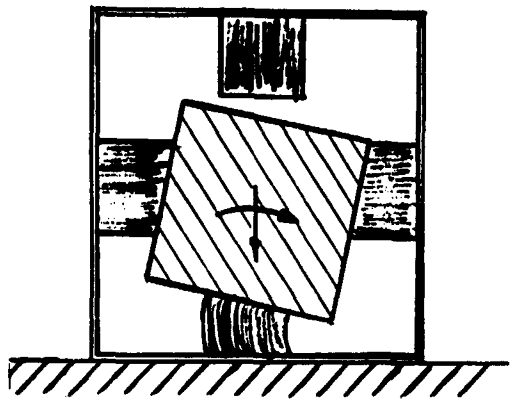


FIGURE 91. COLUMNAR BUCKLING OF CUSHION

Long, slender cushions whose height is proportionately greater than its least lateral dimension will function as a column and have a tendency to buckle when axial forces are applied. Columnar buckling precedes any compression which may occur and negates the protective characteristics of the cushion. This condition, depicted in Figure 91, is most undesirable and may result in damage to the protected contents.

The stability of a cushion pad is dependent upon the ratio of its physical characteristics; this relationship has been established.

a. A cushion will not buckle if:

$$\frac{\sqrt{A}}{T} \geq 1.33 \quad \begin{cases} A \text{ is the cross sectional area} \\ T \text{ is the thickness} \end{cases}$$

b. The minimum bearing area required to prevent buckling:

$$A \min = (1.33T)^2$$

Pneumatic Effects

Recent studies conducted by Picatinny Arsenal have shown that there is a considerable difference in the dynamic properties of cushioning between the "unconfined" and "confined," or as - packaged, states. Confined and and unconfined dynamic drop tests were conducted on like specimens of cushioning material of known density, size and under comparable environmental conditions. From these data static load-versus-peak acceleration curves were plotted, see Figure 92. It can be seen from this figure that beyond the optimum loading range, the peak accelerations transmitted by the unconfined cushion continue to rise sharply. Peak accelerations for the confined cushion show a secondary decrease beyond the optimum loading range, before starting a secondary increase beyond bottoming-out.

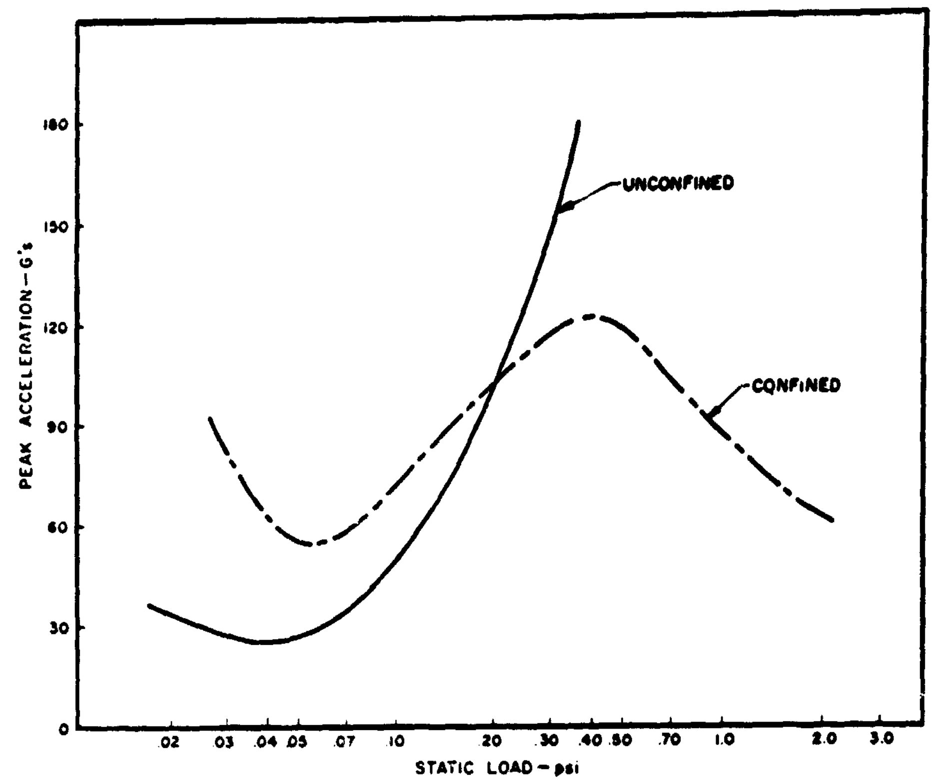


FIGURE 92. TYPICAL PEAK ACCELERATION-VERSUS-STATIC LOAD CURVES FOR CONFINED AND UNCONFINED TESTING OF RUBBERIZED CURLED HAIR

The substantial decrease in peak acceleration for the confineo cushion at some point beyond the optimum loading range is the result of pneumatic effects which augment the cushioning ability by delaying the bottoming-out action. If the static load for the confined cushion is increased beyond 3 psi, it is expected that the peak acceleration will begin to rise rapidly.

The use of dynamic unconfined data in the design of cushioning systems will provide a conservative solution; however, when a sealed outer container is used the actual peak accelerations will differ substantially from the predicted values.

Fungus Resistance

Many applications require the use of cushioning materials inert to the effects of fungi; however, while fungus resistant materials are available, they should not be used indiscriminately. Practically any cushioning material can be made fungus resistant. The treatment usually involves impregnation of the material with a salt which may introduce undetectable corrosive elements.

Hydrogen Ion Concentration (pH)

The hydrogen ion concentration of the aqueous extract of cushioning materials has been considered traditionally to be somewhat of an indication of the inherent acidity and, therefore, the corrosiveness of the materials. Although its value for this is questionable, no better practical test of corrosiveness of cushioning materials has so far been developed. Therefore, this test is frequently specified for quality control purposes in cushioning specifications. A pH rating of 7.0 is considered to be "neutral" (neither acidic nor basic). However, the fact that a pH test indicates the aqueous extract of a material is 7.0 does not necessarily indicate that the material, when placed next to a ferrous metal in the presence of moisture or a humid atmosphere, will not cause corrosion.

Abrasive Qualities

Two aspects of abrasion relative to cushioning materials concern the container designer: (1) The inherent abrasiveness of the component material of cushion materials themselves, and (2) the capability of cushioning materials to prevent abrasion of the item by rough surfaces or projections of other objects (staples, surfaces or crate members, impinging corners of exterior containers of nearby packages, etc.).

Currently, no generally accepted test for the abrasion prevention capability of cushioning materials exists. One formidable obstacle deterring the development of such a test method is that little is known about the nature of the abrasion hazards of service on which such a test must be based.

Amounts of material required to prevent abrasion must be selected according to past shipping records, sound judgment, and common carrier regulations.

Tensile Strength and Flexibility

Minimum tensile strength and flexibility are customarily prescribed in cushioning material specifications in order to insure that the materials will not fail during normal handling and application.

Dusting and Fragmentation

Despite large differences in their composition, all cushioning materials, if subjected to rough handling, will release some fragments. Although further study is needed some investigators have reported that many cushioning materials when vibrated under maximum static load will disintegrate, the degradation of cushioning qualities is obvious. *It is strongly* *recommended that when the container is tested it be vibrated with its cushioning system under static stress loading.*

Even if failure of the cushioning is not catastrophic the liberation of a large number of fragments inside a package is objectionable because these particles tend to work into remote interstices causing possible damage and/or requiring considerable labor in cleaning before the item is usable. Outside a package, the liberation of such particles may constitute a nuisance, both as litter and airborne particles.

APPLICATION TECHNIQUES

GENERAL

The effective and efficient utilization of bulk cushioning is dependent upon the configuration of the supporting pad and the strategic distribution of the material. The geometry of the protected item and the spatial limitations imposed by the container, limit and restrict the latitude of design; however, regardless of these limitations, the performance of the cushion is largely dependent upon the ingenuity and proficiency of the designer.

Based on the recommended design procedure presented, it may be assumed that the proposed application has been analyzed and that the optimum cushioning material has been selected. Having established the following, the designer can then proceed to develop his suspension system:

a. The best material for the specific application.
b. The dynamic characteristics of the material (Gm versus W/A).
c. The minimum cushion deflection (tm) required to mitigate the imposed shock (G) to within the fragility level (Gm) of the item.
d. The identification of accessible bearing points capable of supporting the suspended item.

The designer must next develop a suspension system which will:

a. Support and physically restrain the suspended item.
b. Position and locate the cushion to engage those item bearing points capable of withstanding the developed static stress (psi).
c. Not result in a static stress outside the optimum working stress range of the cushion material.
d. Not jeopardize or compromise the technical and economic aspects of the application.

It becomes evident that the developed stress imposed upon the cushion determines its protective qualities. As stress (S = W/A) is a function of the area of contact; and as the applied load is generally constant, the designer must select those bearing points which will provide adequate contact area and then use only as much of this area as is required to stay within the optimum working stress range of the dynamic response curve (Gm versus W/A) encompassing the pertinent Gm factor of the protected item.

This section provides guidance to assist in the development of a suspension system to satisfy the criteria of both technical and economic feasibility. Examples and illustrations are included to:

a. Suggest methods and proven concepts.
b. Stimulate the designer to develop other satisfactory techniques.

A. *Encapsulation*

Geometric Configurations

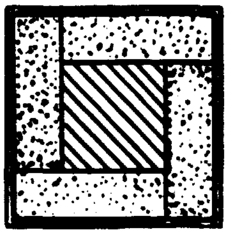


FIGURE 93. ENCAPSULATION

Sheet stock or blankets are used to engage the overall peripheral area of the protected item. The minimum thickness of the cushion is sufficient to mitigate to within the required protective level. The stress imposed upon the cushion by the protected item determines the density of the material used. The amount of cushion used is normally governed by the size of the container cavity and the need for physical restraint. Unless the container body can be tailored to the minimum cushion requirements, this method results in the excessive use of material.

Irregularly Shaped Items

The cushioning of irregularly shaped items often presents special problems, particularly when fragile projections are involved. A primary requisite is that adequate thickness of cushioning must be provided to prevent bottoming of projections. Therefore, the thickness of material to be provided must be measured from the outer container to the outermost projection - not to the item proper. Unfortunately, the effect of projections in reducing the effective thickness of cushions is often overlooked, especially in the production of molded cushions. This practice is illustrated in Figure 94 where the required thickness of material to protect all sides of the hypothetical item shown is represented by T_x.

Molded pads can be manufactured to fit and protect almost any item, regardless of shape or size. A typical example of a pack employing molded pads is shown in Figure 95. Such pads are usually custom designed and produced by the cushioning manufacturer.

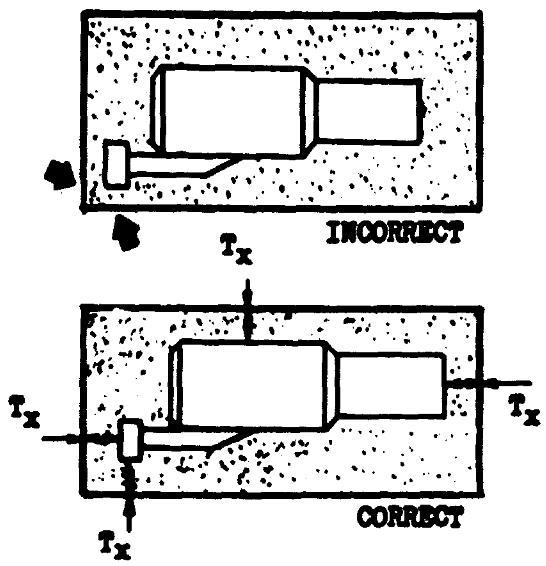


FIGURE 94. CUSHIONING OF AN ITEM WITH PROJECTIONS

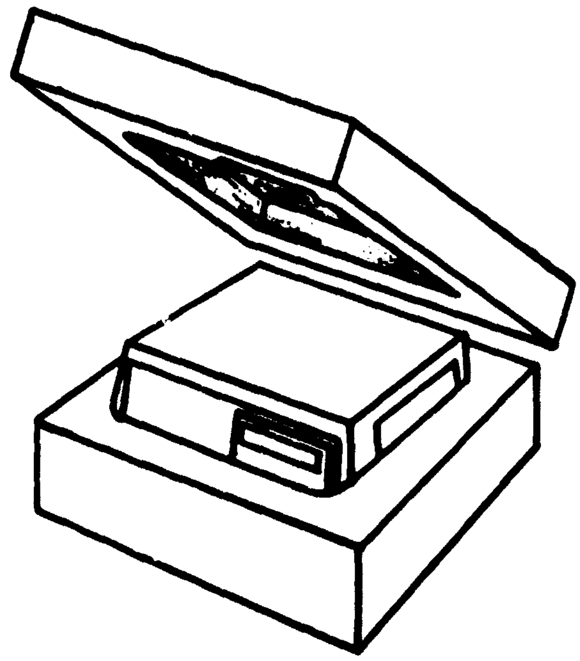


FIGURE 95. USE OF MOLDED PADS

In addition to being well suited to packaging of irregularly shaped items, molded pads are reusable and require less labor for application. However, since they are produced by custom lots, individual pads cost considerably more than equal quantities of sheet stock material.

B. Corner Pads

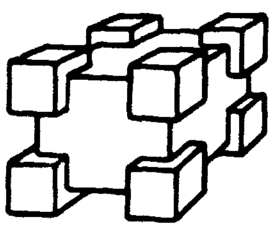


FIGURE 96. CUSHIONING WITH CORNER PADS

Properly designed corner pads can effectively protect items having square corners and which provide more than sufficient surface area to satisfy the cushion stress requirements. The versatility of this suspension scheme and its minimum use of material enhance its economic feasibility.

C. Yoke Supports

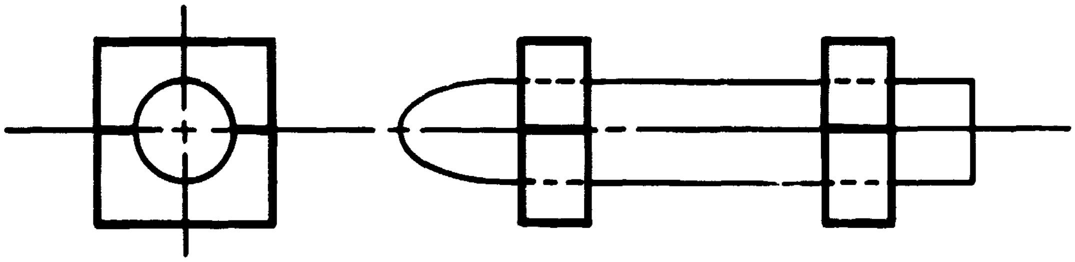


FIGURE 97. YOKE SUPPORTS

Yoke type cushion supports may be applied to protect irregular shaped objects where contact with the item is limited to specific bearing points. The number of yoke assemblies used is a function of the available bearing points and the load distribution of the cushioned item.

D. Bearing Area

The effective bearing area of items having basic geometric configurations can be conveniently determined by simple calculations. The area of that side or end subjected to the impact of a *free fall flat drop* must function to distribute this impact over as much cushion surface area as may be required to assure effective performance.

The calculation of the effective bearing area of basic geometric configurations subject to *cornerwise free fall drops* is rather complex. In cornerwise-drop tests of complete packages, specifications usually require that, when dropped, the corner to be impacted must be aligned along a vertical line through the center of gravity for the package (Figure 98). Upon impact the item, due to its inertia, tends to continue moving vertically downward without rotation, and the supporting cushioning (except that located in close proximity to the impacted corner) is loaded to some degree in shear. If an item was *completely encapsulated* in material, the effective bearing area, A_T, of the item for this situation is the projected bearing area in the horizontal plane of the three sides adjacent to the impacted corner of the item. For example, the effective bearing area of the hypothetical homogeneous item depicted in cornerwise-impact attitude in Figure 98 would be the summation of the shaded areas shown in the top view. This area can be measured by light projection methods or it can be computed for the different conditions described below.

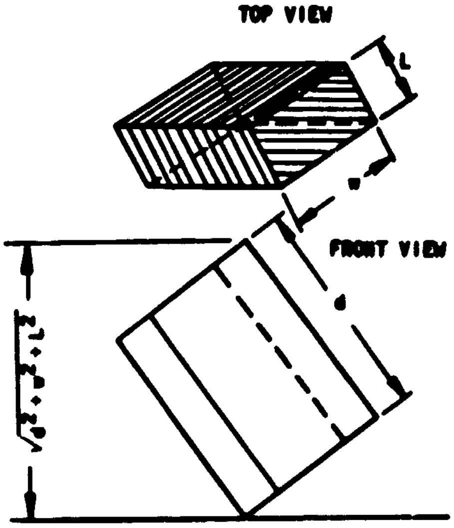


FIGURE 98. HYPOTHETICAL HOMOGENEOUS ITEM IN CORNERWISE IMPACT ATTITUDE

Obviously, A_T is a function of L, w and d of the item. For any item that is a rectangular prism, the relationship between A_T and L, w and d is:

$$A_T = \frac{3(L)(w)(d)}{\sqrt{L^2 + w^2 + d^2}}$$

If the item is a cube, the equation reduces to:

$$A_T = 1.73\ L^2$$

The effective bearing area of irregularly shaped items subject to flat and cornerwise impacts can be found by light projection methods. This can be accomplished by holding the item on the floor in the proper impact attitude directly below an illuminated light bulb. The effective bearing area is the area within the shadow cast by the item. The bulb being located a sufficient distance away so as to minimize the error caused by parallax.

The described light projection method for determining effective bearing area of items is suitable when the cushioning material is to be applied by complete encapsulation, but it is unsuitable for application by corner or side pads.

The effective bearing area (A'_T) of corner pads functioning to protect items subject to cornerwise impacts, is also a function of L, w and d of the item. A'_T is given as:

$$A'_T = \frac{S^2 (d + w + L)}{\sqrt{d^2 + w^2 + L^2}}$$

Where S is the length of the side of one of the corner pads.

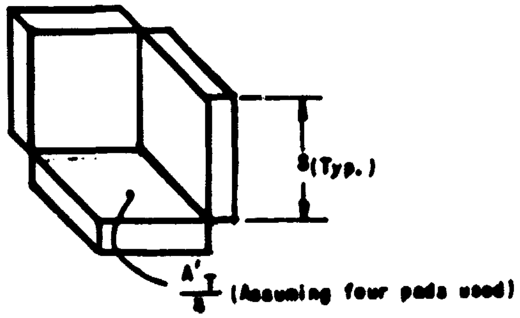


FIGURE 99. EFFECTIVE BEARING AREA OF CORNER PADS

Because of the complexity of the phenomena involved, it is not feasible to calculate A_T when side cushioning pads are used. In such instances, the most practical recourse for the designer is simply to bypass the analytical check for cornerwise drop protection. However, *it is essential to check the effectiveness of the design for both flat and cornerwise drop protection by conducting actual tests of the complete package.*

The effective bearing area of semicircular yoke support cushions is equal to the product of the diameter and width of the yoke.

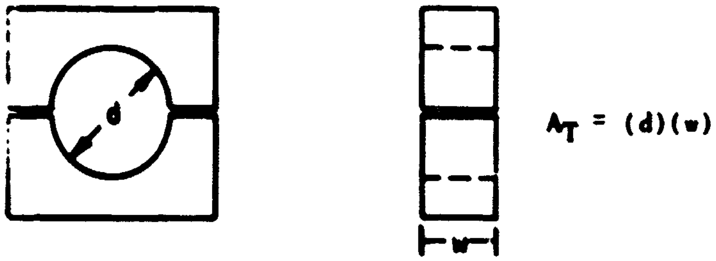


FIGURE 100. EFFECTIVE BEARING AREA OF SEMI-CIRCULAR YOKE SUPPORTS

E. Bearing Area Adjustment

The use of a cushioning material in its optimum load-bearing range often requires the use of a pad size greater or less than the full bearing area of the load producing protected item. In general, this is necessary to minimize peak impact forces by allowing light items to compress the cushioning material appreciably and preventing heavy items from bottoming during impact. Common techniques for obtaining cushioning bearing areas either larger or smaller than the adjacent sides of the items are discussed below.

Increasing Bearing Area - The principal device employed to increase the load-bearing area of an item against a cushion is a load spreader or platen (Figure 101) usually made of fiberboard or plywood. The designer should select platens that are stiff enough to distribute the load without flexing appreciably.

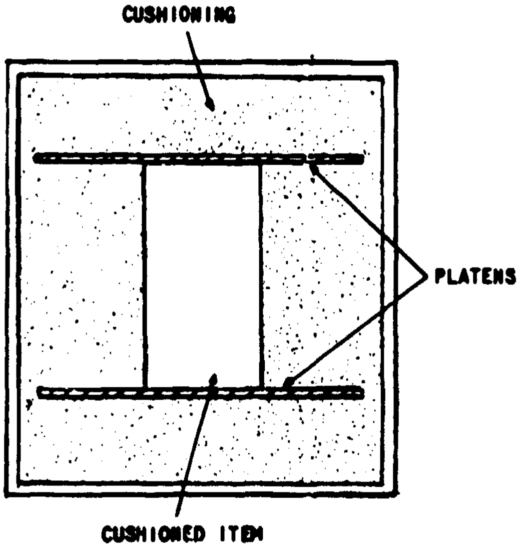


FIGURE 101. LOAD BEARING PLATENS USED TO INCREASE THE BEARING AREA OF AN ITEM AGAINST CUSHIONS

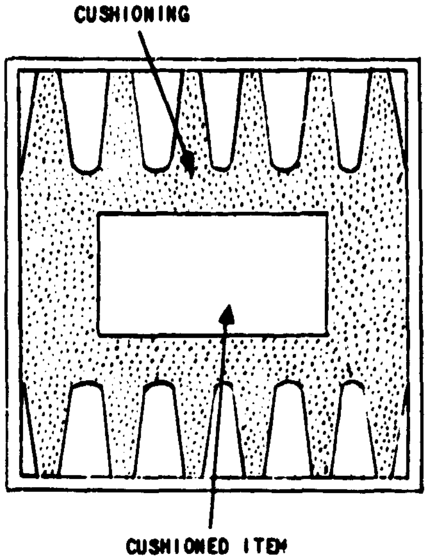


FIGURE 102. RIBBED CUSHION USED TO REDUCE THE BEARING AREA OF AN ITEM AGAINST CUSHIONS

Reducing Bearing Area - Reduction of bearing area of an item against its cushion can be achieved by making the outside bearing of the cushioning less than the inside bearing area of the cushioning. This is easily accomplished in foamed cushioning materials by molding ribs into the cushion (see Figure 102). This method of cushioning is recommended, as an item subjected to shock loading remains firmly encapsulated tending to offset the detrimental effects of compression set and the resulting loss of restraint of the packaged item. Although the item and cushion as a unit may be loose within the outer container, the cushion will provide greater protection to the item than if the item were loose in the cushion.

Bearing areas can also be reduced by the use of corner or side pads.

CUSHION DESIGN WITH ACCELERATION VERSUS STATIC STRESS CURVES

SHOCK ABSORPTION

Peak acceleration versus static stress (G_m versus W/A) curves have generally been proved to be the most practical basis for indicating the shock absorption capability of cushioning materials. The acceleration-static stress curve is essentially a plot of the variation of maximum acceleration (or deceleration) as a function of the static weight per unit area of the load. A single acceleration-static stress curve represents the dynamic compressive response of a single cushion of a particular thickness, density, type, etc. Several acceleration-static stress curves for different thicknesses of a flexible polyester urethane foam are shown in Figure 106.

The shapes of G_m versus W/A curves indicate the versatility and efficiency of the materials. The closer the curve approaches $G_m = 0$ the better protection a material will provide. Materials characterized by curves occurring through a broad W/A range are more versatile than those that extend through a more limited range. Using G_m versus W/A curves the designer has the advantage of reading the static loading required for any G directly from the plot.

Having available acceleration-static stress curves, the designer can select the approximate amount of cushioning material required to protect the item. In using graphic data in the selection of the most satisfactory type of cushion, it is necessary to have knowledge of the weight, bearing area, and fragility of the item to be packaged. The more accurately these values are known, the more accurate will be the cushioning design. Then, the point which corresponds to the static stress (W/A) and the fragility (G) is located on the graphs for the various materials being considered. The material at will protect the item are those which are represented by curves that pass through or below this point. Thus, the curves will indicate which types, thicknesses, and densities of material will protect the item and which will not.

SAMPLE PROBLEM: G VERSUS W/A

A hypothetical problem will illustrate how G versus W/A curves are used. The problem is to determine the most suitable material to package an item weighing 60 pounds and having a bearing area of 300 square inches. The fragility of the item is stated as 50G and it must be given protection for a 30-inch flat drop.

In solving this problem, the static stress of the item is calculated as:

$$\frac{W}{A} = \frac{60}{300} = 0.20 \text{ psi}$$

Then, a check of Figure 106 for the point corresponding to a fragility factor (maximum deceleration value) of 50G and a static stress of 0.20 psi reveals that a flexible urethane foam, 1-3/4 inches thick and having a density of 2 pounds per cubic foot, will protect the item adequately for the free fall flat side drop specified.

FLAT SIDE DROP - SAMPLE PROBLEM

A 37 pound, 18 inch square 27 inch long item with a fragility of 60G must be protected from *30 inch flat drops on its sides.* If urethane foam of 2 lb/ft^3 density is to be used as a cushion, see Figure 106, determine what thickness and size of cushion must be used for protection by:

1) Side Pads, 2) Corner Pads.

The W/A of any side is:

$$\frac{W}{A} = \frac{37 \text{ lb.}}{(27)\ (18)\ \text{in}^2} = 0.076 \text{ psi}$$

In Figure 106 point "A" represents the coordinates 0.076 psi and 60G. The curves indicate that a minimum thickness of 1-1/2 inches is required for adequate protection.

Side pads 1-1/2 inches thick and 18 by 27 inches can be used, see Figure 103; the designer should realize that these might not be the smallest size that will furnish adequate protection.

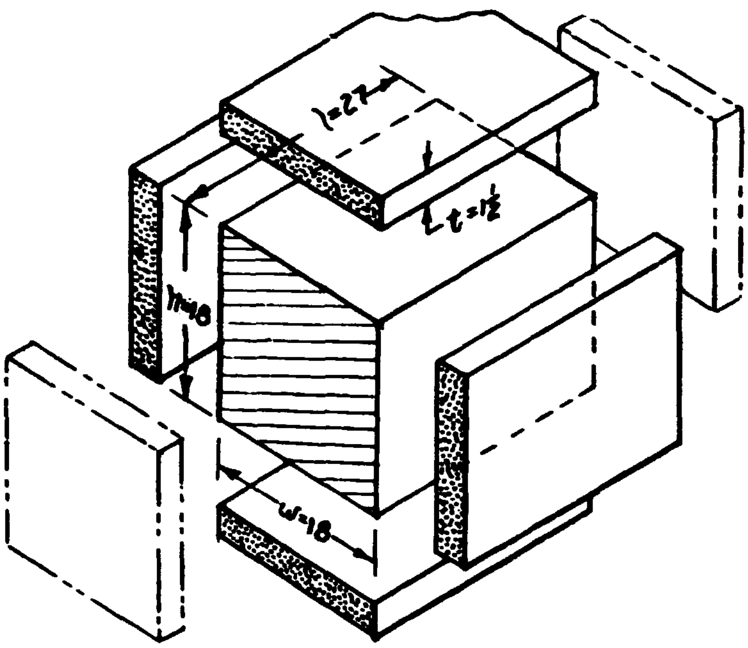


FIGURE 103. CUSHIONING WITH SIDE PADS

In checking the possibility of using smaller side pads, the fragility rating and weight of the item are fixed, but the bearing area of the item against the pad can be changed. Examining the curve for urethane foam it can be seen that adequate protection can be obtained in the W/A range from about 0.06 to 0.13 psi.

The greatest saving of material will result from using the *highest* value of W/A, since this would involve the least bearing area, and therefore size of cushion. In this case the highest value of W/A that will provide adequate protection with minimum area is 0.13 psi; point "B" on Figure 106. The required ar a, 'A' can be computed by:

$$\frac{W}{A} = 0.13 \text{ psi}$$

$$A = \frac{W}{0.13}$$

$$A = \frac{37}{0.13}$$

$$A = 285 \text{ in}^2$$

The length of the side pad required with a width of 18" and an area of 285 in^2 is:

$$A = wl$$

$$l = \frac{A}{w} = \frac{285}{18}$$

$$l = 15.8 \text{ in}$$

Rather than use one side pad 18 by 15.8 inches a better solution would be to use three pads each 1/3 the length l. A set of three 18 by 5-1/4 inches, 1-1/2 inch thick pads will give adequate protection; as of course will any combination of pads providing 285 in^2 of bearing area (see Figure 104).

The use of corner pads provides four small pads for protection against flat drops perpendicular to each side. The required size of each corner pad would be:

$$S^2 = \frac{A}{4}$$

$$S = \sqrt{\frac{285}{4}}$$

$$S = 8\frac{7}{16} \text{ in.}$$

Each pad would be 8-7/16 by 8-7/16 by 1-1/2 inches (see Figure 105a).

For added protection against bottoming during cornerwise impacts, it is usually prudent to fill the void spaces along the edges (see Figure 105b).

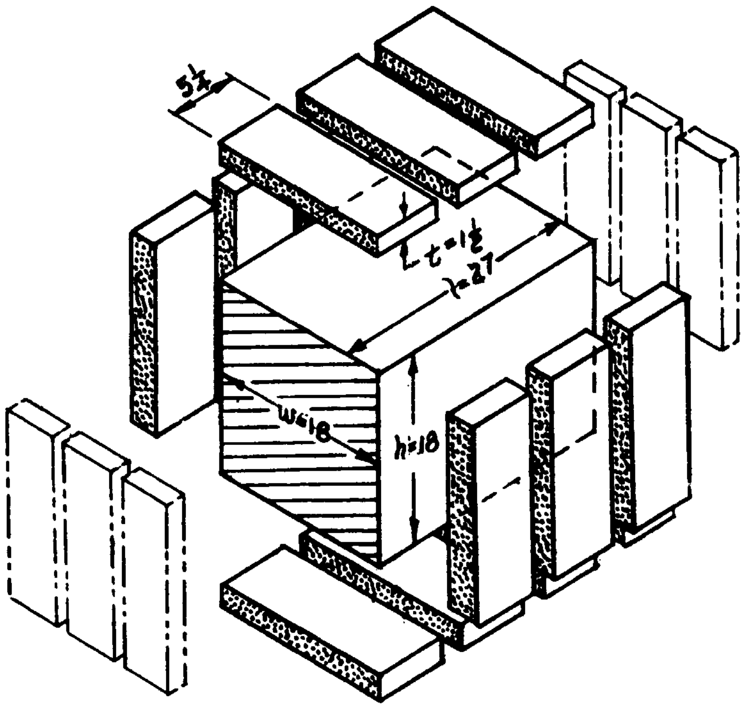
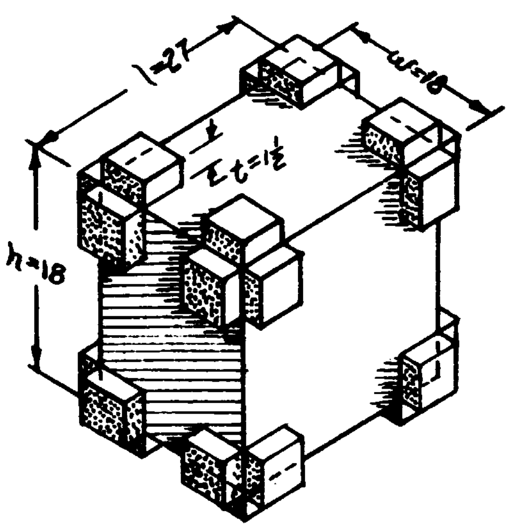
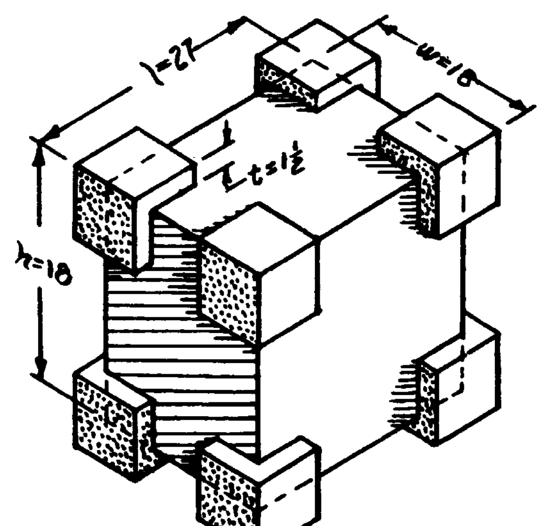


FIGURE 104. SIDE PADS



(a) CORNER VOID



(b) CORNER FILLED

FIGURE 105. CORNER PADS

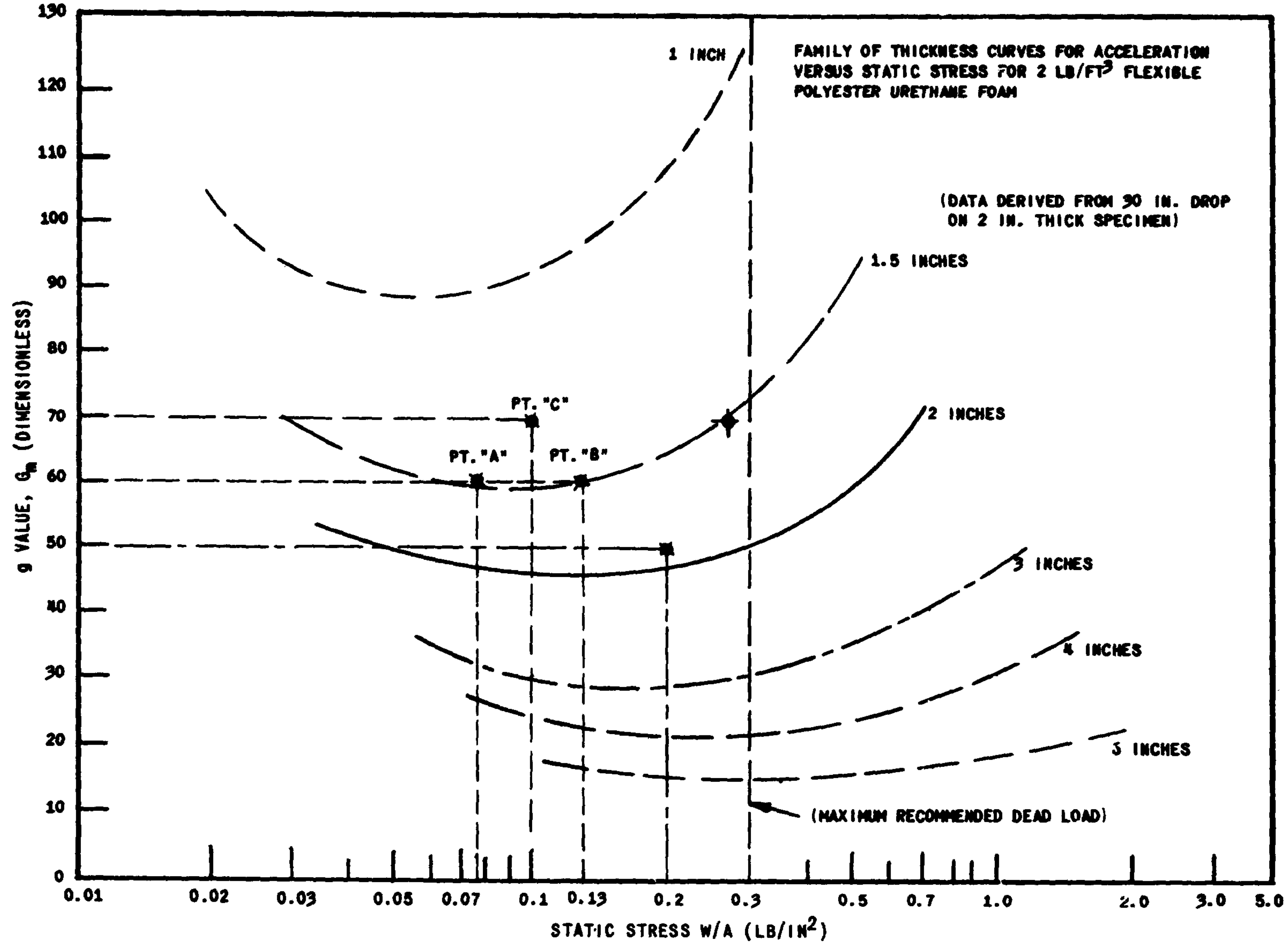


FIGURE 106. TYPICAL ACCELERATION-STATIC STRESS CURVES

The above calculations have provided a solution for the protection required from flat drops of the item on its sides; the protection required for flat drops of the item on its ends should be calculated in a similar manner. Such calculations will show that the side pads, shown in phantom in Figures 103 and 104 will provide adequate protection as will the corner pads shown in Figure 105. The most economical and convenient of these three methods should be chosen as the final design. This will depend on the design of the outer container, the number of items to be packaged, and the sizes of cushioning available commercially.

When calculating the thickness of the cushioning required, it is a good rule-of-thumb to *allow an additional 1/3 of the calculated thickness* in order to prevent the possibility of the packaged item bottoming.

CORNER DROP - SAMPLE PROBLEM

Determine the amount of flexible polyester urethane foam, 2 lb/ft^3 density, that would be required to protect a 30 pound, 6 by 6 by 48 inch item from *30 inch flat and corner drops*. The item will be *completely encapsulated* in foam and will be placed in an aluminum modular-type case. The fragility factor of the item is given by the manufacturer as $G_m = 70$.

The bearing area of each side is:

$$A = (6)(48) = 288 \text{ in}^2$$

$$\frac{W}{A} = \frac{30}{288} \simeq 0.10 \text{ lb/in}^2$$

The curves in Figure 106 show that for coordinates of $G_m = 70$ and $W/A = 0.10$ lb/in^2, point C, an approximate cushion thickness of 1-3/8 inches will provide adequate protection for a 30 inch flat drop.

The projected bearing area for a corner drop is calculated using the following equation:

$$A_T = \frac{3(L)(w)(d)}{\sqrt{L^2 + w^2 + d^2}}$$

$$A_T = \frac{(3)(48)(6)(6)}{\sqrt{(48)^2 + (6)^2 + (6)^2}}$$

$$A_T = \frac{5184}{\sqrt{2376}}$$

$$A_T = 106 \text{ in}^2$$

$$\frac{W}{A_T} = \frac{30}{106} = 0.28 \text{ lb/in}^2$$

Again from Figure 106 with the coordinates of G_m = 70 and W/A_T = 0.28 lb/in^2 the curves indicate that a thickness of 1-1/2 inches of foam would be required for adequate protection for a 30 inch corner drop.

Estimations involving adjacent cushions of different thickness. - - Design against flat drops (especially with rectangular items) often yields different thicknesses of cushioning material against the various sides. This disparity of thickness presents a slight problem in checking the adequacy of the same design for cornerwise-drop protection. However, in such instances, it is suggested that the designer should (1) calculate the effective bearing area for cornerwise impact; (2) determine from the curves the minimum required thickness, and (3) adjust the cushioning thickness of any of the sides, if necessary, to *comply with the minimum required thickness.*

STATIC COMPRESSIVE FORCE-DISPLACEMENT CURVES

The information on displacement of cushioning material by an item at rest is required by the packaging designer to estimate the maximum W/A for which a particular cushioning material should be used. Although the maximum amount of initial static compression of the cushion cannot be prescribed by rule, it is reasonable to restrict this to within 15 percent (a strain of 0.15) of the initial cushioning thickness. In some instances, the shape of the stress-strain curve provides a rather sharp indication of the maximum usable W/A value for the material. For example, with any of the urethane foam cushions represented by the compressive stress-strain curves shown in Figure 107, it is obvious that any W/A value that would load a material in the "plateau" region would be undesirable. Such a condition would cause the cushion to bottom immediately - without the probable additional settling due to creep. Therefore, with such materials, it is prudent to design so that the W/A does not exceed about 80 percent of the stress corresponding to the "knee" of the curve (at the abrupt change in elasticity at the low stress end of the plateau).

The amount of displacement of the cushion by the item at rest is also useful to the designer in the calculation of the inside dimensions for the exterior container. To prevent looseness, the container dimensions are calculated to be the minimum that will accommodate the cushioning and item while at rest. (NOTE: Exclude creep considerations when calculating the exterior container dimensions.) Accordingly, the displaced thickness of the cushioning that supports the item while at rest is discounted in the calculations. As a practical consideration, when the calculated container height occurs between multiples of 1/4 inch, the next lower multiple of 1/4 inch should be used. The following example problem is given to illustrate further the use of static cushioning displacement data.

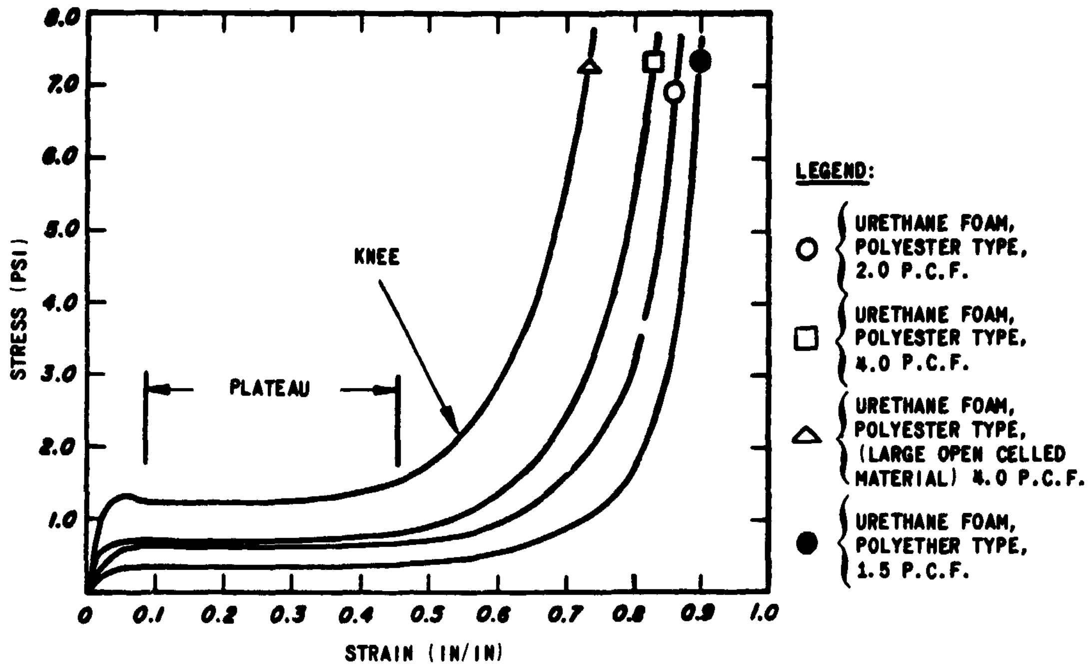


FIGURE 107. COMPRESSIVE STRESS-STRAIN RELATIONSHIP FOR DIFFERENT DENSITIES AND TYPES OF URETHANE FOAM

SAMPLE PROBLEM

A 36" by 5" by 5" item weighing 50 pounds is to be cushioned in 2-1/2 inches of fibrous glass by complete encapsulation. Determine what size of outer container is required to accommodate the item and cushioning.

$$\text{Bearing stress of the item} = \frac{50}{(36)(5)} = 0.28 \text{ psi}$$

The static compressive stress-strain curve in Figure 108 indicates that for this material at a static bearing stress of 0.28 psi, the material will deflect about 0.48 inches per inch of cushion thickness. Since the cushion is 2-1/2 inches thick, the total deflection is:

$$\text{Total deflection} = (2.5)(0.48) = 1.2 \text{ inches}$$

Therefore, the container inside dimensions would be:

$$\begin{matrix}\text{Container} \\ \text{height}\end{matrix} = \begin{matrix}\text{full thickness} \\ \text{of top pad}\end{matrix} + \begin{matrix}\text{item} \\ \text{height}\end{matrix} + \begin{matrix}\text{compressed} \\ \text{thickness of} \\ \text{bottom pad}\end{matrix}$$

$$h = 2.5 + 5 + (2.5 - 1.2)$$
$$h = 8.8 \text{ inches}$$

The width and length are calculated without an allowance for static compression. The inside dimensions of the outer container would be 8.8 by 10 by 41 inches.

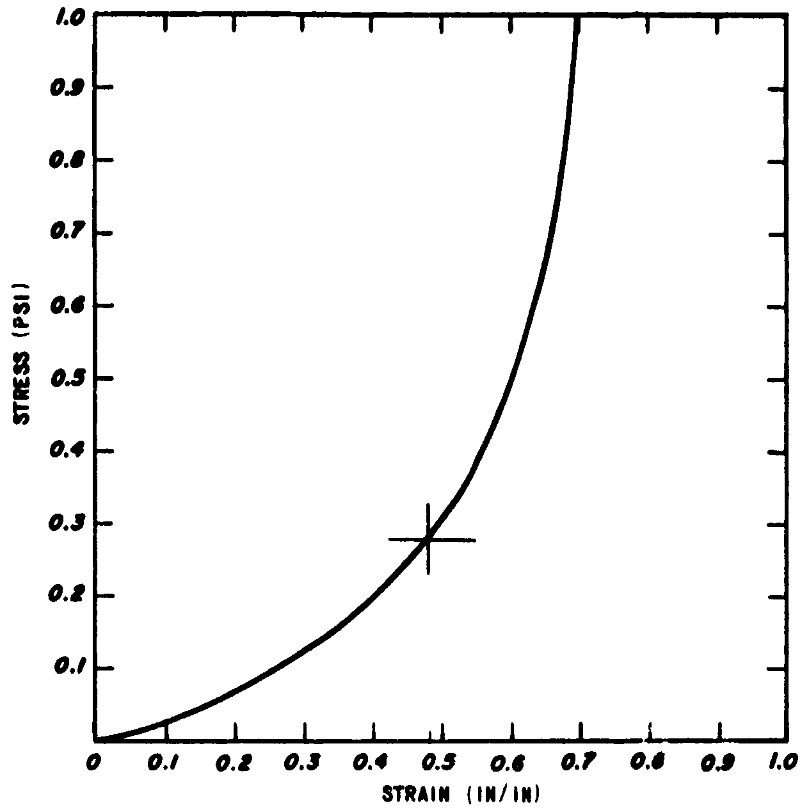


FIGURE 108. STATIC COMPRESSIVE STRESS-STRAIN RELATIONSHIP FOR FIBROUS GLASS

CUSHION DESIGN WITH "CUSHION FACTOR" CONCEPT

The "cushion factor" is a dimensionless ratio relating the maximum stress on the cushion to the energy absorbed by the cushion at this applied load.

$$\text{"Cushion factor," } C = \frac{f_m}{e_m}$$

This ratio has been converted to provide a more practical relationship using known factors to calculate the cushion thickness T, required for a particular application

$$T = \frac{(C)(h)}{G_m} \text{ or } C = \frac{(G_m)(T)}{h}$$

These data, with C plotted as the ordinate and f_m as the abscissa, produce what is known as a cushion factor-stress curve.

Two typical cushion factor-stress curves are shown in Figure 109. The materials represented by these curves are, as indicated, rubberized curled hair and flexible urethane foam. It is to be noted that each curve goes through a minimum with increasing stress. This minimum, or point of lowest cushion factor, is the point of optimum cushioning properties for the respective material since it represents the least thickness of material and consequently the maximum efficiency. Also indicated by Figure 109, the materials having broad curves - such as that shown for the flexible urethane foam - can be used to cushion items having a wider range of static loads than cushioning materials represented by relatively narrow curves.

The designer, having a requirement to protect an item of known weight and fragility factor (G_m), is then able to calculate the dynamic stress from $f_m = W G_m/A$ and to read the corresponding cushion factor from the graph. Finally, the required thickness, T, of cushioning material can be computed.

SAMPLE PROBLEM: C VERSUS f_m

A sample problem illustrates how cushion factor-stress (C versus f_m) curves and the design equations are used to determine the most efficient cushioning for a specific set of conditions. The problem is to determine the minimum thickness of cushioning material to be used to package an item weighing 100 pounds, having a fragility factor of 60 G's and a bearing area of 300 square inches. Assuming that the maximum drop height to which the package will be subjected is 30 inches, the following calculations should be made:

The maximum stress, f_m, can be computed by:

$$f_m = \frac{W\,G_m}{A} = \frac{(100)\ (60)}{300} = \text{20 pounds per square inch}$$

Then the minimum required thickness of cushioning material can be calculated. However, the value for C is obtained from the cushion factor-stress curve for the material to be used. Since the required thickness, T, of the cushioning material is proportioned to cushion factor, C, the packaging engineer selects the material having the lowest cushion factor corresponding to the maximum stress, f_m. Referring to Figure 109, it can be seen that in this instance urethane foam would be the more efficient of the two materials. Its cushion factor, corresponding to a dynamic stress of 20 psi, would be 4.8. Therefore, the required thickness, T, of urethane foam (polyester type, 2-pound per cubic foot density) is:

$$T = \frac{Ch}{G_m} = \frac{(4.8)\ (30)}{60} = 2.4 \text{ inches}$$

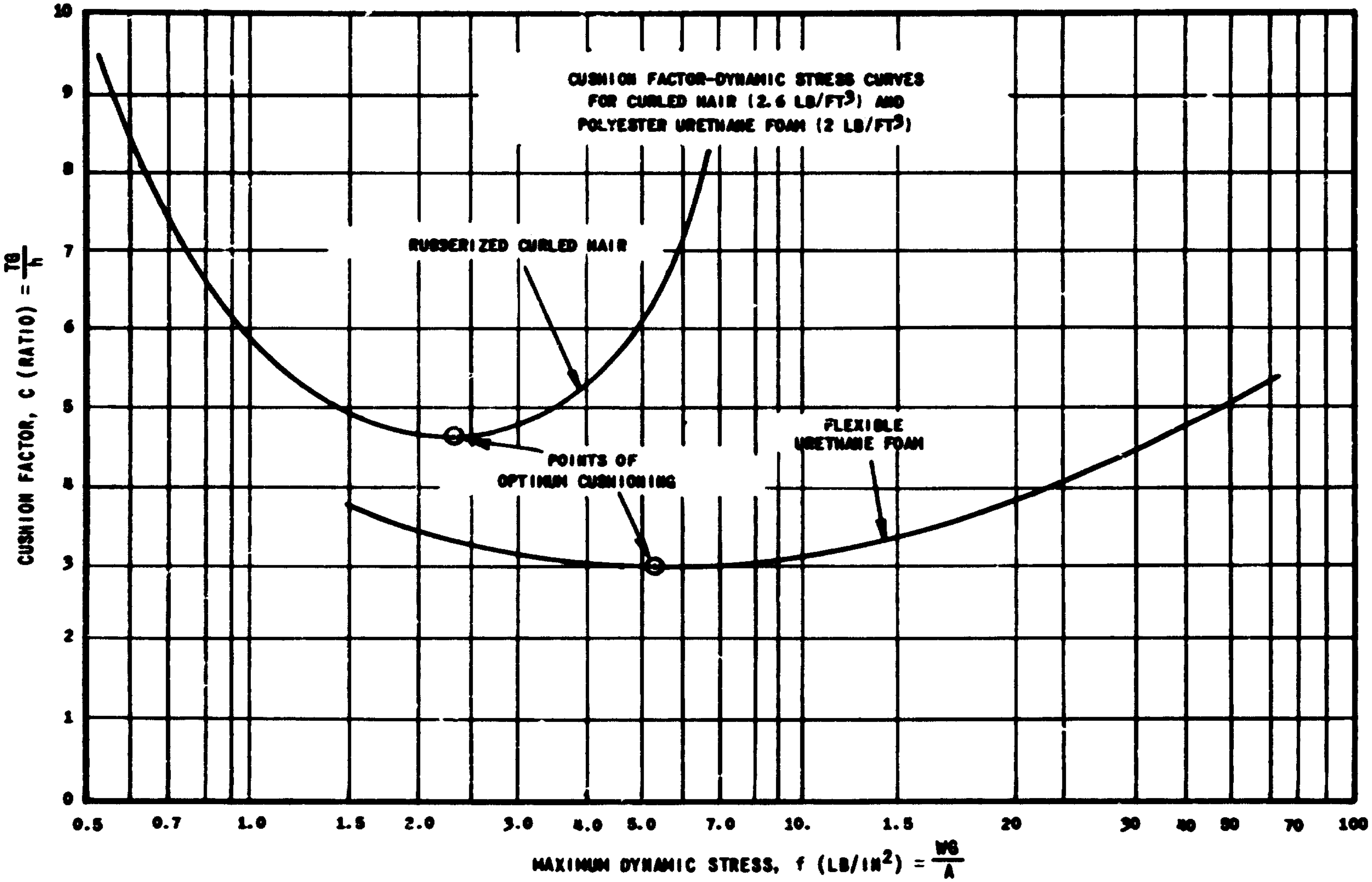


FIGURE 109. TYPICAL CUSHION FACTOR - DYNAMIC STRESS CURVES

LIMITATIONS OF "CUSHION FACTOR" METHOD

The potential of information of this type at one time appeared very large, since it permitted a single curve for a given density of material to be used in design work for several cushion thicknesses or drop heights. Then, having prepared a series of such curves for several different cushioning materials in varying densities, the designer was able to select the most efficient material by choosing the one whose cushion factor is at a minimum for a given dynamic stress.

However, recent studies carried out under Government auspices and in industrial laboratories - and using testing procedures complying with ASTM Test D1596-59T - have indicated that *cushion factor-stress curves are feasible for use principally with nonpneumatic materials. So-called "pneumatic" materials are those whose cushioning ability is abetted by the pneumatic effects contributed by their cell structure.* In such materials (e.g., some forms of flexible urethane foam), air is entrapped within the cushioning material and cannot escape in the time that the stress is applied. This is one reason why the static and dynamic test results for these materials are greatly different.

Moreover, it has been shown that pneumatic effects are dependent upon the dimensions of the test specimens. When some pneumatic materials are tested, it is found that the path of the cushion factor-dynamic stress curve changes as the thickness of the cushion being evaluated is varied. It is obvious, then, that data which varies with thickness cannot be used to determine the thickness of the cushioning required. *Therefore, when a cushion factor-dynamic stress curve is for any reason found to be impractical, acceleration-static stress curves should be used.*

COST AND TESTS

COST

If the designer makes an initial estimate of the amounts of different kinds of cushioning that will protect the item, his next step would be to compute the cost related to the use of the different materials and application methods. The minimum amount of material is not necessarily the one with the lowest overall cost. Often 4 inches of material A will cost less than 2 inches of material B. However, the thicker material will increase the container size; therefore increasing both the cost of the outer container and the cost of shipping.

Foam-type cushioning materials are usually sold by the pound as a result the density of a cushioning material affects its cost of usage. Generalizations about the correlation between cushioning performance and density of material should be avoided; many materials, especially plastic foams, exhibit little direct correlation between performance and density.

The method of fabrication directly affects the cost of cushioning; materials that can be purchased in slabs and simply cut to the desired size will be more economical than materials which must be molded to shape. This is especially true in low volume items where die and molding costs cannot be amortized over a large number of items. Often there is a reluctance to embark on a program involving molded cushioning because of the relatively high cost of purchasing a low number of cushions for testing and qualification with little assurance that they will provide the desired protection.

Included in the cost of a cushioning material should be the cost of protective coatings or treatments required to prevent degradation of the cushion under the environmental conditions encountered in its logistic pattern.

TESTS

The calculations described in the text will give a good first estimate of the cushioning requirements; however, vibration tests of the complete package must be conducted before the package design is finally accepted.

In order to obtain the true performance of the package *all testing must be progressive. Shock tests should be performed first then vibration tests should be conducted on the same cushioning and package.* It is further recommended that vibration testing on cushioning materials be conducted with the cushion under a static compressive load. This recommendation is made in order to preclude the possibility that the cushion will disintegrate under combined vibration and static stress loading. When testing containers for shock it should be noted that *flat drops of containers against their sides will generally transmit higher shock values to the item than any other type of drop.* Therefore, cushioning design is primarily concerned with providing ample flat drop protection. However, corner drops of containers are often required by acceptance tests in specifications; as a result the designer must be certain that his design, based on flat drop protection, will also provide sufficient corner drop protection.

In addition to shock and vibration tests, specifications will require that the container be subjected to other tests such as shock at low temperatures, moisture absorption, resistance to fungus, etc., (see Chapter IV for a description of tests).

CUSHIONING MATERIALS
THE RAMIFICATIONS OF MIL-C-26861A

GENERAL

Prior to the development of Military Specification MIL-C-26861A, all existing cushioning specifications contained qualitative requirements. The performance characteristics of cushioning materials, especially their shock absorption capability, were loosely and indirectly controlled. Therefore, considerable variation in performance between successive lots of materials was allowed. Since analytical cushioning design is based upon inference from data for previously tested material, variation in material performance produces a reduction in analytical design accuracy. MIL-C-26861A was developed primarily to enable the designer to procure cushioning materials with known performance characteristics.

MIL-C-26861A does not provide a complete solution to the cushioning performance stabilization and procurement problem. Its chief disadvantage is that procurement by this specification involves many classes and grades of materials and tends to be burdensome. Nevertheless, so far all research efforts devoted to development of a simpler classification method for cushioning performance (by the use of cushion factors and cushion factor-stress curves) without large inaccuracies have been unsuccessful. Therefore, despite its complexity, procurement by MIL-C-26861A is the most rational means available for the designer to obtain cushioning materials with known performance characteristics.

Because it contains performance-type tests and requirements and because it is desirable to reduce the number of specifications involved in procurement, MIL-C-26861A was written to include a variety of resilient cushioning materials (urethane foam, fibrous glass, expanded polystyrene, rubberized hair, etc.) MIL-C-26861A eventually may supersede such specifications as MIL-C-7769 (rubberized hair), PPP-850 (expanded polystyrene), and MIL-C-26514 (foamed polyurethane).

PRINCIPAL FEATURES OF MIL-C-26861A

The most important feature of MIL-C-26861A is the classification of cushioning materials in grades and classes according to their dynamic compression characteristics. However, the specification also contains provisions for evaluation and control of other characteristics, such as creep, static compressive force-displacement, compression set, density, tensile strength, pliability (flexibility), breakdown (fragmentation), hydrogen ion concentration (pH), and hydrolytic stability (stability during hygrothermal exposure).

CLASSIFICATION OF MATERIALS ACCORDING TO DYNAMIC COMPRESSION TEST DATA

To comply with the specification, the supplier must submit to the qualifying activity peak acceleration-static stress (G_m-W/A) curves for each kind, density, and thickness of cushioning material for a constant drop height. The qualifying activity then classifies the materials on a qualified products list according to how the curves intersect a grid composed of range limits for G_m and W/A. To be classified within a particular grade and class, the curve representing any particular material must occur *completely below* the boundary for the grade and through the entire W/A range represented by the class.

For example, the curve shown below represents a material that would qualify under class 1 as grades C and D; class 2 as grades A, B, C, and D; class 3 as grades B, C, and D; and class 4 as grade D.

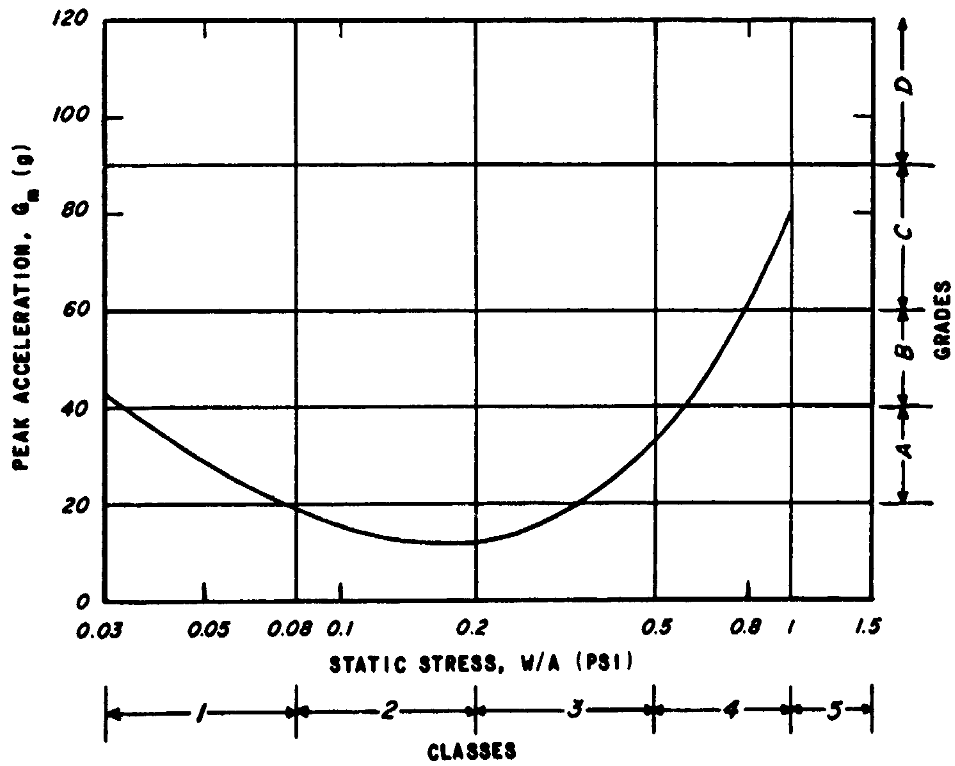


FIGURE 110. MIL-C-26861A CLASSIFICATION GRID SUPERIMPOSED UPON G_m-W/A CURVE FOR URETHANE FOAM

REQUIRED DYNAMIC COMPRESSION TESTING PROCEDURE

MIL-C-26861A requires the use of a dynamic compression testing procedure. This test procedure is based upon ASTM method D 1596-59T. At least three specimens of each kind and thickness of material must be tested with a constant equivalent drop height.

RAMIFICATIONS IN CUSHIONING DESIGN

As previously stated, a manufacturer wishing to have his cushioning material qualified under MIL-C-26861A must submit dynamic compression test data to the qualifying activity. This requirement will result in the derivation of cushioning performance data that have been previously unavailable. For qualification purposes, the performance tests of materials need be conducted only once by the manufacturer, providing that he certifies that the production process for subsequent lots is not altered. Since qualification of new (or altered) materials under MIL-C-26861A will entail some time delay and cost (due to testing), it is expected that these factors will tend to standardize cushioning materials and their dynamic compression characteristics.

Packaging designers are however, interested in cushioning data for drop heights other than the 24 inches, as required by MIL-C-26861A for qualification purposes. A requirement for such data was not included in the specification as to do so would raise the costs of qualification prohibitively. Dynamic compression test data are becoming more readily available as progressive manufacturers discover their value and conduct tests on their own initiative.

MATERIAL PROCUREMENT UNDER MIL-C-26861A

The packaging designer, having determined that he wishes to use a particular kind and thickness of cushioning material, must then determine its classification under MIL-C-26861A for procurement purposes. This should be accomplished by checking the official MIL-C-26861A qualified products list.

It is expected that users, once they have become familiar with the different MIL-C-26861A classes and grades for cushioning materials, will stock only the few commonly required combinations.

CHAPTER VIII

THE CONTAINER BODY
TYPE - CONFIGURATION - MATERIALS - DESIGN

GENERAL

The container body and its structural members provide an envelope to protect the suspended mass. The structural members function to support the suspension system and provide resistance to buckling and distortion. The body performs to shield the suspended mass and is often required to provide environmental protection by incorporating seals, valves and other auxiliary devices. In addition, the body or shell may, when pressurized, be required to perform as a pressure vessel capable of resisting the pressure differential of its environment. The container assembly must provide for compatibility with handling and storage operations. The complexity, configuration, size and weight of the container must not hinder nor impede its utility and its cost must satisfy the criteria of economic feasibility.

The primary function of the container assembly is to provide protection to its contents. The container must compensate for the inability of the missile to resist the effects of its logistic environment. Too often, the protective level of the container provides superfluous protection. Many missiles have, inherent within their design, characteristics which are capable of resisting the effects of the hazards encountered. Obviously, if the container also functions to protect against these same hazards the container is over-designed and the protection provided becomes superfluous. The container concept must consider the ability of its contents and compensate for only those deficiencies pertinent to the applicable environment.

The nature of the contents to be protected, dictates the size of the container. The factors affecting size are:

a. The physical dimensions of the suspended mass.

b. The sway space, or deflection required to protect to within the fragility level of the suspended mass.

c. The suspension system and its hardware necessary to support and restrain the suspended mass.

Quite often, the capacity limitations of transit media and the human engineering factors prevalent in the logistic environment restrict the size of the container. It may be necessary to dismantle the missile assembly and house its components separately. Typical items currently housed within containers falling within the scope of this document include:

a. Completely assembled missiles and rockets.

b. Major subassemblies of missiles and rockets.

c. Loaded solid propellant motors.

d. Unloaded, or inert propellant motors.

e. Live warheads.

f. Inert warheads.

g. Appendages (fins, wings, etc.)

h. Ancillary Equipment.

The practice of shipping sections of large missile systems as separate items is common and quite prevalent within the Army. The many containers constituting a system may be considered a family and as such should have common characteristics. To minimize logistic support and to reduce operational complexity, those components common to containers within the same system should be identical provided their use does not degrade or compromise performance.

TYPES

There are, within the Army Missile System, two general types of containers:

a. Top or Chest Opening.

b. End Opening.

The distinguishing characteristic of the top opening container, normally used for large missile or missile components, is the full-length cover often hinged or capable of vertical lift-off.

The end-opening type, as the name implies, includes removable ends to permit longitudinal withdrawal of the contained missile.

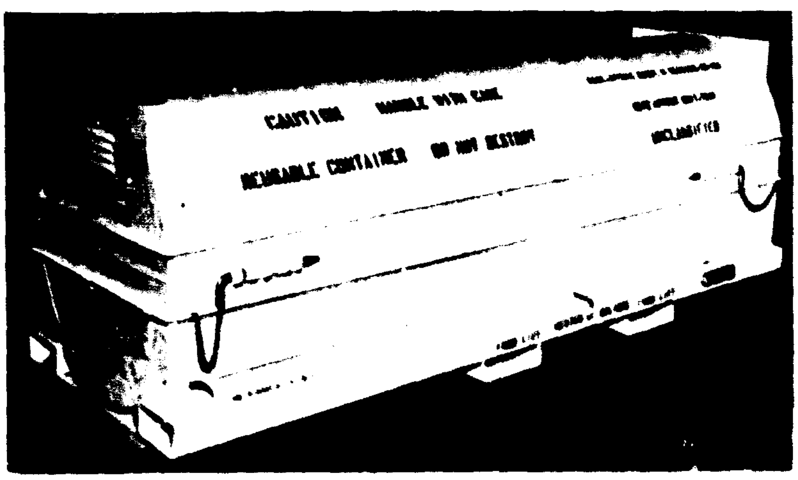


FIGURE III. TOP OPENING CONTAINER

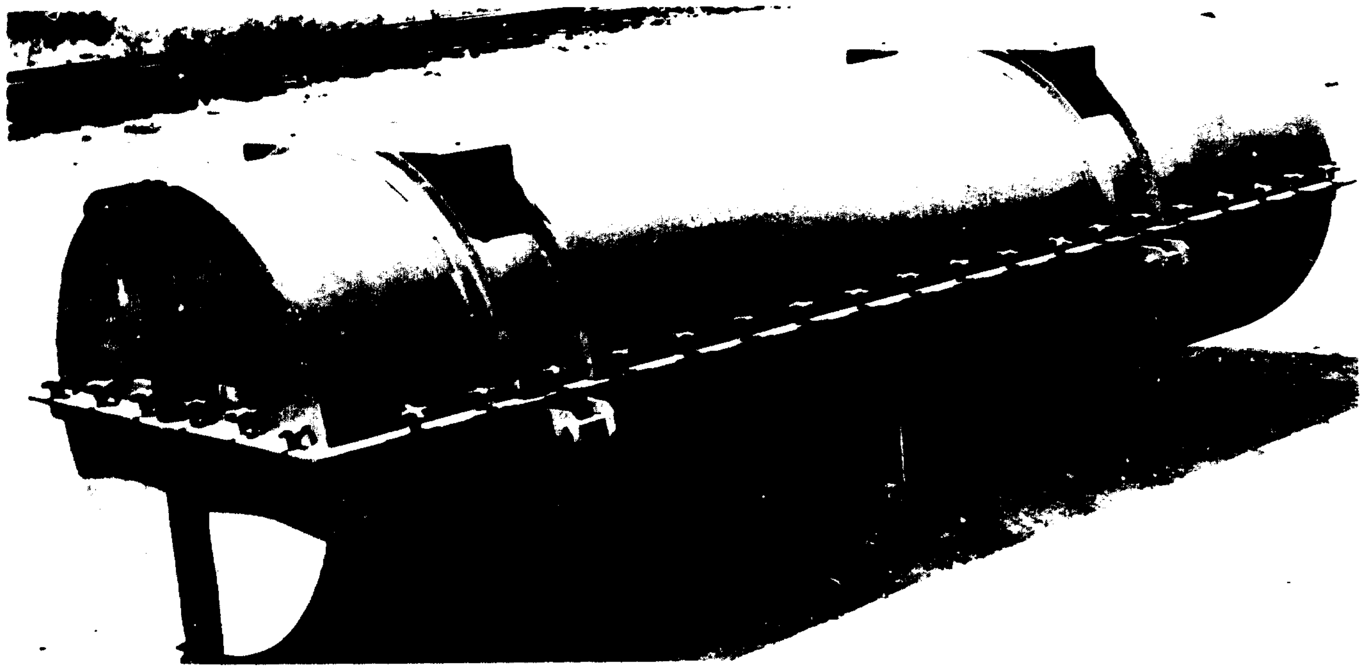


FIGURE 112. TYPICAL TOP OPENING CONTAINER. NOTE EXCESSIVE NUMBER OF CLOSURES

ADVANTAGES OF TOP OPENING CONTAINERS

a. Complete accessibility of the container interior.

b. Provides for a relatively simple suspension system as compared to that required for other types.

c. Permits for the convenient manual removal of the contents or by any available overhead lifting device.

d. Accessibility to all portions of the container interior facilitates maintenance and repair.

e. The design requires less cubage resulting in less overall weight and consequently is less costly than other types.

DISADVANTAGES OF TOP OPENING CONTAINERS

a. A large, heavy and often unwieldly cover must be removed to gain access to the contained item.

b. Top-opening containers separate longitudinally and require a longer seal when such a barrier is required. As the effectiveness and reliability of a seal varies with its length, the design of the seal joint becomes more critical with an increase in length.

c. Precautions must be taken to avoid lifting the container through its cover as to do so would subject the closure hardware to stresses beyond their design capability.

d. The lengthy seal of a top-opening container requires relatively more closures than other types to provide an effective barrier.

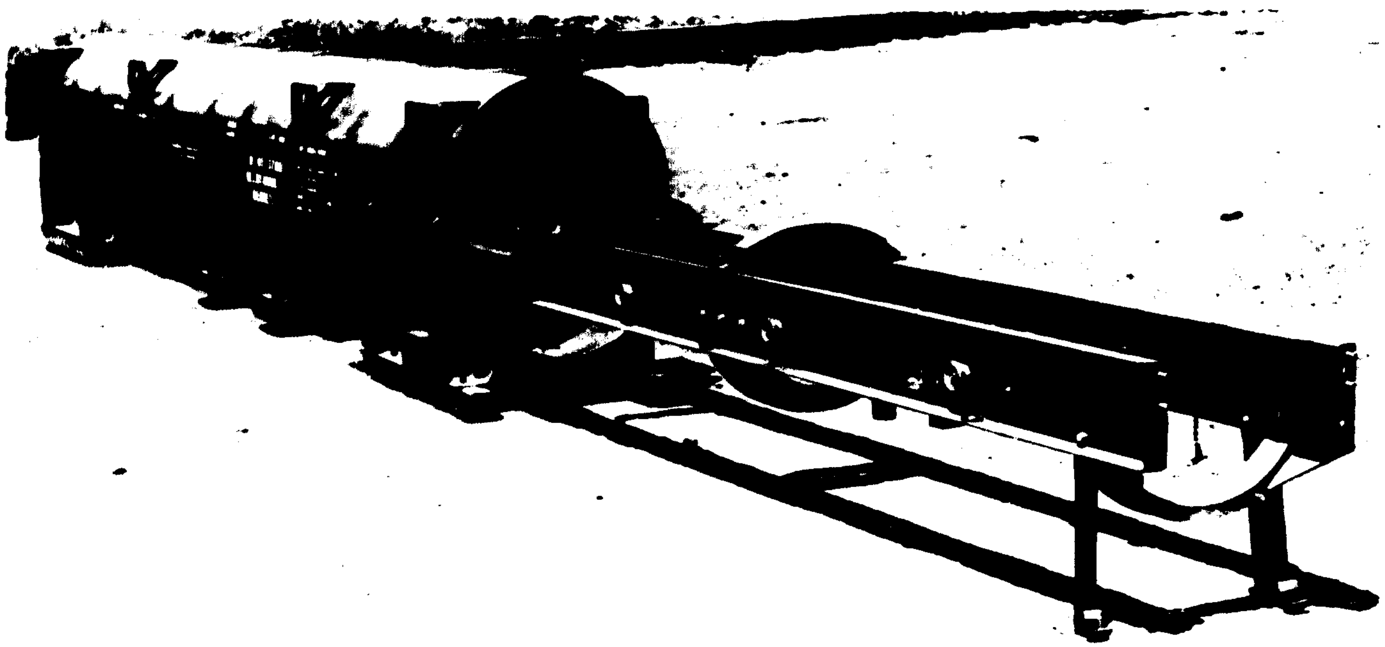


FIGURE 113. TYPICAL END-OPENING CONTAINER

ADVANTAGES OF END-OPENING CONTAINERS

a. The seal is simplified and more effective by virtue of its relatively short length.

b. Less closure hardware is required.

c. End covers are small and easily handled as compared with the large unwieldly covers of top-opening containers.

d. The container may be lifted from either the top or bottom with the only restriction limited to the removable end or in containers longer than five feet, both removable ends.

e. End-opening containers due to their configuration provide a shield to both their contents and to their interior to resist penetration of rain, snow, etc., even when the ends are removed.

DISADVANTAGES OF END-OPENING CONTAINERS

a. The need for a complex suspension mounting system results in a considerable weight penalty and introduces a complex, erratic mechanism.

b. Increased maintenance costs result from the need for a complex, telescopic, roll-out suspension system.

c. Malfunction of the suspension support structure would prevent access to and removal of the container contents.

d. The longitudinal removal of the contained missile requires the availability of often limited floor space.

e. Auxiliary bipods or struts are required to support the cantilevered missile.

f. Longitudinal transfer of the load CG results in a lack of stability with tip-over a potential safety hazard.

g. Complexity of design requires excessive logistic support.

h. The complexity of the support mechanism introduces potential areas of failure and compromises performance reliability.

HINGED COVERS

Many designs include hinged covers with spring, torsion bar, or counterweight assists; however, it has been found that these accessories merely add to the complexity of the design and complicate the logistic support requirements. The size and weight of the cover is proportional to the size and weight of the contained contents. As such, it may be assumed that if handling equipment is required for content removal, the availability of such equipment precludes the need for hinges, springs, etc., to assist in manual lift of a hinged cover. Therefore hinged covers are not recommended for containers.

However, where the contents are within the weight limits established for manual handling it may be advantageous to hinge the cover; in such instances the cover is small and lightweight and will require no complex, erratic assist mechanism.

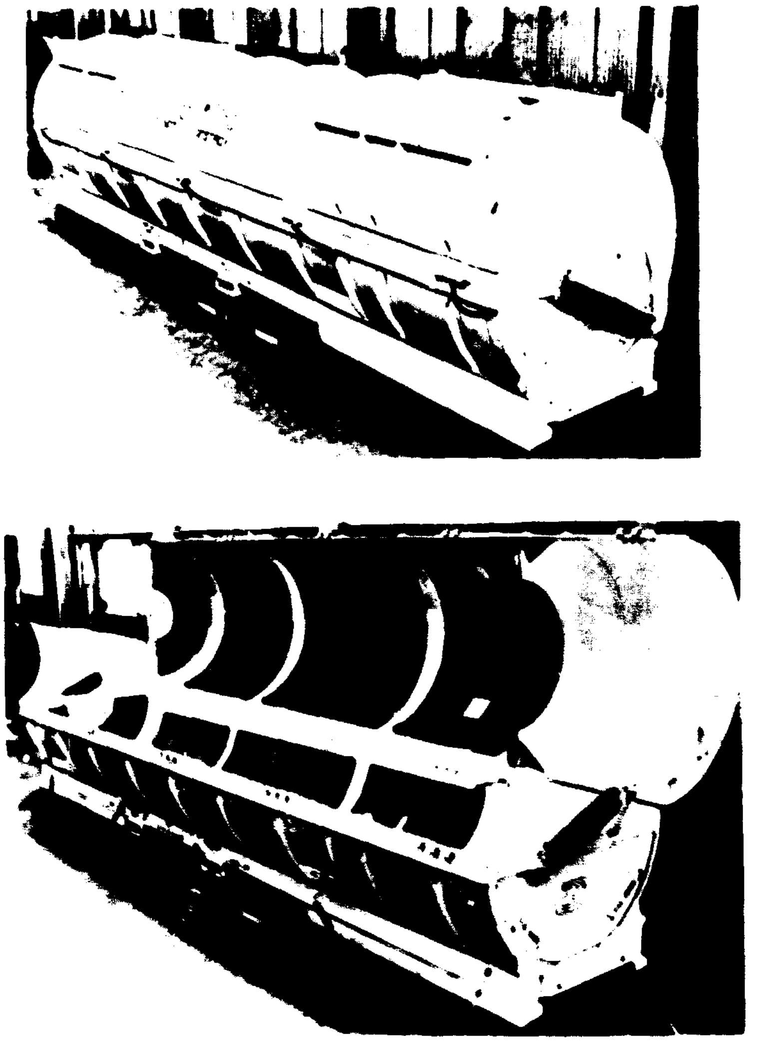


FIGURE 114. HINGED COVER WITH SPRING ASSIST

SMALL CONTAINERS • BODY TYPES

Containers whose gross weight does not exceed 150 lbs. and which are capable of being handled manually, may be classified as "small." Generally, the shock suspension system for lightweight contents is either simple or of the bulk cushion type and the body structure is divorced from the need to provide localized support. As the container can be handled manually, those accessories necessary to accommodate mechanical handling devices, need not be included.

The small container may be required to provide either or both physical and/or environmental protection. For contents whose requirements include environmental protection, an end-opening type having a shorter seal may be preferable to the top-opening type. Those containers providing only physical protection may use any of the numerous schemes currently used in military packaging.

Small containers may be considered as sophisticated packages and subject to the techniques applicable to Military Packaging adequately documented in existing DOD publications. TM 38-230, "Preservation, Packaging and Packing of Military Supplies and Equipment" is typical of the many documents providing guidance in packaging technique.

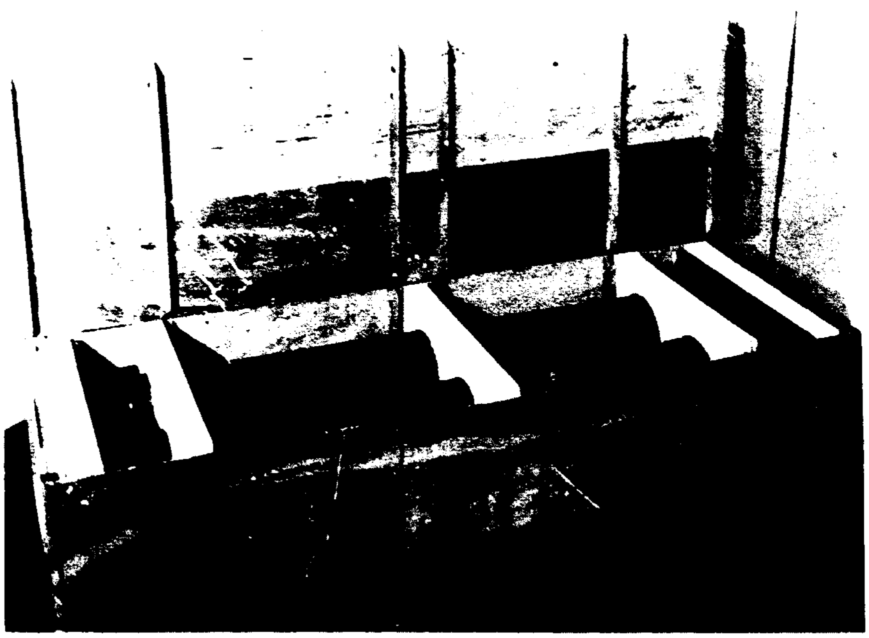


FIGURE 115. SMALL, WOOD, WIREBOUND OVERPACK CONTAINER WITH FOAM PLASTIC YOKE TYPE SUSPENSION. HERMETICALLY SEALED CONTENTS REQUIRE ONLY PHYSICAL PROTECTION.

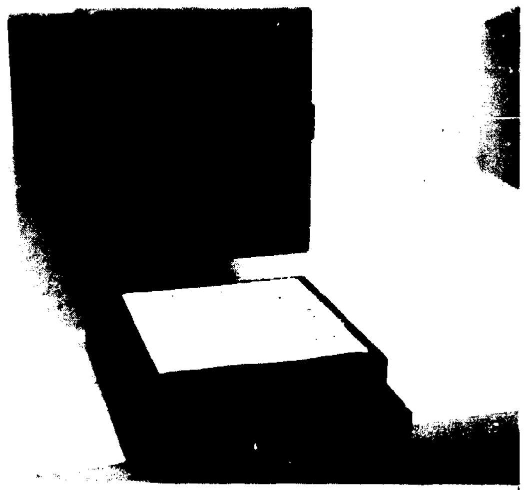


FIGURE 116. SMALL, END-OPENING, SEALED CONTAINER WITH FIBER GLASS CUSHION SUSPENSION

FIGURE 117. SMALL, SEALED, HINGED TOP CONTAINER WITH CURLED HAIR CUSHION SUSPENSION

CONTAINER BODY SIZE

The container size is primarily determined by the envelope of the missile or missile component, missile fragility level, and missile weight and weight distribution.

The principal factor affecting the size of the shipping container is the envelope of the suspended mass. As a general rule, ignoring clearances required for shock and vibration isolation purposes, a container of modest size, that is less than 5 feet in any dimension, may be expected to be at least 2 inches greater in outside dimensions than the envelope dimension of the contents. For larger size containers, where significant structural strength must be built into the container, the minimum increase in over-all exterior dimensions is on the order of one foot.

It should be noted that the dimensions discussed are concerned with the maximum dimensions of the contents. In the case of completely assembled missiles, the over-all wing span and not the body diameter must be considered as the basic limiting dimension for the proposed container. The cushioning clearances required are determined by the most delicate components of the complete assembly; therefore, the clearances required for the complete missile are considerably more than would be required for a majority of the individual components.

Early consideration of disassembly for shipment is of paramount importance. For example, assume a missile 7.3 feet long and equipped with cruciform airfoils with a 4-foot span, no portions of which may be disassembled after checkout. Allowing for a 6 inch deflection for the suspension system to protect delicate components, a shipping container like that illustrated in Figure 118 will result.

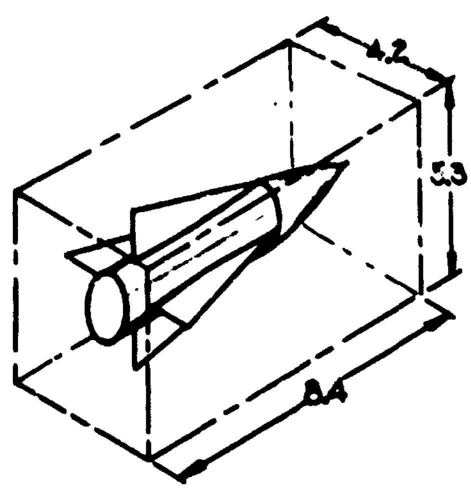


FIGURE 118. SIZE OF CONTAINER FOR A COMPLETELY ASSEMBLED MISSILE

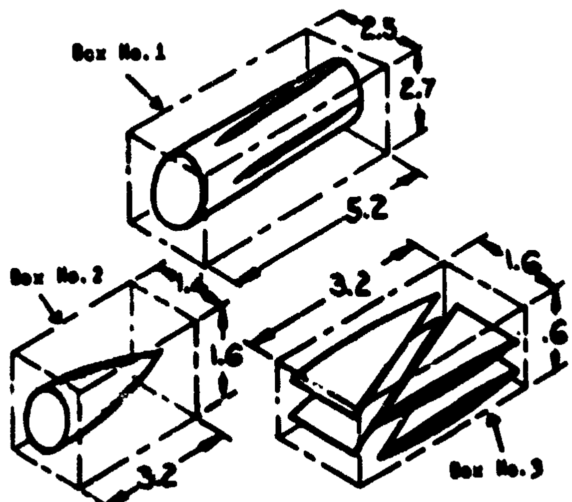


FIGURE 119. SAME MISSILE AS IN FIGURE 118 BUT KNOCKED DOWN

COMPLETE ASSY. BOX	= 186.98 cu.ft.
Box No.1	= 35.10 cu.ft.
Box No.2	= 7.17 cu.ft.
Box No.3	= 4.61 cu.ft.
TOTAL for K/D Shipment	= 46.88 cu.ft. = 25% of complete assy. box
CUBE SAVED	= 140.10 cu.ft. = 75% of complete assy. box

If the missile can be disassembled into three major groupings, it is possible to obtain a 75 percent reduction in cube size. In examining Figure 119, it will be noted that the 6 inch clearances for the delicate guidance section have been maintained but the more rugged warhead and the very rugged airfoils can be packaged in containers of considerably smaller size and complexity. While the savings shown in the foregoing example may be somewhat high, 50 percent cube reduction often is easily achievable. The necessity for intelligent planning of the missile design to permit partial disassembly for shipment (particularly removal of protruding airfoils and antennas) is obvious.

In planning for disassembly, however, the following points also must be considered, as well as orderly arrangement in the container:

a. Field reassembly conditions, such as tools, fixtures and skills available.

b. A boxing arrangement which permits reassembly in logical sequence.

c. Boxing arrangements compatible with deterioration prevention requirements.

d. Segregation of explosive and dangerous components.

The second most important factor determining overall size of the shipping container is the fragility level of the missile or missile component under conditions of storage, shipment, handling or test.

The third factor which affects the size of a shipping container is the missile weight and weight distribution. The content weight directly affects the container in the following ways:

a. It limits the styles of containers which may be selected.

b. Within a selected style, it has a major controlling influence on the sizes of container members and the types of joints.

c. Through its major effect on gross weight, it influences transportation cost.

d. It controls the type and capacity of shock and vibration isolation system selected.

e. It establishes handling requirements, manual or mechanical and the size and location of handling fittings on the container.

f. Assuming that cubage is within transportation limitations, it determines the number of items which may be transported by any given transportation unit; that is, single airplane, railroad car, or truck, and the number which can be put in any given storage space.

The weight distribution of the missile or missile component affects the container in the following manner:

a. Through the interrelation of weight distribution and missile size, it affects the overall size of the container, thus limiting the choice of container style.

b. It determines the size of container members. For example, for any given style of conventional container, the member sizes vary with whether the contents are an easy, average or difficult load. An easy load is an item which has low or moderate density conforming to the shape of the container, thus lending support to the container. An average load is an item which has low or moderate density and which when packed directly into a shipping container provides nonshifting support at several points in the container. A difficult load is an item characterized by irregular shape which does not lend support to the container or characterized by great density, great bulk or extreme fragility.

c. Weight distribution is of paramount importance in the design of the shock and vibration isolation system.

CONTAINER CONFIGURATION

The lateral cross section of the missile container may be in the form of any of the common geometric configurations or a composite of these basic forms. Many are basically round; others are square; and elliptical cross sections are quite common; however, in almost all containers, regardless of the basic configuration, the outer envelope periphery will invariably be square or rectangular. The square or rectangular form is most compatible with economical cubing patterns and provides stacking stability.

The nature and size of the suspended mass and its shock mitigating suspension affect the overall configuration. In addition, the material and the optimum fabricating methods peculiar to the material also contribute to the final shape of the container. In isolated cases, it may be necessary to apply pressure vessel design technique to withstand the effects of pressurization. There are numerous factors which must be considered in establishing an optimum container configuration; these include:

a. Size and nature of the proposed contents.

b. Sway space requirements.

c. Suspension system support requirements.

d. Pressurization requirements if applicable.

e. Need for providing environmental protection.

f. Field maintenance requirements.

g. Disposition of container - reusable or disposable.

h. Material and its characteristics.

i. Fabricating techniques peculiar to the material used.

j. Projected quantity requirements affecting manufacturing process.

k. Logistic requirements for stacking, hoisting and handling.

l. Human Engineering factors.

m. Cost limitations based on function as dictated by Value Engineering technique.

A typical container lateral cross section would be a composite of conventional geometric configurations. The elongated elliptical body would be supported by a series of rectangular trusses modified to include round corners for effective rollover performance. The number of trusses would vary with length and provide characteristics to result in optimum cubing and stacking patterns.

FIGURE 120. REINFORCED, WOOD, FREE BREATHING RECTANGULAR CONTAINER

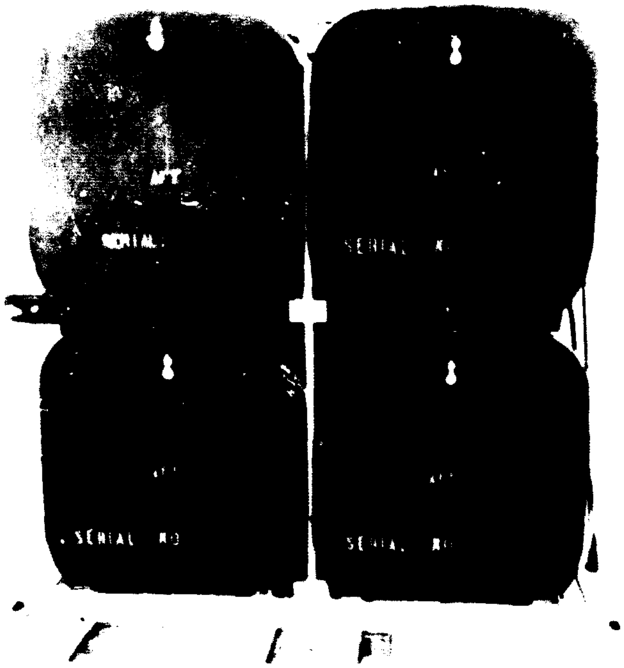


FIGURE 121. STEEL, END-OPENING, CONTROLLED BREATHING RECTANGULAR CONTAINER EQUIPPED WITH STACKING PADS, SKIDS, AND MODIFIED CORNERS

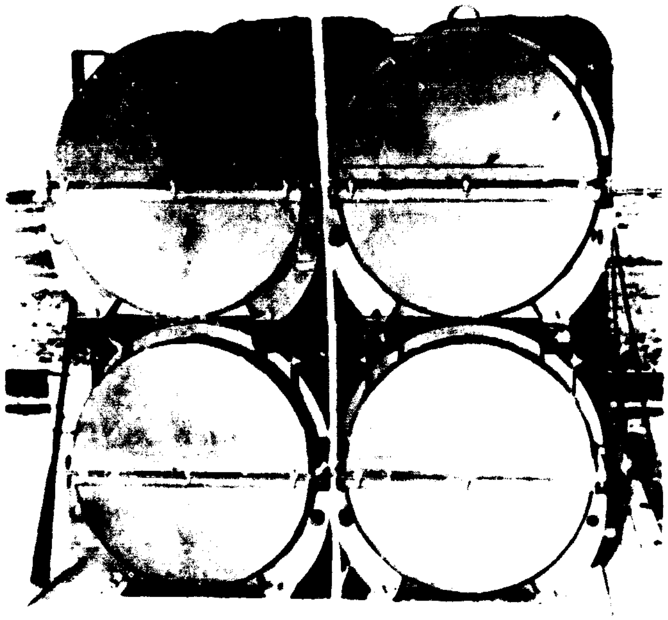


FIGURE 122. STEEL, CHEST TYPE, ROUND CONTAINER WITH STACKING PADS AND SKIDS FORMING RECTANGULAR PERIPHERY

FIGURE 123. PRESSED STEEL, RIBBED MODIFIED ELLIPTICAL CONTAINER WITH STACKING PADS AND SKIDS TO PROVIDE RECTANGULAR PERIPHERY

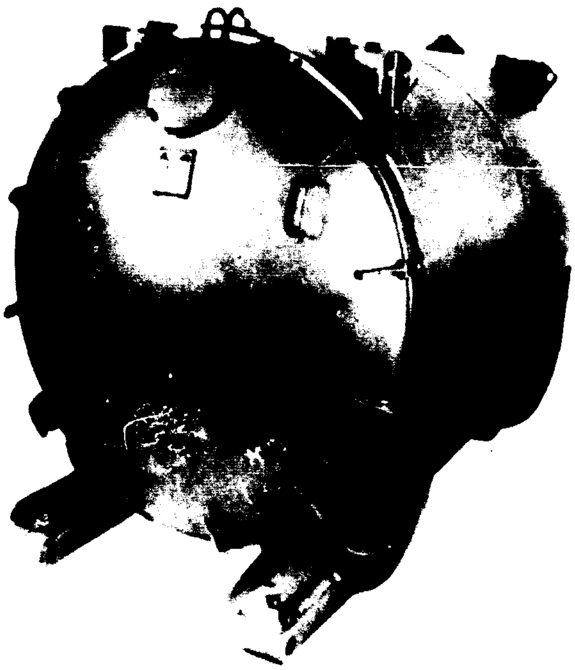


FIGURE 124. RECTANGULAR CONFIGURATION PROVIDED BY STACKING PADS AND SKIDS.

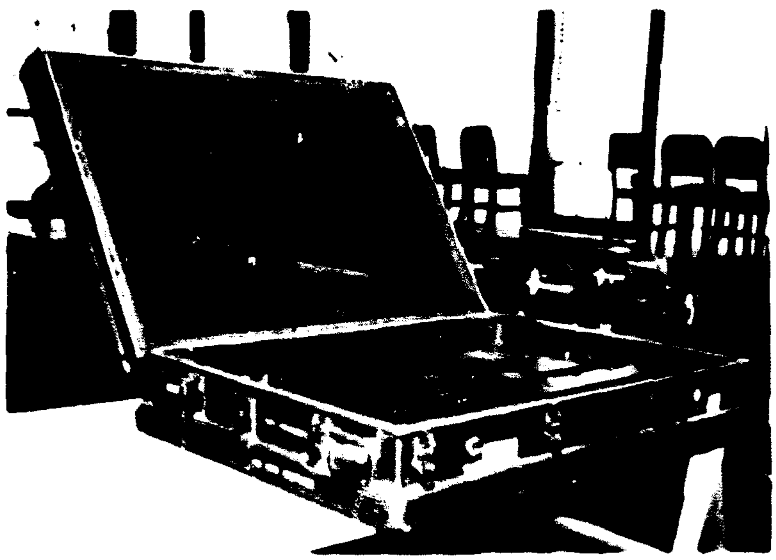


FIGURE 125. [illegible] CONTAINER WITH RECTANGULAR CROSS SECTION TO FACILITATE CUBING AND STACKING

FIGURE 126. TYPICAL STACKING PATTERN - CONTAINER STRUCTURE MUST RESIST VERTICAL LOADING

MODULAR DESIGN

In an attempt to reduce costs by standardization, modular design concepts have been developed which provide versatility and result in expeditious container procurement. The concept is based upon the use of common standard components; in particular, cast corners and extruded edges having the capability of accepting side panels whose size may be varied to satisfy the container spatial requirements. MIL-C-22443 (Wep) delineates the requirements of this concept and establishes the scope of application. Figure 127 depicts a modular container and its method of fabrication.

The economic feasibility of the modular concept is based on its versatility and the need to stock only a minimum assortment of basic parts. The availability of these building-blocks can satisfy the demands of both limited and high volume procurement requirements.

The technical feasibility is limited, within the scope of this document, to the small container field as the variable side panels are not capable of supporting localized stress concentrations without auxiliary bracing. In addition, the need to caulk, bond, or weld the various components into an assembly capable of resisting climatic exposure limits its application and any degree of climatic protection provided becomes marginal. Consequently, the modular design is recommended for small container applications whose contents can survive in a free or controlled atmosphere.

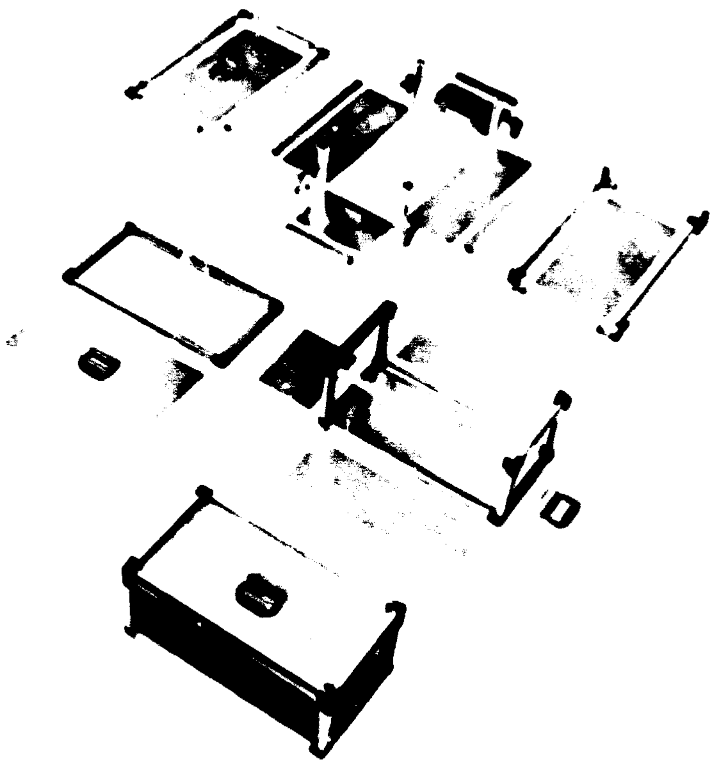


FIGURE 127. MODULAR DESIGN CONTAINER

A modification of the modular concept makes available a knock-down feature which provides economy in the return shipment of empty reusable containers. Due to their nature, these containers are not suitable where prolonged climatic exposure will prove detrimental and consequently the use of the knock-down concept should be limited and restricted to materiel inert to climatic exposure or to shipments exposed to only a controlled environment.

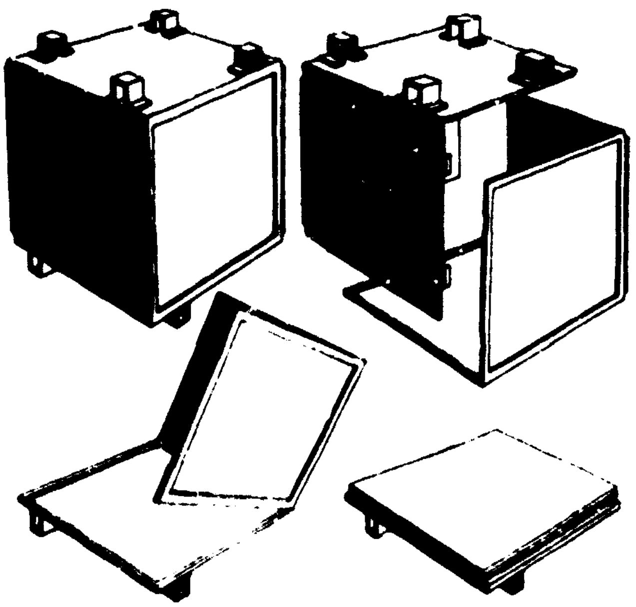


FIGURE 128. KNOCK-DOWN CONTAINER

EXPENDABLE CONTAINERS

The modern, mobile field army operating in a hostile environment should not be required to perform salvage and reclamation functions which will impede its "shoot-and-scoot" capability. Unfortunately, today's missiles and many of the rockets currently available to the Army are highly sensitive and require a level of protection which makes necessary the sophistication found in the majority of protective containers. The cost to provide this level of protection makes mandatory the reuse of these items; many of which are in essence climatic chambers.

The demands of the tactical environment and those relating to economic feasibility are diametrically opposed and present a paradox which the container designer must recognize and resolve to the satisfaction of both the field commander and the logistician. Obviously, the designer must be prepared to make "trade-offs" without sacrificing the physical and protective integrity required of the container.

The integrity of the missile and/or rocket cannot be compromised; its reliability is paramount. This tenet is basic to the field of container technology and is not subject to negotiation or "trade-off." However, the designer is provided sufficient latitude in the selection of materials, configuration, etc., to provide an optimum container whose cost will be consonant with its function.

The container designer must be cognizant of the Military Characteristics pertinent to the overall weapon system and establish as his goal, the development of an expendable container. The connotation associated with "expendable" is low cost and the result of the development effort must be an inexpensive container. The cost analysis of any container should consider, in addition to initial procurement cost, the following factors whose sum represents actual cost:

a. Final assembly costs.

b. Maintenance costs.

c. The cost to compensate for container limitations necessary to qualify for "worldwide distribution."

d. Return shipping costs.

e. Reconditioning costs.

f. Secondary use at point of destination whose value can be credited to the overall cost.

A review of these contributing factors will then permit classifying the container as either reusable or expendable.

In many instances, overdesign contributes most to the need to classify a container as reusable. Too often the cost to supply superfluous protection prohibits disposal of the container.

Unfortunately, it is impossible to establish rules for classification. In summary, the designer must practice good design and be prudent in the selection of materials and components. The principles of Value Engineering must be applied and the result of the development effort evaluated to determine the economic feasibility of disposal versus reclamation.

CONTAINER BODY MATERIALS

The five materials most commonly used in container body construction are:

a. Steel
b. Aluminum
c. Wood
d. Plastic
e. Fiberboard

In addition to the above, sandwich material comprised of aluminum, wood, or plastic or any of these in combination are being used in container construction. Use of this fabricated material results in high cost; however; where weight to strength ratio is critical, the use of this sophisticated material may be justified.

Selection of the material to be used is dependent upon many factors, in particular, those peculiar to the operating environment and those characteristics of the material affecting structural load bearing capacity. In addition, the ability to resist penetration and the durability of the material must be considered.

As a rule, the container designer should consider the following when selecting a material:

a. Ability to provide the level of physical protection required.

b. Ability to resist penetration both physical and environmental.

c. Compatibility of material with its contents to avoid deterioration by galvanic action, chemical exposure, etc.

d. Density as affecting overall weight.

e. Ability to support suspension system.

f. Structural capacity to resist buckling.

g. Availability during time of hostility.

h. Ease of field maintenance and repair.

i. Fabricating characteristics and the economic aspects of manufacture.

j. Cost relating to both small production lots and those of mass production.

k. Utility of end item; reusable or expendable.

TABLE 17
CONTAINER BODY MATERIALS - SELECTION GUIDE

MATERIAL	ADVANTAGES	DISADVANTAGES
STEEL See Fed Spec QQ-S-698 Fed Spec QQ-S-741 MIL-S-13281	a. Adaptable to large volume, low cost production. b. Excellent resistance to moisture - vapor transmission. c. Excellent adaptability to pressurization of container. d. Excellent fire resistance. e. High strength. f. Ease of repair. g. Long life when properly finished. h. Highly resistant to physical penetration. i. Excellent structural rigidity.	a. Use of steel results in high weight. b. Subject to corrosion unless treated or finished.
ALUMINUM See Fed Spec QQ-A-250/11b Fed Spec QQ-A-274 MIL-C-22443	a. Light weight b. Noncorrosive c. Adaptable to modular construction and mass production.	a. Easily damaged. b. High maintenance costs. c. Cannot be conveniently repaired in field. d. Welds and sealed joints tend to crack and leak.
WOOD See TM 38-230 for comprehensive review. MIL-C-104 Fed Spec NN-P-515 Fed Spec PPP-B-585	a. Inexpensive. b. Lightweight. c. Performs to absorb shock. d. Supply abundant.	a. Deteriorates unless treated. b. Low strength. c. Easily damaged. d. High moisture vapor transmissibility. e. Subject to physical distortion - shrinking & warping. f. Highly combustible. g. Subject to attack by rodents, insects, etc.
FIBERBOARD See TM 38-230 for comprehensive review. Fed Spec PPP-B-636 Fed Spec PPP-B-640	a. Inexpensive. b. Uniform strength characteristics. c. Can be treated to resist water penetration. d. Can be prefabricated. e. Can be collapsed and shipped flat. f. Easy to assemble. g. Lightweight. h. Provide shock protection.	a. Use limited to small, relatively lightweight items. b. Easily damaged by penetration and structural distortion. c. Experiences loss of rigidity when exposed to water or prolonged moisture. d. Highly inflammable. e. Normally cannot be reused and does not permit periodic inspection of contents.
PLASTIC See MIL-M-22544 MIL-C-4150E	a. Excellent moisture-vapor barrier. b. Can be molded to minimize assembly operations. c. Available in various compounds and densities to provide shock protection. d. Inexpensive when mass produced. e. Inert to climatic exposure.	a. Use currently limited to small containers. b. Reliability of bonding technique questionable. c. Small lot production - uneconomical. d. Stress concentration at corners compromises structural integrity. e. Subject to distortion at high temperature.
HONEYCOMB SANDWICH See MIL-STD-401A MIL-C-21275A MIL-C-8073A	a. Lightweight. b. Excellent strength characteristics. c. Excellent insulating characteristics.	a. Expensive. b. Complex assembly procedure. c. Currently not suitable for mass production. d. Need for caulking and resin bonds compromises performance. e. May become unavailable for container use in time of emergency.

SELECTIVE SALVAGE

The fragility of many missiles is often of a level requiring complex, costly shock mitigating devices. In some instances, this is the only protective requirement and the use of an inexpensive wood or fiberboard container body is permissable. The container body as such, can be considered expendable due to its relatively low cost; however, the cost of the container assembly, including the suspension system prohibits its disposal and often dictates that it be reused. In such instances, the technique of selective salvage can be introduced which permits those expensive components to be stripped from the container and returned as reusable components. This practice reduces return shipping costs and affects only those items worthy of salvage.

The designer can apply the selective salvage technique and the use of flexible barriers to wooden and fiberboard container design to result in an assembly providing both physical and climatic protection which can qualify as being expendable; subject to disposal after "one-shot" use.

FLEXIBLE BARRIERS

The conventional missile container in addition to supporting and physically protecting its contents, is often required to function as a barrier to resist the transmission of liquid water and water vapor. The designer can, by selecting the proper materials, satisfy both requirements.

Steel, aluminum and plastic provide excellent resistance to the transmission of liquid water and water vapor and when used in conjunction with effective seals, provides a container having both the required rigidity and climatic resistance necessary to satisfy the protective and handling requirements. However, the use of these materials and the fabrication methods peculiar to their application results in relatively high cost. Consequently, the developed container through economic necessity, is classified as reusable and subject to the reclamation processes discussed in previous sections of this chapter.

In many instances, particularly in small containers, the designer can divorce from the container body the need to resist moisture penetration and assign to the body only those requirements necessary to provide structural support, physical protection and a practical handling configuration. This separation of function provides the designer with more latitude in the selection of materials and permits the use of the less expensive wood and fiberboard.

Climatic protection, including the resistance to water vapor transmission, can be provided by the use of auxiliary flexible barrier materials. The state-of-the-art makes available an assortment of materials which function to resist the penetration of water vapor; MIL-B-131D establishes the requirements for these barrier materials and provides guidance in their application. The use of flexible barriers, when technically feasible, will often result in a less costly container which may be classed as expendable.

EQUIPMENT LOGS

GENERAL

The equipment log is the historical record for a specific type of equipment. It is a control device for mandatory recording of events during the life cycle of equipment, including receipt, operation, condition, maintenance accomplished, modification, and transfer. This record begins at time of delivery of the equipment by the manufacturer and is permanently identified with the item of equipment until it is finally "washed out" of the Army inventory.

The equipment log is a compilation of maintenance information on Department of the Army forms and must be controlled and safeguarded against loss or damage. The log is permanently identified with the applicable equipment by nomenclature and registration or serial number.

The most important use of the equipment log is to provide commanders with up-to-date information concerning the readiness of the item of equipment to which the log applies. The condition of equipment as recorded in an equipment log also permits selection of equipment requiring the greatest maintenance effort. Logical priorities for turn-in or "washout" may thus be determined when partial replacement issues of similar new items become available.

The equipment log may be used as a control document for operational dispatch of equipment. When used for this purpose, the equipment log will be under the control of the operator or crew at all times.

The equipment log, currently in use, is a hard-covered binder, having dimensions of 10 x 8 x 2 1/2 inches with a transparent plastic wrap. It has replaced the soft-covered weapons records book DA Form 9-13, Part I - "Major Items Complete Record" which has dimensions of 6 1/2 x 4 x 3/8 inches and may be folded or rolled to fit a cylindrical records receptacle either outside of or extending into the body of the missile container. The relative size of the new and old equipment logs is shown in Figure 129.

The records binder contains DA Forms of the type and size prescribed in TM 38-750 - "Army Equipment Record Procedure" for each specific piece of equipment. The plastic slot located on the front of the binder is provided for identification of the piece of equipment to which the log applies.

RECORDS RECEPTACLES

The records receptacles shown in Figures 130, 131 and 132 are examples of receptacles which are of adequate size to contain the old books but cannot accommodate the new binder. Figure 133 shows the records receptacle of the Sergeant Rocket Motor Container XM419. This receptacle is of adequate size to contain the new binder.

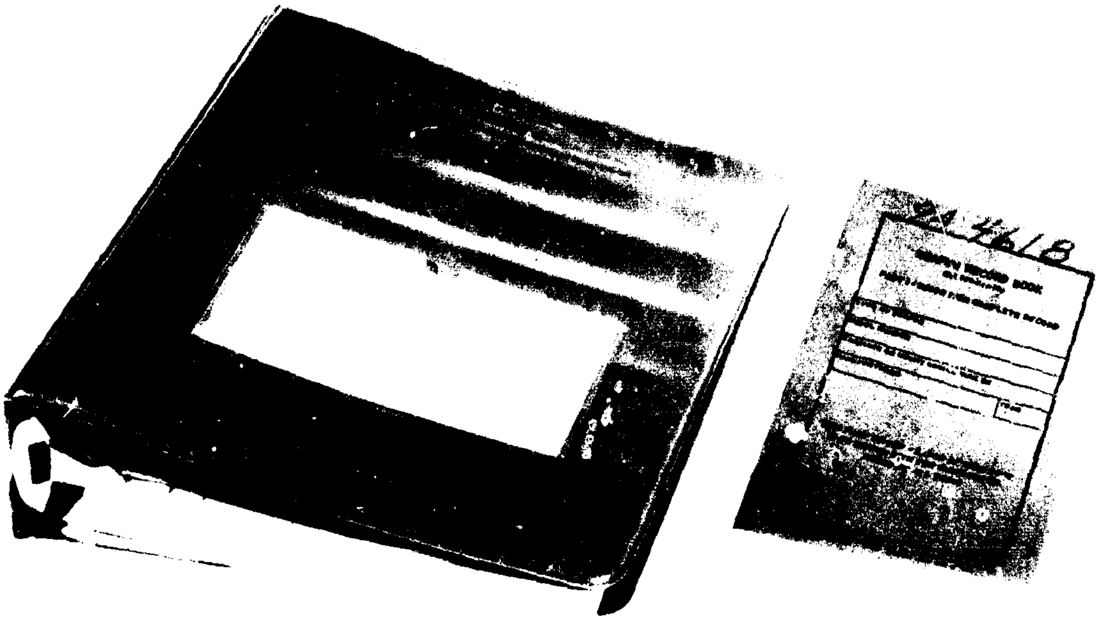


FIGURE 129. PRESENT AND PAST EQUIPMENT LOGS

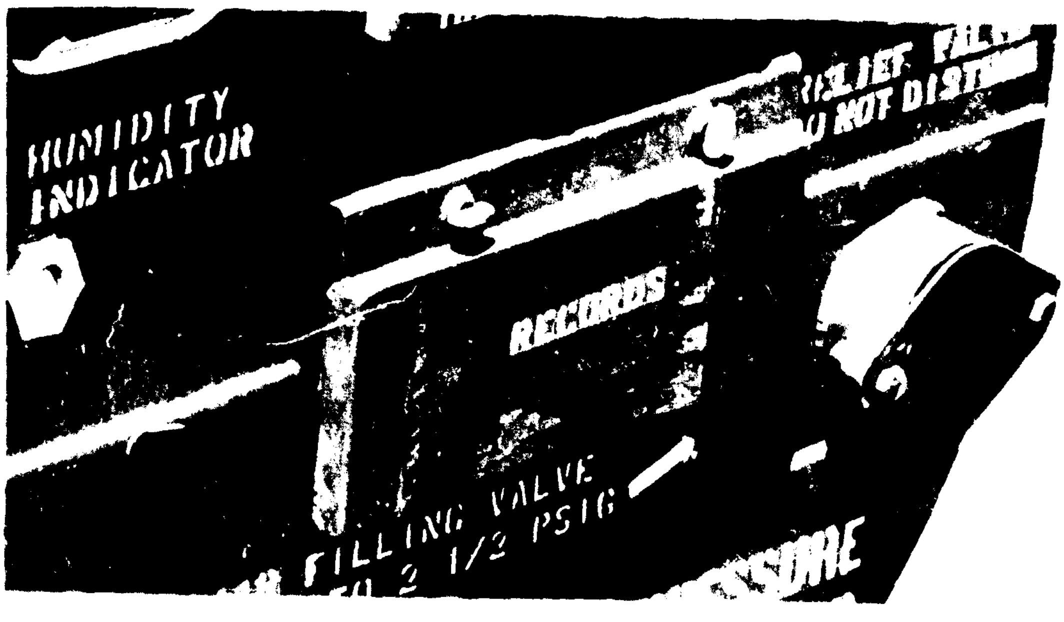


FIGURE 130. INADEQUATE RECORDS RECEPTACLE

FIGURE 131. COMMERCIALLY AVAILABLE CYLINDRICAL RECORDS RECEPTACLES

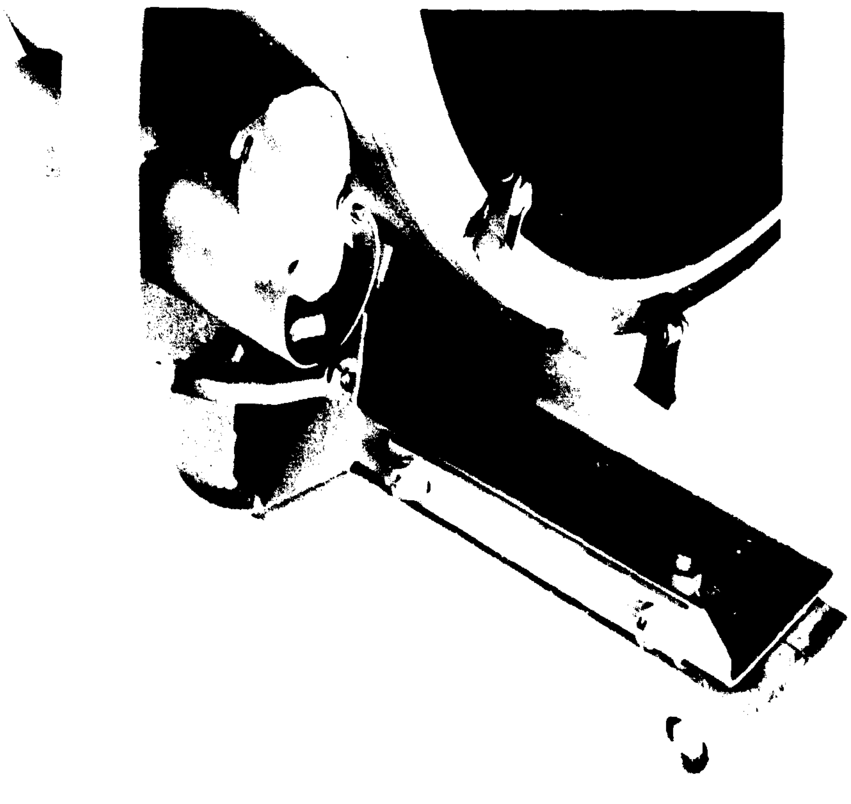


FIGURE 132. CYLINDRICAL RECORDS RECEPTACLE

The records receptacle must be waterproof and must protect the contents from damage by all environments. The sealing material used must permit repeated opening and closure without impairment of the sealing quality. Figure 134 illustrates the use of polyurethane plastic foam stripping glued to the container cover to provide a waterproof seal.

Records receptacles large enough to accommodate the new binder may either be top opening or end opening as shown in Figures 134 and 135 respectively. The end opening type has the advantage that it can be incorporated in the roll-over provision and therefore is easily accessible from the front of the container. This is especially desirable when the containers are stacked. The end opening receptacle also requires less sealing material than the top opening type. The top opening receptacle has the advantage of hinges which affix the cover to the container body. The end opening type requires a connecting wire for this purpose.

SECURITY SEALS

In order to discourage and detect tampering with the equipment log, the receptacle is provided with a security seal which has to be broken in order to open the covers as shown in Figure 136. Holes in the latches are for the purpose of attaching the lead seal in the manner shown in Figure 137. The lead disk is then pressed closed and imprinted with the applicable agency identification. Such security seals may only be used once and must be replaced when the lead seal or wire has been broken.

Security seals are also used to seal a container by securing the seal through both the cover and body. By this means, it cannot be opened without breaking the seal.

DATA PLATES

Data plates must display only information that is necessary for the safe shipment, storage and use of the container. The information should include the container nomenclature, Federal stock number, container serial number, part or drawing number, and the manufacturer's name. Figure 138 is an example of a typical missile container data plate. These plates must be (1) consistent in size and shape, (2) logically oriented with respect to each other, (3) clearly visible, (4) placed where they will not be damaged, and (5) horizontally labeled to read from left to right.

The material used for data plates must be compatible electro-chemically with the unit to which it is to be attached. The materials preferred for data plates are given below in the order of preference:

a. Copper-base alloys
b. Aluminum, magnesium or zinc-base alloys
c. Anodized aluminum plate
d. Unalloyed or low-alloy ferrous metals

FIGURE 133. CLOSED LOG BOOK RECEPTACLE

FIGURE 134. OPEN LOG BOOK RECEPTACLE

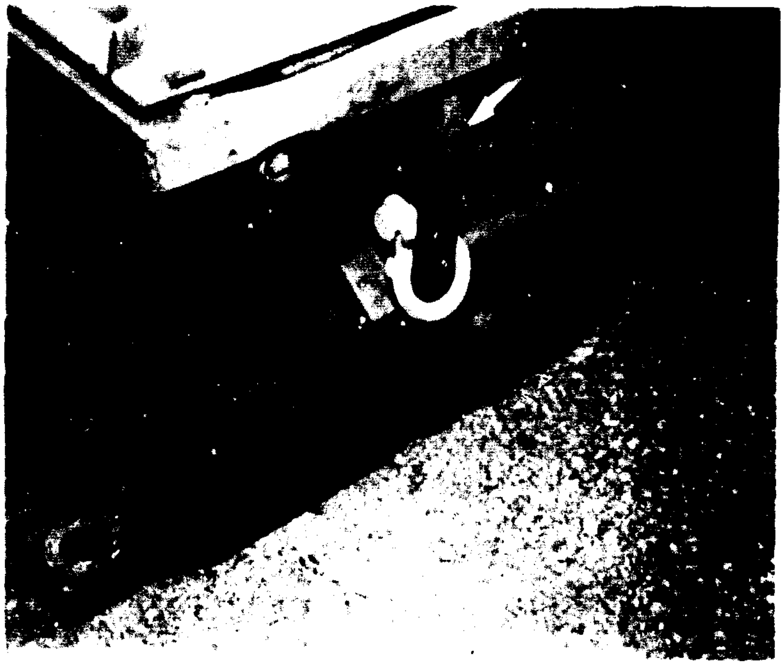


FIGURE 135. END OPENING RECORDS RECEPTACLE

FIGURE 136. LEAD SECURITY SEALS

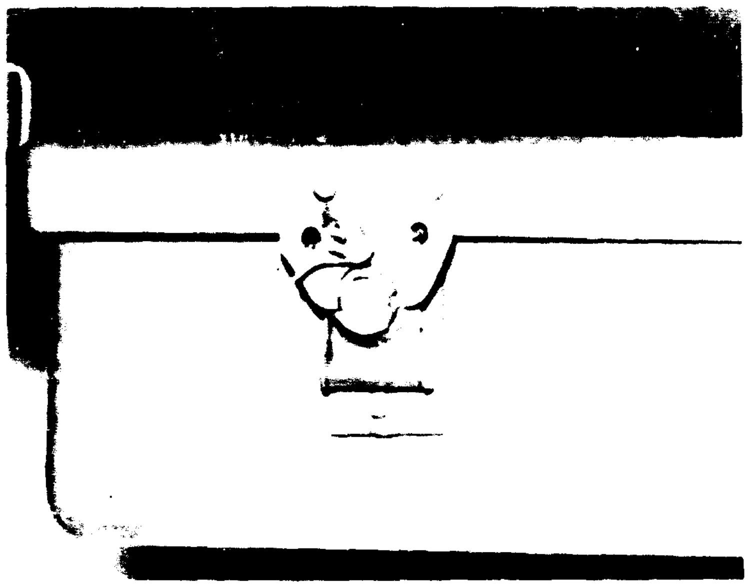


FIGURE 137. TYPICAL APPLICATION OF SECURITY SEAL

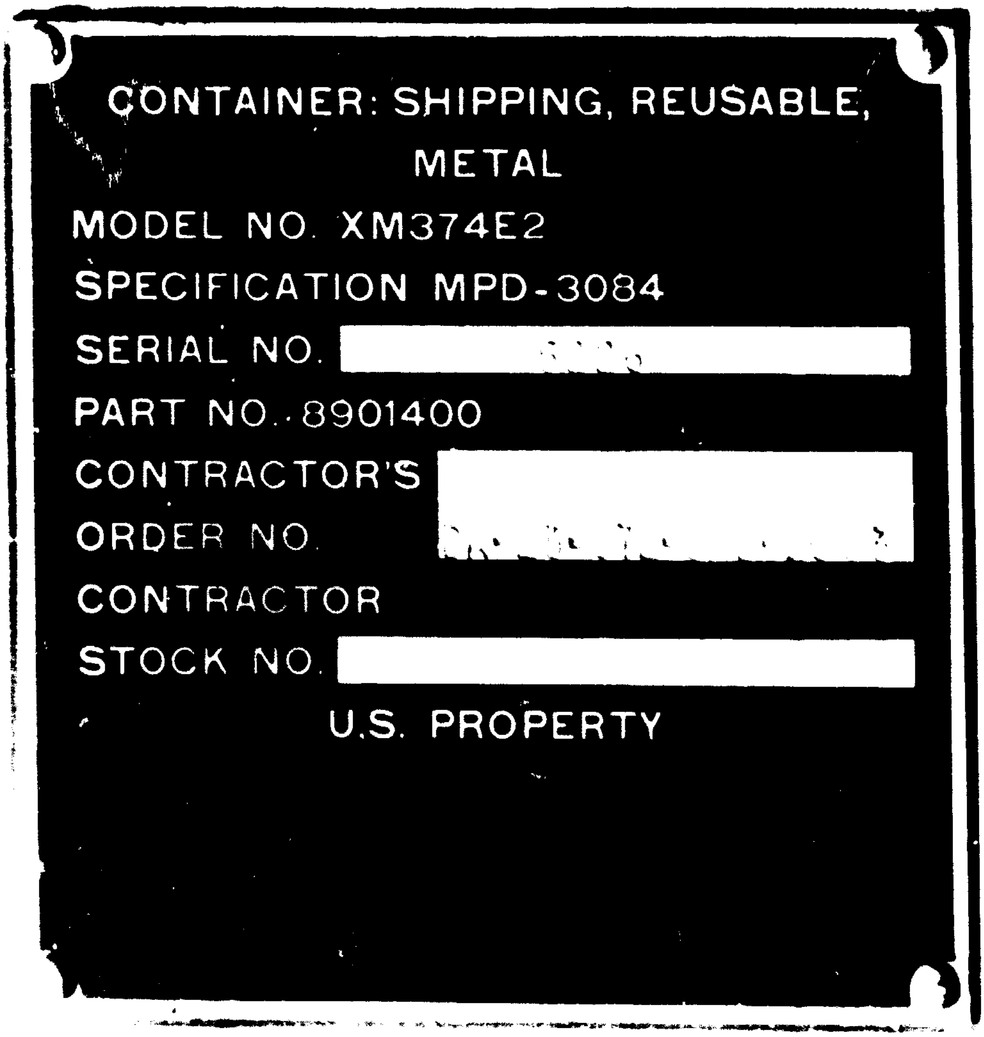


FIGURE 138. CONTAINER DATA PLATE

Copper-base alloys shall conform to specification QQ-B-637. Anodized aluminum plates are plates which have been made the anode of an electrolytic cell. This oxidation of aluminum produces a surface coating which displays a relatively high resistance to corrosion and abrasion and provides high electrical insulation to the underlying metal. Anodized aluminum plates shall be made of aluminum conforming to specification QQ-A-250/1c, 1/4 H temper.

Lettering on data plates shall be gothic or futura capitals and the numbers shall be arabic. Borders, blocks and other characters shall be raised by etching the background to a minimal depth of 0.003 of an inch. The plates themselves shall be 1/32 of an inch thick. The forming of designations such as serial numbers which vary from plate to plate is usually done by stamping.

The size of the characters for the container nomenclature or name should be at least 5/32 of an inch but no more than 1/4 of an inch in height. All other lettering and characters should be between 1/8 and 5/32 of an inch high with a 1/8 of an inch spacing between lines. Border widths shall be 3/32 of an inch.

Container data plates shall be drilled or punched at all four corners with holes not less than 1/8 of an inch or more than 3/16 of an inch in diameter. These plates shall be fastened to the container with rivets.

The anodizing of aluminum plates shall be in accordance with MIL-STD-171, Finish No. 7.2.1. The background of data plates shall be finished in accordance with Finish Nos. 20.4, 20.8, 21.3, 21.5 or 21.11 of MIL-STD-171, Color No. 37038 (black) of FED-STD-595. Finish Nos. 20.4 and 20.8 are lusterless paint finishes, and Finish Nos. 21.3, 21.5 and 21.11 are semi-gloss paint finishes. The unpainted portions shall be painted with clear lacquer.

CHAPTER IX

HANDLING DEVICES

GENERAL

The container, in addition to being required to resist the hazards and deteriorating effects of its environment, must also provide compatibility with the handling operations necessary to move the container to its destination. The functional mobility of the container is usually dependent upon the auxiliary handling equipments operating within the logistic cycle; however, the container must include devices to result in compatibility with these handling equipments. It is the container and these devices which are of particular concern to the designer as it is in this area which he can make a significant contribution to the expeditious and safe delivery of materiel.

Except for special applications, the container designer has little or no control of the equipment which will be used for handling; however, he must be cognizant of and consider these handling equipments when designing the container.

Those elements of the logistic cycle whose effective performance is dependent upon the container and its handling devices are delineated below and shall be discussed in subsequent sections of this chapter.

1. Manual Handling
2. Mechanical Handling
3. Unitization
4. Skids
5. Stacking Provisions

1. Manual Handling

The ability of a container to be manually handled is dependent upon its weight and/or size. In addition, the principles of Human Factors Engineering dictate and establish limits which the designer cannot exceed. These design parameters are contained in Table 18 to establish the maximum weight which any one individual will be required to lift.

TABLE 18
MANUAL HANDLING DATA

Distance Lifted from Ground	Weight
5 feet	36 pounds
4 feet	55 pounds
3 feet	77 pounds
2 feet	139 pounds
1 foot	142 pounds

The chief distinguishing characteristic of containers capable of manual handling are handles whose number will be in direct proportion to the ratio of gross weight to the established man-carry limits. The state-of-the-art makes available to the designer an unlimited selection of types and styles of handles. Those considered applicable to military container application, must embody certain characteristics which are considered essential; the data contained in Table 19 provides guidance in the design and selection of acceptable lifting handles.

TABLE 19
DESIGN AND SELECTION OF LIFTING HANDLES

Weight to be Lifted per Handle	Handle Diameter	Finger Clearance	Handle Width
Under 25 pounds	$\frac{1}{4}$ to $\frac{1}{2}$ inch	2 inches	$4\frac{1}{2}$ inches
Over 25 pounds	$\frac{1}{2}$ to $\frac{3}{4}$ inch	2 inches	$4\frac{1}{2}$ inches
Lifted by Gloved Hand	---	$2\frac{1}{2}$ inches	5 inches

In addition to the above, the preferred handle should encompass the following:

a. Spring loading to retract the handle to within the container profile when not in use.

b. A rubber bale to provide both comfort and an effective friction grip.

c. A positive stop to restrict the handle motion to 90 degrees to avoid injury to operating personnel.

d. Corrosion Resistance.

e. Unaffected by subfreezing temperatures and ice formation.

A handle embodying the preferred characteristics is depicted in Figure 139 and may be procured in any of the conventional materials from numerous military and commercial supply sources.

The handle illustrated should be spot welded to the container shell provided the materials are the same and the shell can or is adequately braced to withstand the stresses imposed by the load. Bolts may be used where welding is not feasible; however, a backing plate should be provided to assure adequate stress distribution. Handles should be symmetrically located above the container center of balance and shall be conveniently positioned to provide ease of operation.

Certain container configurations will permit the use of inexpensive round rod handles permanently positioned and fastened to the body shell; however, such handles should not protrude beyond the container profile nor degrade the stacking and/or unitizing characteristics.

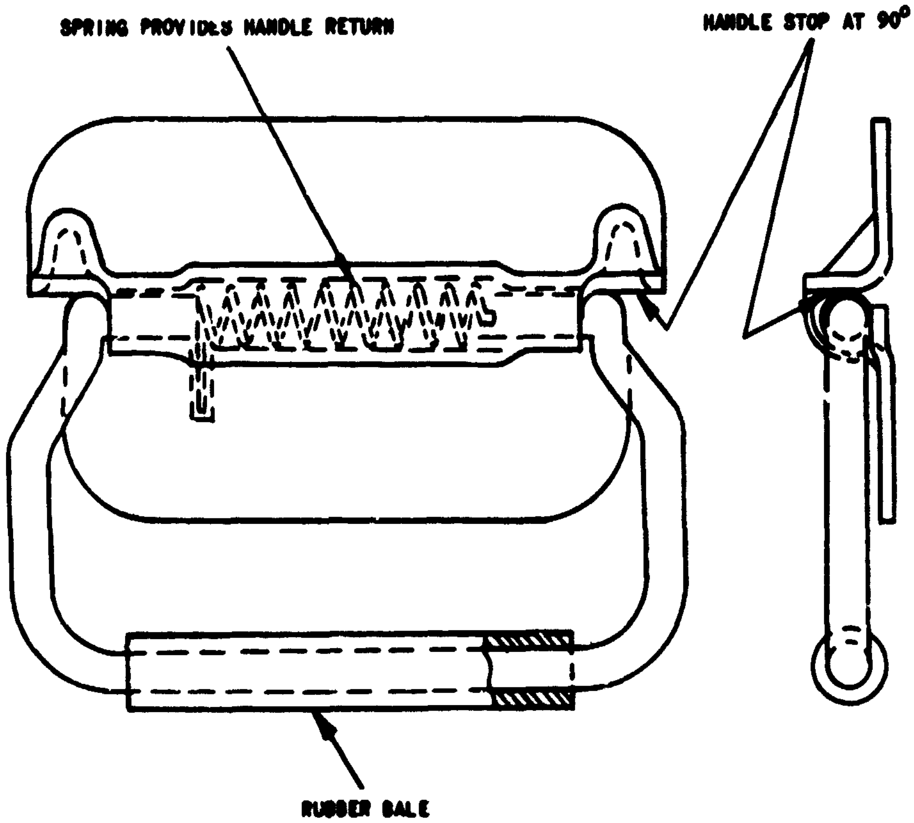


FIGURE 139. HANDLE EMBODYING PREFERRED CHARACTERISTICS

Molded plastic or fibrous glass containers may incorporate within the outer shell, recesses, hand grabs or handles to facilitate handling. See Figure 144.

Wooden containers and overpacks may utilize simple, inexpensive rope handles to conform to par. 3.3 of MIL-B-2427B(Ord).

The restrictions imposed by the demands of economic feasibility do not permit the use of body recesses to house handles; the designer should avoid this costly practice regardless of its esthetic desirability.

Handles may perform a secondary function as tie-down receptacles provided the forces imposed are within their load carrying capability.

II. Mechanical Handling

Within the environment of "worldwide distribution" may be found a wide assortment of materials handling equipments ranging from the simple block and tackle to elaborate automated conveyor systems. Falling within these extremes are the more common fork-lift truck, overhead crane and hand truck. The effectiveness of these equipments is dependent upon the container and the handling devices it encompasses to facilitate the handling process. These devices may be divided into four general and occasionally overlapping categories:

a. Hoisting fittings
b. Tie-down fittings
c. Towing fittings
d. Fork-lift provisions

A. *Hoisting Fittings*

Overhead cranes whether they be stationary or mobile utilize hooks, slings and/or yokes to engage and support the suspended container. Obviously, the container must incorporate or be provided with devices to accept and be compatible with these handling methods.

Handling devices, either integral or attached to the container which will provide the required compatibility may take the form of eyes, rings or lugs. They may be located anywhere on the container; however, it is preferable that they be positioned above the center of gravity of the supported item to assure load stability during the lifting operation. Hoist fittings attached to large, top-opening, sealed containers should be located on the bottom half of the container to avoid subjecting the cover latches to the full weight of the suspended mass and degrading the effectiveness of the barrier seal. Hoisting fittings may serve a dual purpose by functioning as stacking pads and/or tie-downs.

Some applications may warrant special cable slings permanently attached to the container. This is typical of missiles whose attitude is considered critical and proper container orientation is mandatory.

Small containers, with or without handles, will not normally require hoist fittings. Containers whose gross weight exceeds 150 pounds shall be equipped with lifting rings or eyes whose clear inside diameter shall be at least 2½ inches (preferably 3½ inches). These fittings shall not protrude beyond the container envelope when not in use nor shall they degrade the cubing capability of the container configuration. A design factor of safety of no less than 4 to 1 shall be applied to hoist fittings. Should the function of the hoist fitting be limited merely to the removal of the container cover, they should be clearly marked as to their limitations; however, it is preferable that they be capable of supporting the total mass as they will undoubtedly be exposed to misuse at some time within the operating environment.

B. *Tie-Down Fittings*

The requirements for tie-down fittings are fully documented in the Bureau of Naval Weapons publication WR-11. Paragraph 6.5 of Part I is quoted in toto to provide the required guidance:

1. Tie-down fittings shall be provided on all containers grossing 1,000 pounds or more. Such fittings may include the hoisting fittings.

2. The design load in any direction below the plane of the fitting must be at least 1.5 times the maximum load of the fitting based on the yield strength.

3. Whenever possible, place fittings at least 18 inches above the base line and above the plane of center of gravity of the loaded container. Space fittings along each side, equidistant from each other and symmetrical above the center of gravity.

4. The actual number required shall be the theoretical number, except that at least 3 fittings shall be provided on each side of a container more than 10 feet long and at least 2 on each side of a container less than 10 feet long. When a container is more than 75 inches wide, furnish at least one fitting on each end.

5. A clear inside diameter of 2½ inches is required.

C. *Towing Fittings*

Medium to large containers shall be equipped with two tow eyes at each end. They shall be positioned as close to the ground as possible and suitably supported by a structural member capable of withstanding the draw-bar pull developed by the towing action. These fittings shall include a ring or an eye having a minimum diameter of 2 inches and their design shall include a safety factor of at least 4. Strategically located hoist fittings may preclude the need for tow fittings and conversely the tow fittings may negate the need for hoist fittings.

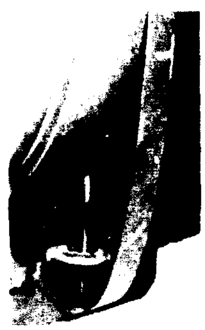


FIGURE 140. TOW FITTING

D. *Fork-Lift Provisions*

The versatility and wide acceptance of the fork-lift truck since World War II has assigned to this handling mechanism a unique position of general application; it will be found in all transit and storage environments. Consequently, one may assume that virtually all containers will at some time be handled by a fork-lift truck. To provide the required handling compatibility, the container should incorporate provisions to accept the tines of the fork-lift truck. This requirement is applicable to all containers whose gross weight exceeds 300 pounds; containers weighing less than 300 pounds may or may not incorporate handling devices to facilitate tine positioning. The decision is left to the container designer and is dependent upon the anticipated handling methods of the proposed application. Quite often small containers are unitized (see section III) and positioned on skids or pallets to provide handling compatibility.

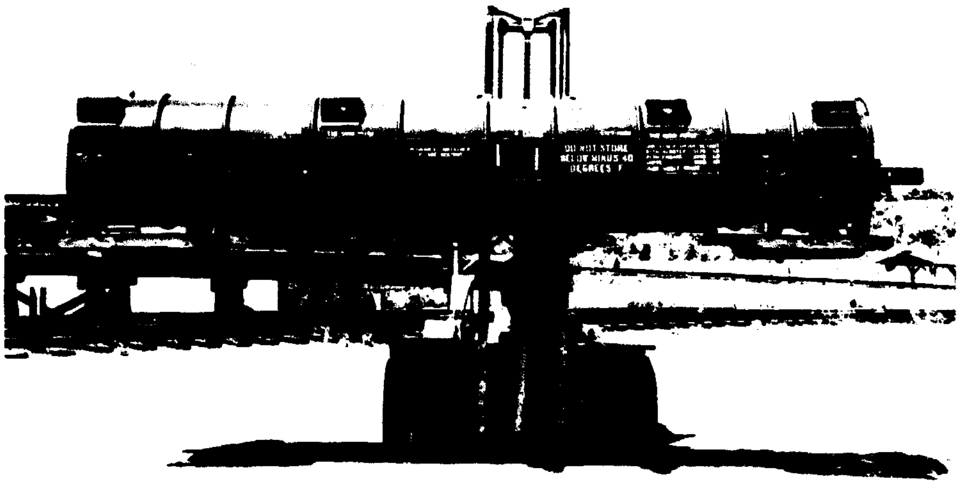


FIGURE 141. FORK LIFTING A CONTAINER

To permit for general application, fork-lift trucks have been standardized according to their lifting capacity, height of lift, degree of mobility and fork configuration. Of these characteristics, only the tine size and fork spread affect the dimensions of the container. Table 19 provides fork truck data to assist the container designer in providing handling compatibility.

TABLE 20
FORK TRUCK DATA

Nominal Capacity* Lbs.	Fork Thickness At Heel**	Fork Width	Fork Length Max.	Fork Together Max.***	Fork Spread Min.***
2,000	1½	4	36	12	28
4,000	1¾	5	40	12	32
6,000	2	6	40	15	34
10,000	2½	7	48	18	52
15,000	2½	8	48	18	58

*Measured with load center 24" from heel. On loads more than 4 feet wide, capacity is reduced by taking the moments from fulcrum, i.e., the front axle.

**One-half inch for all at the tip.

***Outside to outside.

The characteristics of a typical container designed to be compatible with fork-lift truck handling methods are:

a. Underclearance or apertures (tine openings) shall be provided at both ends and on each side. As end handling accounts for one-third of all material transfer operations, end openings are necessary to permit movement through narrow doors and aisles.

b. The spread of the fork apertures shall be designed to accommodate all fork lift trucks that have the capacity to handle the container. In order to assure maximum load stability, the maximum lateral fork spread possible shall be used, i.e., for a 5,000 pound container a fork spread of 34 inches outside to outside shall be used.

c. The amount of underclearance or depth of tine aperture shall be capable of accepting any or all of the convention truck forks including rough terrain models.

d. The container center of gravity shall, if possible, fall within the load center limits of the fork length as limited by the truck configuration and capacity.

e. Tine openings shall be symmetrically located about the center of balance of the loaded container.

f. The container body shall be reinforced or protected in those areas which will make contact with or be exposed to the forks. Figure 142 is an example of a container that was not protected in the area of the end fork lift openings. Notice the dents in the bottom of the container.

g. Push or bumper plates should reinforce the periphery of the fork aperture to resist the pressure exerted by impacting fork ends. Quite often, containers are pushed and must be provided with bumper plates (see Figure 143).

FIGURE 142. CONTAINER INSUFFICIENTLY PROTECTED FOR END FORK LIFT HANDLING

h. When physically feasible, fork openings shall be 12" wide x 3" high. This size fork lift opening will accommodate most sizes of fork lift trucks.

i. Fork lift provisions should be fastened to the container in such a way so as not to impose any load directly on the shell. These provisions should be attached to reinforcing members which absorb the load or distribute it more evenly over the surface of the shell.

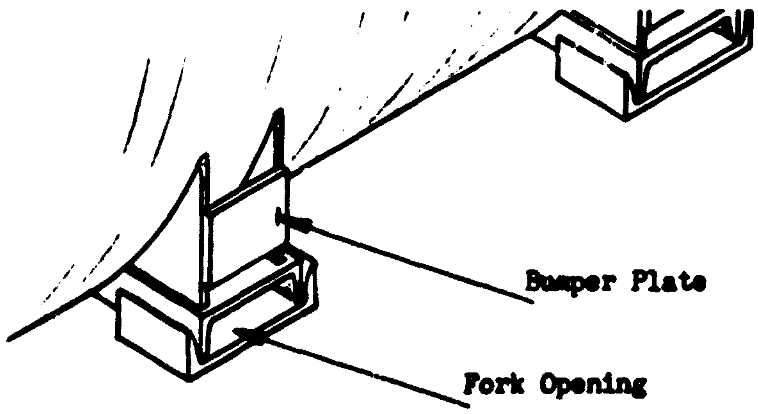


FIGURE 143. FORK OPENINGS AND BUMPER PLATES

III. Unitization

Loads are unitized to facilitate handling and to provide stability. Unitization refers to stacking patterns and/or devices used to interlock containers into one solid unit capable of convenient and efficient handling. Small containers may be alternately stacked and interwoven or their configuration may provide interlocking capability by nesting (see Figure 144). Quite often the unitized load is placed on a skid or pallet and is strapped to these handling devices.

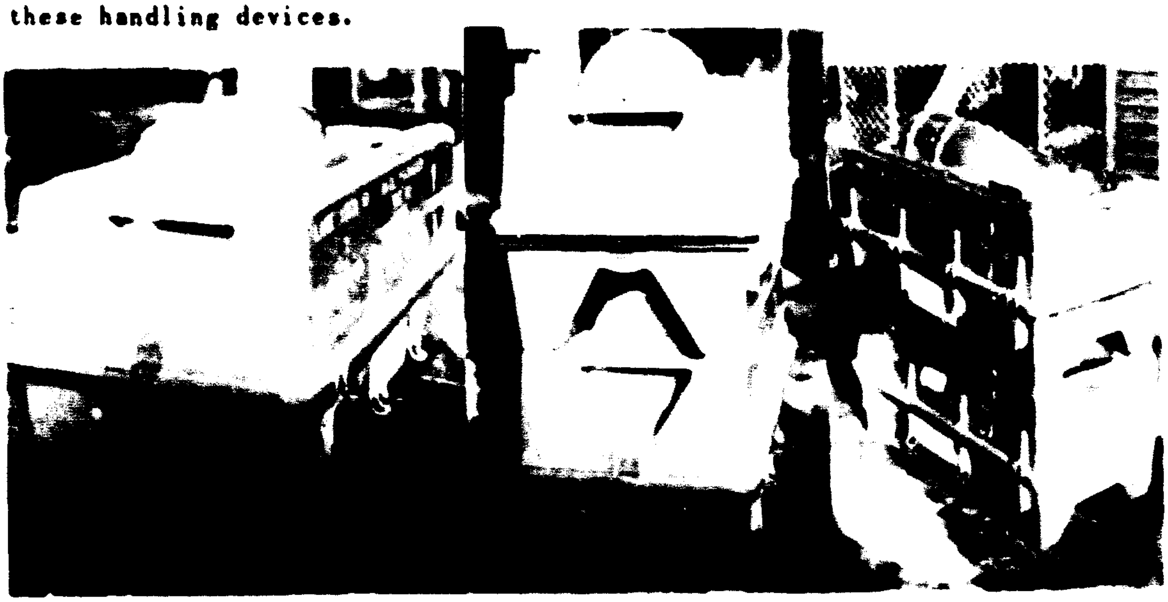


FIGURE 144. STACKING AND NESTING

Large containers may often be equipped with tie bars to connect one to the other to result in a self-supporting rigid structure. These tie bars must be designed to resist the dynamic effects of the transit environment (see Figure 145).

FIGURE 145. TIE BAR FAILURE

There are various techniques applicable to the interlocking process (see Figure 146). However, regardless of whether the load is unitized or not, some form of strapping or tie-down is used to restrain the load during transit. As the location of strapping cannot be controlled or predicted, the designer must provide a container which will withstand the stress imposed by the restraining device(s) along its entire length.

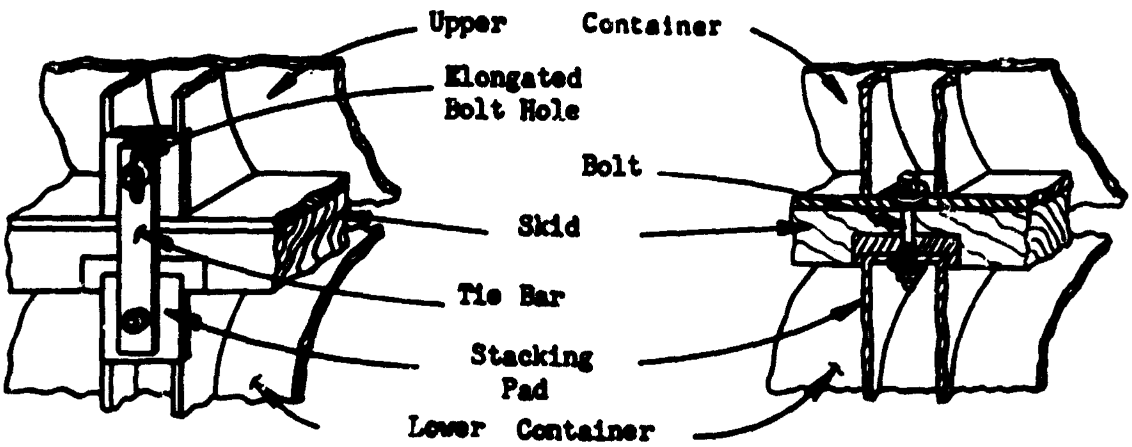


FIGURE 146. UNITIZING DEVICES

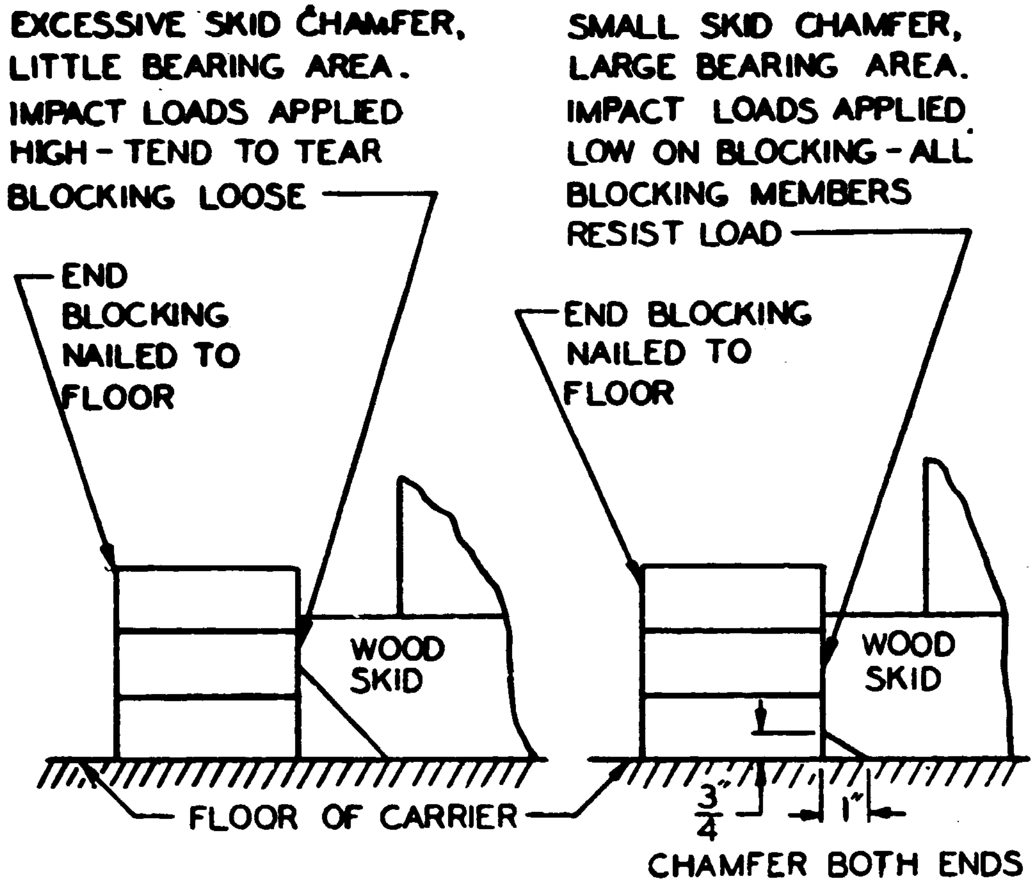
IV. Skids

Any container that must be pushed, dragged, or handled by mechanical equipment should be provided with wooden skids. The skids should be positioned longitudinally at or near the extreme width of the container to provide maximum lateral stability and maximum width for fork lift and entry. Lateral skids should never be used.

Skid height should be such as to allow about 3 inch clearance from ground level to the bottom of the container. A minimum of 2 1/2 inches should be allowed between the top of one container and the bottom of the next container stacked on it, to permit removal by fork lift.

The bottom edges of both ends of skids should be chamfered as shown in Figure 147, to reduce the tendency to catch on irregularities of the floor or ground, and to reduce splitting of skids. The chamfers should not be more than 3/4 inch high by 1 inch long. Chamfers that are too large hinder effective end blocking in transportation. The blocking contacts the skids so high that it cannot adequately resist impact loads, and tends to tear loose from the floor of the carrier. The ends of the skids should also project at least 2" beyond the extreme end of the container.

The inner ends of wooden skids should be backed up by stops, integral with the structural members of the container, and of sufficient strength and



(a) Undesirable (b) Preferred

FIGURE 147. SKID CHAMFERS

rigidity to prevent longitudinal shifting of the skids under rail impact loads (Figure 148). Maximum impact velocity in rail impact tests is eight miles per hour. When a rail car loaded with containers is rolled into a string of stationary cars (humped), the containers tend to continue forward, but the skids are restrained by blocking. If the skids are attached to the container only by bolts, without the use of stops, relative movement between the container and skids may occur, causing the wood to split through the bolt holes.

The skids should also be notched on the bottom with the notch being the same width as the stacking pad and 1/2 to 1 inch deep. The notched skids will prevent any longitudinal movement of stacked containers while the stacking pad design will prevent any transverse movement of stacked containers (Figure 148).

Additional precautions should be taken to reduce the possibility of longitudinal splitting, and to prevent the skids from breaking apart if they do split. The most common method of preventing splitting of wooden skids is by installing carriage bolts transversely through the skids two or three inches from each end. Washers should be used under the nuts. These carriage bolts shall be positioned as shown in Figure 149. When the nut and end of the bolt protrudes outside of the extremeties of the container, the bolt hole shall be countersunk on the outside of the skid so as to recess the nut and end of the bolt within the perimeter of the container. The carriage bolt shall be positioned so that the head is always on the inside of the skid.

The incorporation of cushioning, springs, or other shock mitigation features in skids or between the skids and container structure should be avoided. Containers having such skids cannot be effectively unitized, or tied down for shipment unless dunnage is used under the structural members of the container to raise the skids off the vehicle floor and provide solid bearing. The skids then are no longer effective in isolating the container and contents from transportation shocks and vibrations. If the containers are not blocked, flexible shock mitigation arrangements allow the containers to bounce as the springs or cushioning alternately compress and recover. During the compression phase of the cycle, slack develops in the shipping bands; during recovery, the upward motion of the containers imposes excessive forces on the shipping bands. The condition would be amplified when the containers are stacked one on another. If rigid, crushable cushioning is used, and the containers are supported on the skids during shipment, the cushioning will crush as soon as the design load is exceeded. These materials provide little or no shock mitigation after they crush because they do not recover. It may also happen that the material will not crush simultaneously at all four skids. In that case, the load will become more unstable. Figure 150 shows a cushioned skid that has been damaged by rough handling.

The bearing areas of skids must be adequate to support the weight of the container without causing excessive stresses in the skids and without exceeding floor loading limitations. Normally, the most critical floor

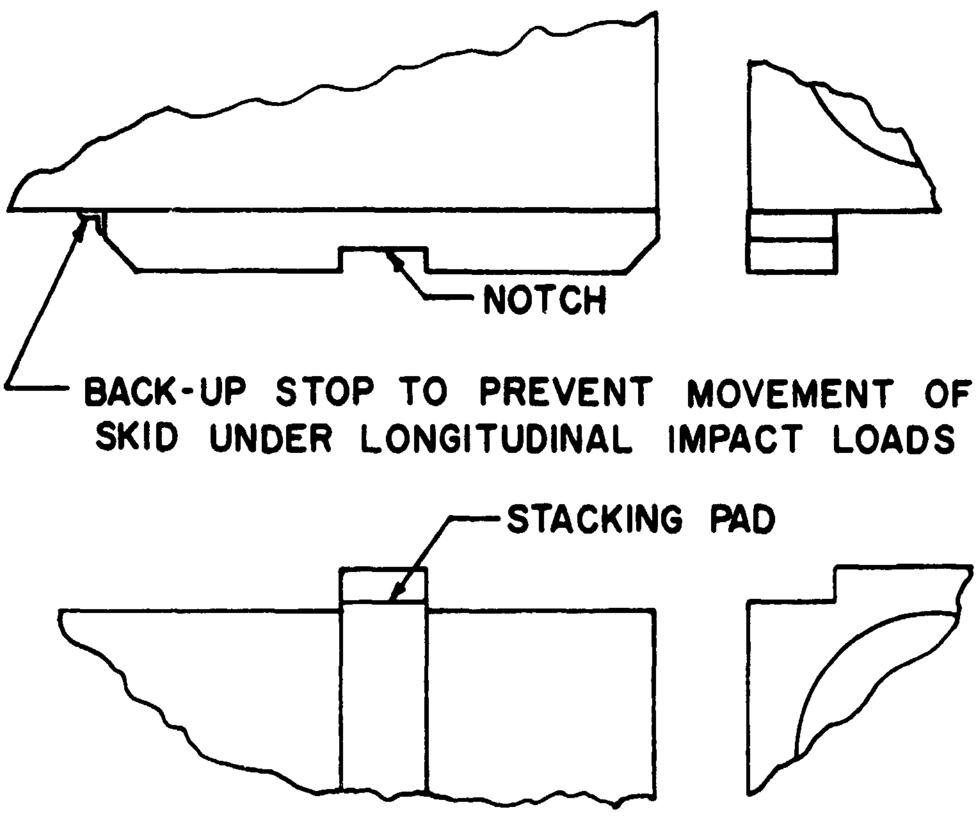
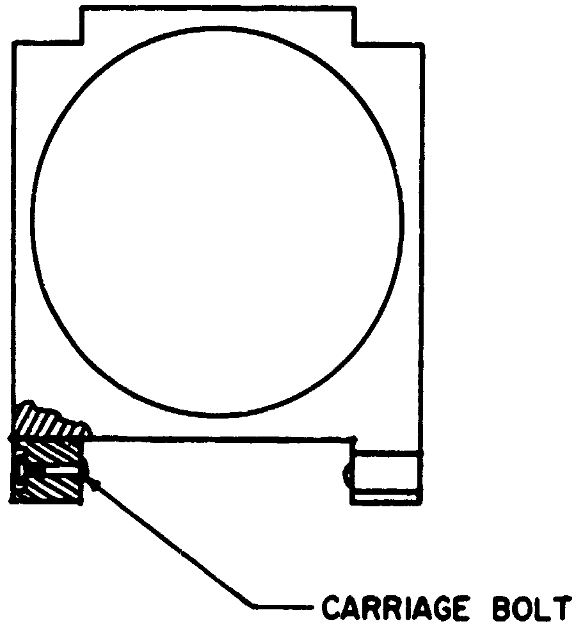


FIGURE 148. INTERLOCKING SKID



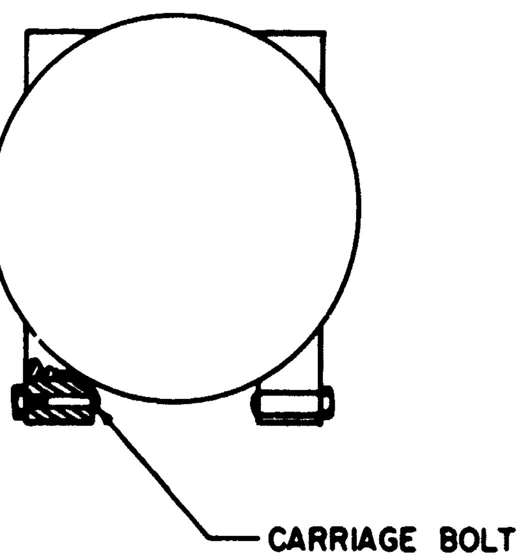


FIGURE 149. LOCATION OF CARRIAGE BOLTS

FIGURE 150. DAMAGED CUSHIONED SKID

loading limitations will be those established for aircraft. The designer should provide enough bearing area to stay within the limitations imposed by any aircraft in which the missile is expected to be transported.

Wooden skids shall be made of hardwood in accordance with Specification MM-L-736, "Lumber and Timber: Hardwood", number 2 common, unplaned and air-seasoned.

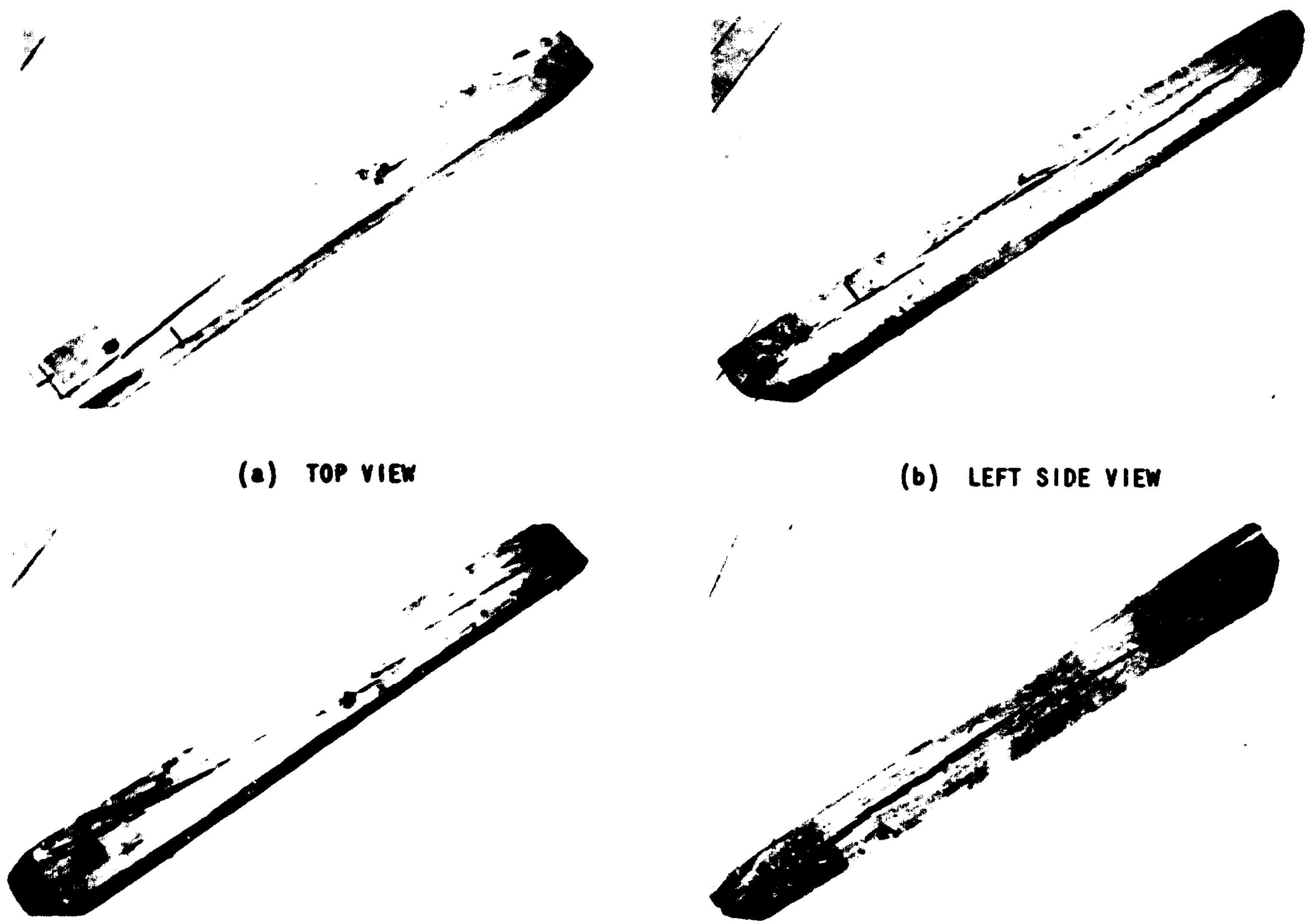
Under no conditions should green lumber be used for the fabrication of skids. Green lumber is lumber that has been freshly sawn and has received no intentional drying, and for oak it may have a moisture content ranging from 64 to 83 percent. Lumber with a moisture content of this much would take a considerable period of time to dry to 18 percent moisture content if it were continuously stored outdoors. The shrinkage and distortion of wood due to its drying only occurs when the wood is dried to a moisture content below the fiber-saturation point. The fiber-saturation point for all species of wood occurs at approximately 30 percent moisture content. Green lumber may therefore be dried to approximately the fiber-saturation point without any apparent shrinkage, checking or distortion. Further drying below the fiber-saturation point may easily cause these defects. Therefore if the skid is fabricated when the moisture content is at or above the fiber-saturation point, subsequent drying of the skid could result in distortion of the skid.

In order to help eliminate this condition, the establishment of moisture content limits at the time of acceptance, and a further check at the time of fabrication, should be incorporated. These limits should be set at 18 percent maximum at the time of acceptance and should be noted as a requirement on the skid drawing. Eighteen percent should also be specified as the maximum moisture content permitted at the time of fabrication. Figure 151 shows a skid that was fabricated from wood with an excessive moisture content and was subsequently dried to a lower moisture content after fabrication.

Wooden skids shall be preserved by pressure treatment in accordance with Specification TT-W-571, using pentachlorophenol equivalent to 5 percent (Specification TT-W-570, in petroleum oils conforming to AWPA Standard P9). A minimum net retention of 10 pounds per cubic foot or refusal, whichever is less, should be specified. This method of preservation is used for lumber products in contact with the ground or water and is suitable for the treatment of products that do not require painting.

Some skids have previously been preserved in accordance with finish number 25-1 of MIL-STD-171. This treatment is used when painting of the skids is required. This method of preservation for skids is not recommended, however, since the skids will be in contact with the ground and water. It is also doubtful as to what value painting adds to the skid. The disadvantages of painting are the increased cost and the bleeding of the preservative through the paint.

Creosote has also been used as a preservative on skids. The main disadvantages of this preservative are the objectionable odor, bleeding and tar deposits. When the container is pushed or pulled during handling, transportation and storage, a tar skid trail is often left behind.



(a) TOP VIEW

(b) LEFT SIDE VIEW

(c) BOTTOM VIEW

(d) RIGHT SIDE VIEW

FIGURE 151. SKID WITH EXCESSIVE WARPAGE, CRACKING AND SHRINKAGE

Water-borne preservatives are another common type of preservative used for the preservation of wooden skids. The main disadvantage of water-borne preservatives is that they do not offer adequate protection to the item since leaching results when it is exposed to water or ground areas of moderate or high rainfall. Wood impregnated with it swells upon treatment, requires re-drying for most purposes, and shrinks upon drying.

Pressure treating with water-borne preservatives could also possibly contribute to distortion of wooden skids. This type of treatment could raise the moisture content of the skid to such a degree that uncontrolled drying could result in checking, warping and distortion.

Wooden skids shall be cut to the final required dimensions before being subjected to a preservation treatment.

Skids with boxed heart should be eliminated. Boxed heart is the term used when the pith (the small softcore found in the structural center of the log) is located entirely within the four faces of a piece of wood. This condition is known to aggravate many of the defects associated with drying. The skid shown in Figure 151 is a good example of a skid that contains the pith of a tree.

Wooden skids may be laminated (Figure 152) as an alternate construction method. The laminations shall be constructed of group IV woods with each lamination being from 3/4 to 1 5/8 inches thick. The bonding adhesive shall be per MMM-A-181. When nails are to be used for pressure during cementing, they shall be located approximately 1/2 inch from the bottom of the skid. Transverse carriage bolts, assembled according to Figure 149 shall be used to prevent delamination.

V. Stacking Provisions

Stacking is the placing of material in a self-supporting pile that assures stability and facilitates removal. The economic aspects of efficient space utilization has imposed upon the container the requirements that it resist the effects of stacking. Stacked in tiers, the container must:

a. Retain its integrity when subject to both the static and dynamic loads imposed upon its structure.

b. Contribute and provide support to the overall stability of the stacked configuration.

The physical integrity of a container is the result of its structural design and the material used in construction. In order to retain the integrity of a container while stacked, it should be provided with a load bearing structure capable of supporting an established weight. The container top and the stacking pad must not be deformed when one container supports another, and the container should be designed so that it can be stacked in such a manner as not to interfere with the fork lift access. For small containers, the body may be required to resist the loads imposed by stacking. Ribs or corrugations may be pressed or molded into the body of a small container to provide the required rigidity.

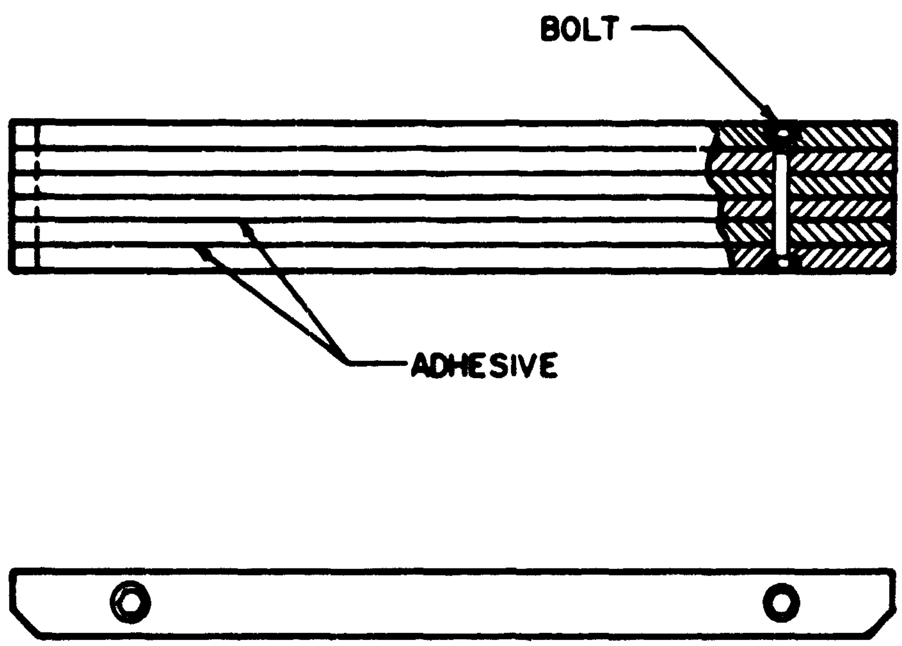


FIGURE 152. LAMINATED SKID

Stacking brackets that are welded onto the container must be structurally strong and must also provide enough area for a strong weld. Two of the weaker designs are shown in Figure 153 and should be avoided in container design. These designs, in order to withstand the required loads, must have gusset plates welded inside their configuration or be made of heavy gage material. This method defeats the objective of maintaining a minimum weight. A better method is to design the structural integrity into the bracket itself. Two acceptable designs are shown in Figure 154.

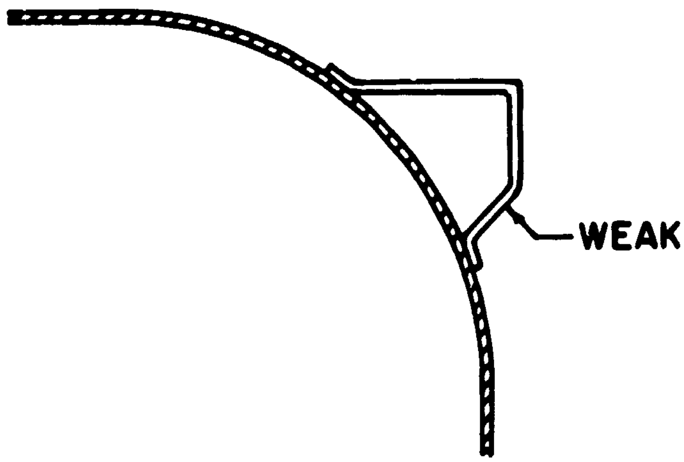
Large containers may incorporate structural members enveloping and supporting the relatively less rugged body shell. With the stacking pads welded to the container shell directly over the structural members, the necessary rigidity required for stacking is provided (Figure 155). The structural members function as a truss and the shell of the container is theoretically free of any externally imposed forces and merely functions to envelop its contents. With stacking pads integral to the structural truss, proper alignment of the load-bearing truss and unitization of the stack is facilitated. Such alignment allows the forces, imposed on the container by stacking, to be transmitted by the structural members, acting as columns, to successive tiers to relieve the container shell of the need to provide the required support. Figures 156 and 157 illustrate some of the various stacking pad designs that have been used on missile containers. The designs shown in Figure 156 incorporate a lateral stop while those shown in Figure 157 do not provide lateral stops and are, therefore, inadequately designed. Figure 158 shows damage caused when structural members are not used in container shell. Figure 159 shows the damage caused when inadequate structural members are incorporated in the container.

To achieve stability in stacking operations, wide skid spacing with allowances for the addition of roll rings is desired. Roll rings are introduced to enable a single container to roll or tip without imposing excessive lateral shock on the item. Roll rings are especially recommended for the bottom half of the container and, where it is structurally and economically feasible, are recommended for the top half of the container. This configuration is shown in Figure 160.

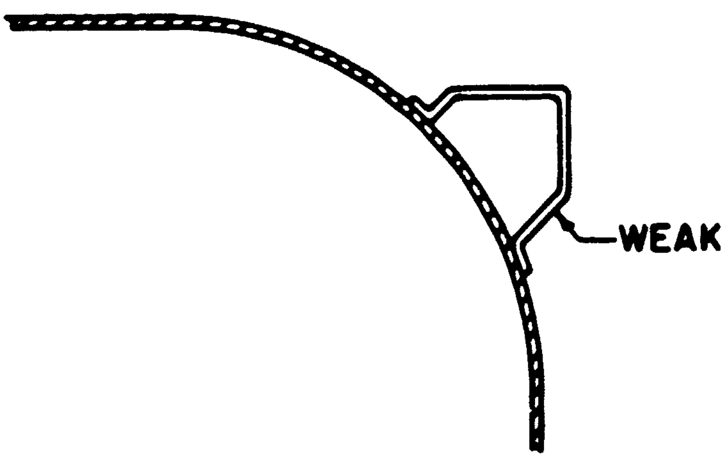
Provisions should be made for interlocking stacked containers to provide stability and prevent shifting while in transit. Proper skid and stacking pad design will reduce the likelihood of accidental tipping or shifting while in storage or transit. The stacking pad should prevent the skid of the container from moving in both the lateral and longitudinal directions and provide stability when subjected to both static and dynamic loads. Two possible stacking pad-skid configurations are shown in Figure 161.

Figure 162 illustrates stacking pad provisions incorporated in design of small containers.

Stacking patterns and procedures are based upon the gross weight of the container and or the limitations of available space. In addition, the transit environment will introduce dynamic loads which will limit the stack

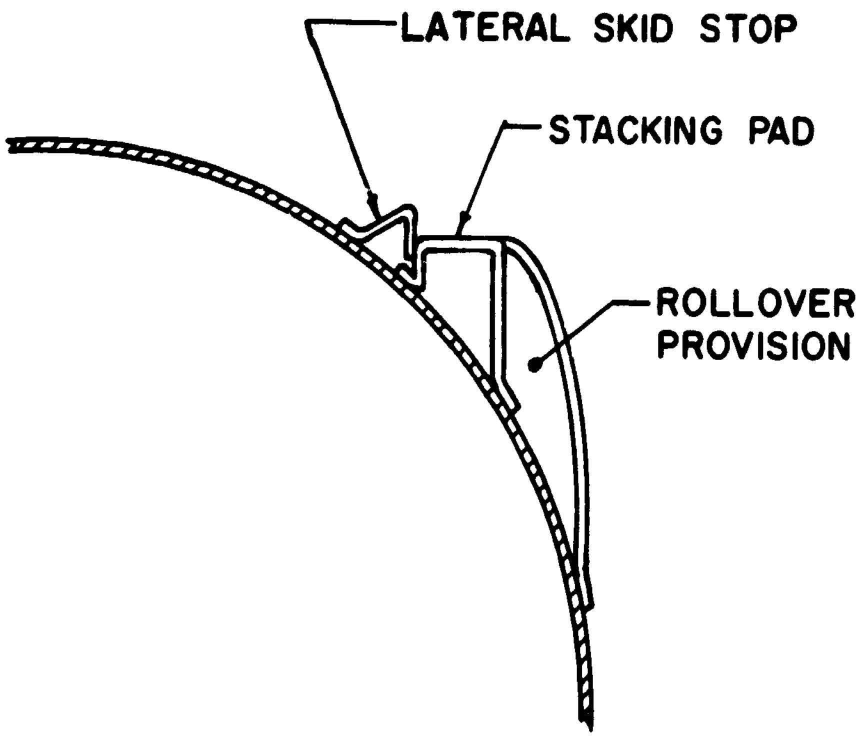


(a)

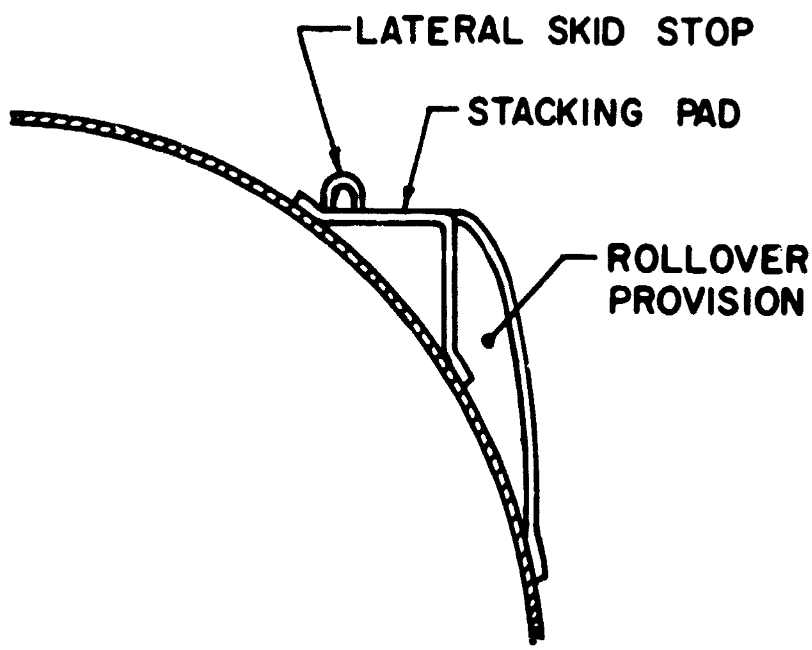


(b)

FIGURE 153. UNDESIRABLE STACKING PAD DESIGNS



(a)



(b)

FIGURE 154. ACCEPTABLE STACKING PAD DESIGNS

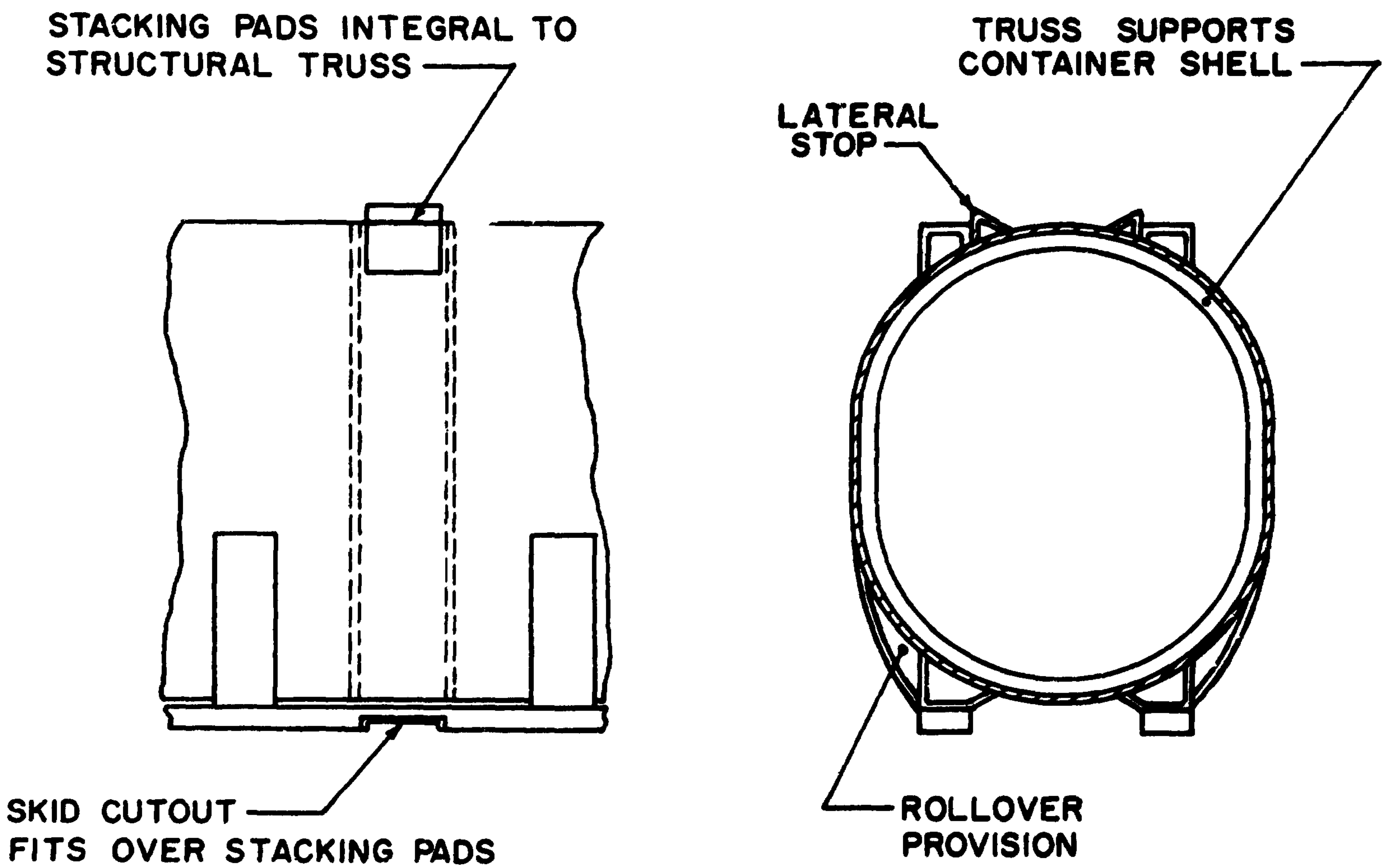


FIGURE 155. CONTAINER INCORPORATING ROLLOVER PROVISIONS AND STRUCTURAL TRUSSES

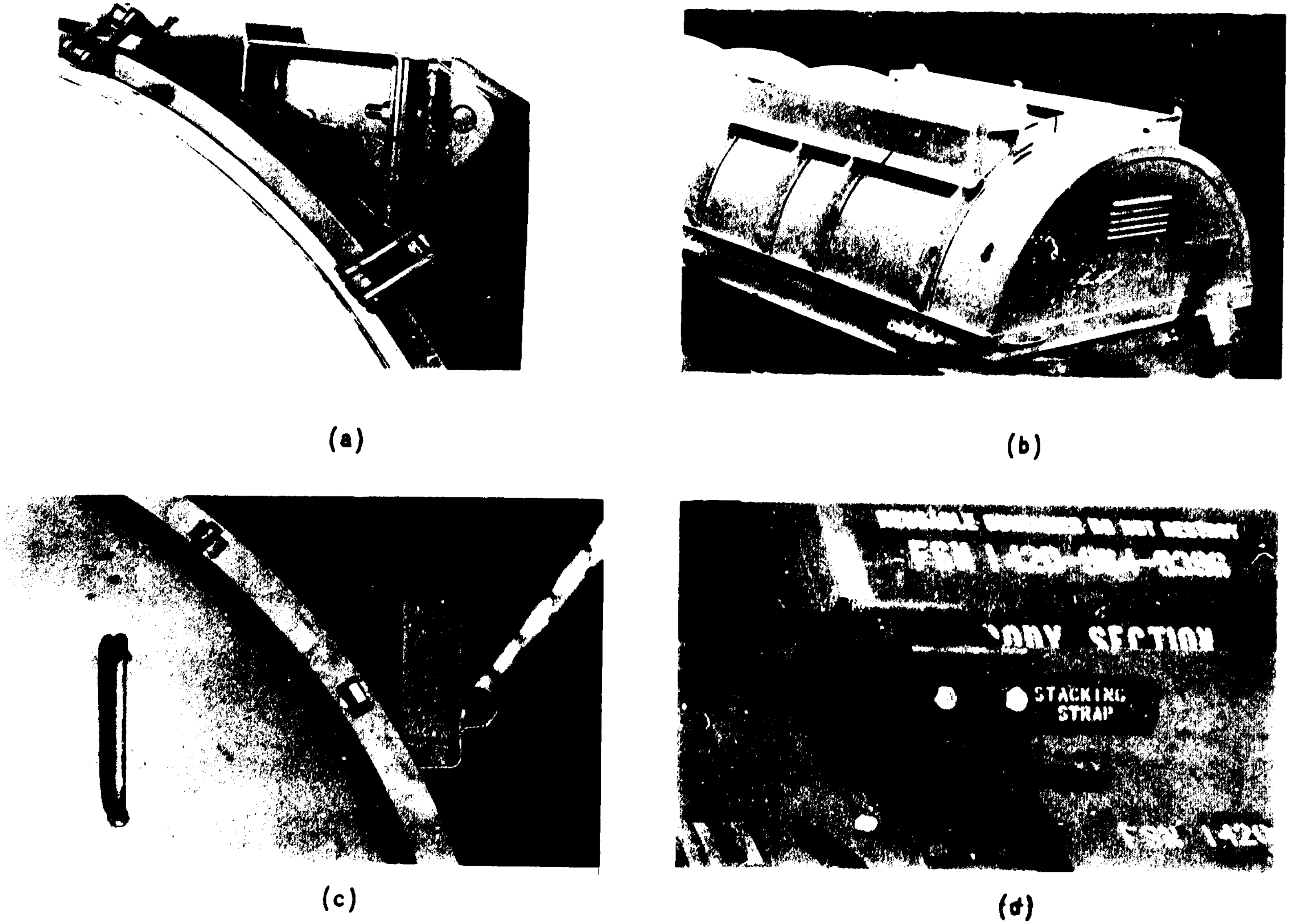
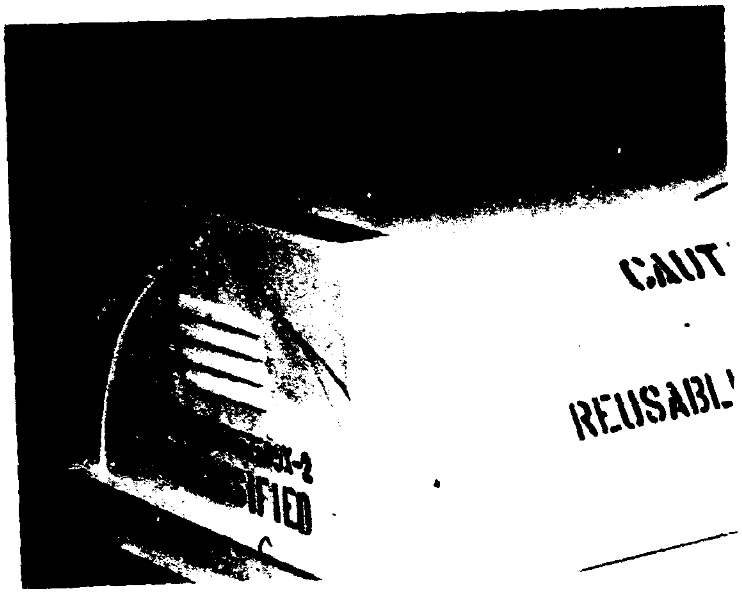
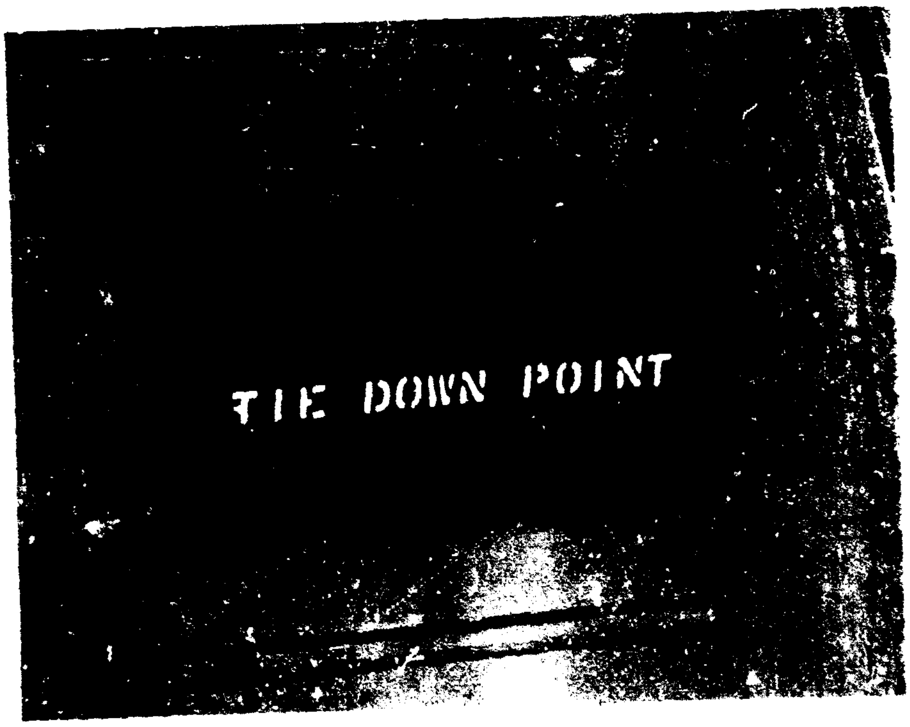


FIGURE 156. PREFERRED STACKING PAD DESIGNS



(a)



(b)

FIGURE 157. INADEQUATELY DESIGNED STACKING PADS

FIGURE 158. DAMAGE DUE TO LACK OF STRUCTURAL MEMBERS

FIGURE 159. DAMAGE DUE TO INADEQUATELY DESIGNED STACKING PAD

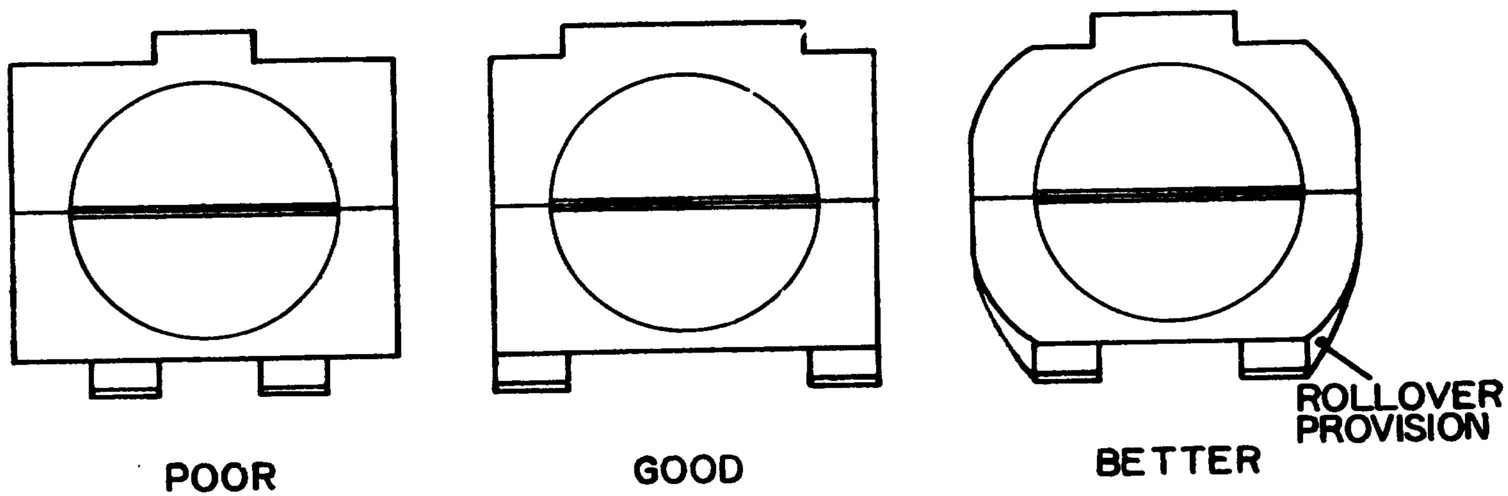
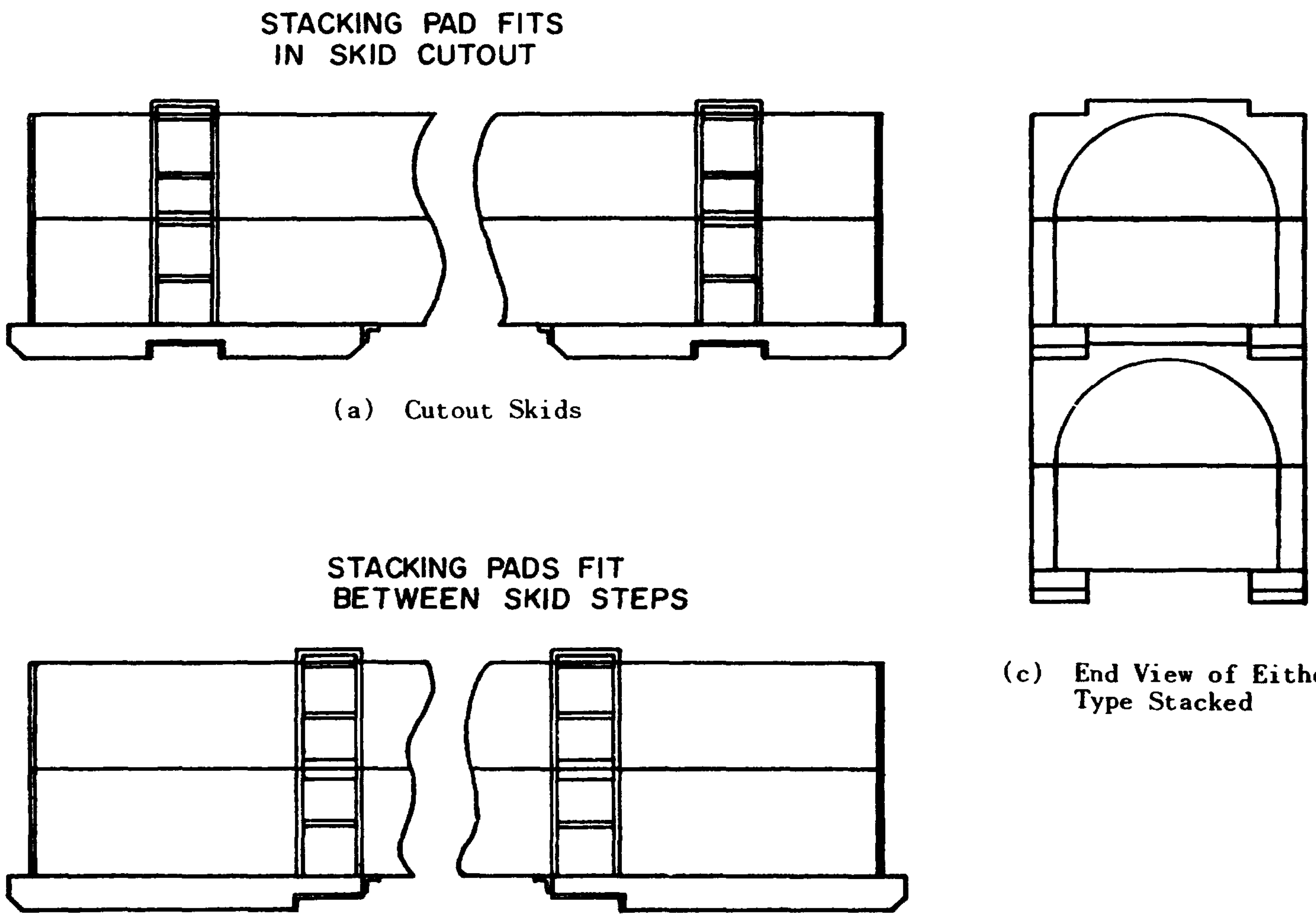


FIGURE 160. SKID SPACING



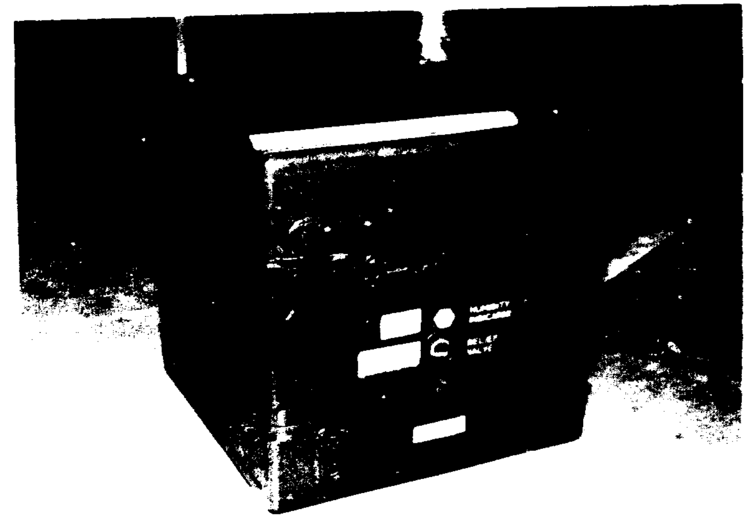
(a) Cutout Skids

(b) Stepped Skids

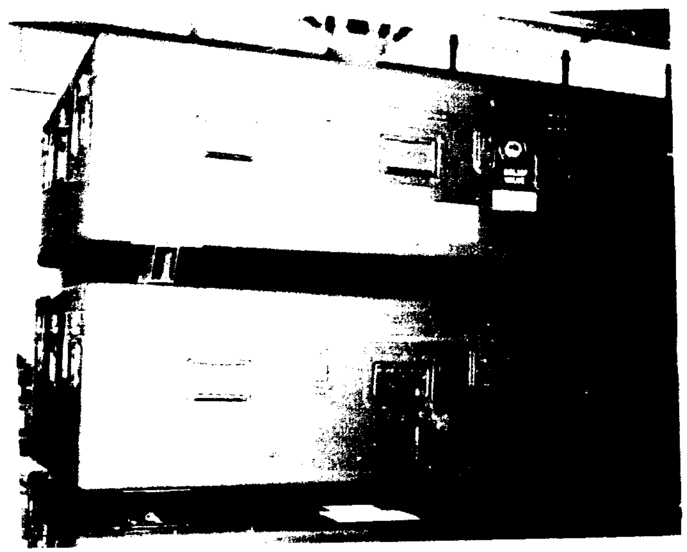
(c) End View of Either Type Stacked

FIGURE 161. STACKING PAD SKID CONFIGURATIONS

(a)



(b)



(c)

FIGURE 162. SMALL CONTAINERS INCORPORATING STACKING PROVISIONS

to a height less than that permissible in a passive storage environment. Stacking procedures and technique must consider both situations and design for that condition which is prevalent and/or most severe. Table 21 provides guidance to the container designer and is representative of those conditions which exist in today's environment of worldwide distribution.

TABLE 21

STACKING LIMITATIONS

Container Gross Weight	Normal Stack Height
5,000 lb. and up	Generally not stacked because of size and weight.
2,500 to 5,000 lb.	2 High
2,500 lb. or less	3 High or to a height of 15 ft.

CHAPTER X

BREATHING AND DEHUMIDIFICATION

GENERAL

As a result of evaporation, the atmosphere in which we live always contains some moisture in the form of an invisible vapor. The amount of water vapor contained in a unit of atmosphere is a function of the temperature. As the water vapor becomes more dense, the pressure it exerts becomes greater until the air has absorbed all of the vapor possible at that temperature at which time it is said to be saturated.

The volume of atmosphere confined within a sealed container consists of a mixture of dry air and water vapor each contributing to the total pressure an amount equal to that it would exert if allowed to occupy the entire space alone, ($P = Pa + Pw$, Dalton's Law). It has been found by test that the saturated vapor pressure of a liquid has materially different values when measured at different temperatures. A rise in temperature causes the confined atmosphere to become less dense and is accompanied by an increase in pressure. A fall in temperature increases the density of the mixture and if the temperature falls to a sufficiently low value, the atmosphere becomes saturated and the vapor begins to condense forming corrosive dew. Also at this temperature level, the pressure exerted by the confined gas is reduced and may result in a vacuum.

The General Gas Law which merges the relations discovered by Boyle and Charles, establishes the relation between pressure, volume and temperature of a fixed mass of atmosphere:

$$PV = MRT$$

For a given mass of confined atmosphere, as in a structurally rigid container, the constant MR and the volume V are of fixed values; consequently the relationship becomes:

$$\frac{P}{T} = \frac{MR}{V} = \text{constant}$$

therefore: T is directly proportional to P.

As temperature T is directly proportional to the pressure P, it becomes evident that as the temperature rises, the pressure of the confined atmosphere increases and as the temperature drops, the pressure decreases.

In addition to temperature fluctuation, the effect of pressure variation is of concern to the container developer. At sea level, the atmospheric pressure is approximately 14.7 psi and decreases with elevation to a value of approximately 4.4 psi at 30,000 ft. As such, a sealed container must be capable of withstanding this pressure differential in addition to the effects of the temperature variance of these altitudes.

TABLE 22

ALTITUDE/PRESSURE CHART

ALTITUDE (FT.)	PRESSURE (Psia)	PERCENT CHANGE PER 1000 FT.
0	14.7	-
1,000	14.2	4%
2,000	13.7	4%
3,000	13.2	4%
4,000	12.7	4%
5,000	12.2	4%
7,500	11.1	
10,000	10.1	
12,500	9.17	
15,000	8.30	
17,500	7.50	
20,000	6.76	
25,000	5.46	
30,000	4.37	
35,000	3.47	
40,000	2.73	
45,000	2.15	
50,000	1.69	

TABLE 23
ALTITUDE/TEMPERATURE CHART

ALTITUDE (FT.)	TEMPERATURE - °F	
	*COLD ATMOSPHERE	*HOT ATMOSPHERE
0	-60.0	100
1,000	-46.5	99.2
2,000	-33.0	95.4
3,000	-19.3	91.5
4,000	-18.0	87.6
5,000	-15.0	83.7
7,500	-15.0	73.8
10,000	-15.0	63.9
12,500	-20.8	54.5
15,000	-29.1	44.9
17,500	-37.5	36.1
20,000	-46.1	26.5
25,000	-63.9	6.7
30,000	-82.3	-12.3
35,000	-85.0	-30.1
40,000	-86.0	-44.8
45,000	-96.6	-42.6
50,000	-122.9	-40.2

*Probable extreme minimum and probable extreme maximum temperatures.

The combination of these physical phenomena (thermal, humidity and elevation) and their effects upon the container and its contents are of prime concern to the designer.

One of the many functions of a container is to protect its contents from the deteriorating effects of moisture without compromising those characteristics favorable to the logistic aspects of "worldwide distribution." A container subject to "worldwide distribution" will, at some time, be exposed to any or all of the conditions resulting in the phenomena previously described.

Early effort to protect sensitive and sophisticated materiel utilized a pressurized sealed container purged of moisture laden atmosphere. The need for a perfect seal and a structurally sound container body imposed a weight penalty not compatible to an economical logistic pattern. The sealing effectiveness was marginal and the resultant weight required to withstand the pressure differential was considered objectionable, particularly when subject to air transport.

To provide a lightweight effective container, capable of performing its protective functions in a "worldwide distribution" environment, a new concept was developed; *that of free breathing*. Free-breathing containers are based on the use of tubes open to the atmosphere which allow the container to "breathe" when subject to pressure differentials. The tubes, open to the atmosphere, provide an air passage to equalize the internal and external pressures of the container. This technique permits the use of thinner, lighter weight materials and precludes the need for a perfect seal. The tubes provide an air passage but, by design, impede the transfer of moisture vapor. An empirical ratio of 1:10 has been established for the tube diameter to minimum length. The tubes may be bent to restrict the entrance of rain or sea water; however, any trapped water may freeze during air-lift, destroying the ability of the container to breathe.

The present state-of-the-art makes available high flow breather valves to permit application of the *controlled breathing technique*. These valves (pressure and vacuum relief) constantly adjust the container pressure to changes in the atmospheric pressure and prevent excessive pressure differentials during airlifts. Controlled breathing in conjunction with the use of a dehydrating agent minimizes the corrosion introduced by excessive humidity. Controlled breathing permits the use of lightweight materials; minimizes the complexity of the system and results in less hazardous operation.

Sealed containers exposed to the 24 hour diurnal cycle subject the encased atmosphere within their confines to fluctuations in pressure. As the temperature of the external environment rises and falls during a 24 hour period, (diurnal cycle), the internal temperature of the container will also rise and fall. It has been shown that the pressure varies directly as the temperature and as the temperature rises, the internal pressure increases. Also, as the temperature drops, the internal pressure decreases proportionately. A perfectly sealed container must provide sufficient structural rigidity to withstand the effects of pressure fluctuation caused by the diurnal cycle. In addition, the change in temperature of the encased air may approach the dew point and cause condensation of the suspended water vapor. This small amount of condensate can be conveniently and effectively absorbed by desiccants, a dehumidification technique to be discussed in subsequent sections of this chapter. A sealed container is both logistically and economically unfeasible and the level of protection initially provided will gradually diminish as the result of gasket and seal deterioration and will in time perform as an imperfectly sealed structure or free-breathing container. Consequently, the perfectly sealed container is not recommended and is discussed only for its historical significance.

Imperfectly sealed containers, both free and controlled breathing, will when heated, exhaust air from within their confines. Conversely, as the air cools, the internal pressure will drop creating a vacuum causing air to enter the confines of the container. In effect, the container breathes and by so doing, maintains equilibrium between the internal pressure of the container and the atmospheric pressure of its environment. Consequently, free-breathing containers are not exposed to a pressure differential and the destructive stresses imposed upon a sealed structure. Controlled breathing technique minimizes the pressure differential and subjects the structure to negligible stress forces.

The advantages provided by controlled and free breathing are unfortunately offset by the periodic introduction of new moist air which must be purged of its vapor content. The new air, introduced by the breathing cycle, can be effectively dehumidified by desiccants.

"Fundamentals of Guided Missile Packaging" includes the following statement: "An indoor temperature rise of 5°F will force approximately 1% of the contained air out of an imperfectly sealed structure." It may be assumed that the reverse is true and that with a temperature drop, the same amount of air as that exhausted will be replaced by moist air entering. In certain environments (desert) it is not uncommon to experience a 50°F temperature drop during the diurnal cycle. Based on the above ratio of 1:5, the container will exhaust and replace 10% of its initial volume during a 24 hour period and the moist air entering must be dehumidified.

In addition to the amount of air displaced and replaced by the phenomena of breathing, of prime concern is the rate at which breathing is performed. In certain situations, (rapid descent of cargo aircraft; abnormal temperature drops; etc.) those factors affecting the breathing cycle may change radically and within a matter of minutes. The flow of air through the breather ports or valves must be adequate to avoid subjecting the container structure to the destructive forces of a momentary pressure differential.

TABLE 24
AIR TRANSPORT DATA

Cargo Air-Craft	Rate of Ascent at Sea Level Ft/Min	Cargo Compartment Pressurization	Temperature Maintenance Level in Cargo Compartment °F	Allowable Floor Bearing Pressure Lb/Ft
HU-1A	2,060	NO	-	300
H-34	-	NO	-	200
H-37	-	NO	-	300
C-46	-	-	-	185
C-47	-	-	-	125
C-54	-	-	-	200
C-118	1,000	YES	68° - 74°F	
C-121	1,100	YES	68° - 74°F	
C-123	845	NO*	Equipped with Heaters	200
C-124	3C0	NO*	Equipped with Heaters	200
C-130	1,950	YES	68° - 74°F	288
C-133	1,300	YES	68° - 74°F	300
C-135	2,500	YES	68° - 74°F	
C-141		YES	Equipped with Heaters	200

*Normal flight altitude 10,000 to 14,000 feet.

BREATHING AND ITS RAMIFICATIONS

In addition to those characteristics discussed in previous chapters, the missile container may be further classified as to its ability to provide climatic protection. The most common types are tabulated below in an order reflecting the progressive level of protection provided:

A. Open containers
B. Vented containers
C. Free Breathing containers
D. Controlled Breathing containers
E. Sealed containers

A. *Open Containers* are merely fixtures which function to support their contents. They often are equipped to provide physical and mechanical protection. The container as such, provides no climatic protection nor does it function to resist exposure of its contents to those elements peculiar to the climatic environment. Any climatic protection provided must be by auxiliary devices (barrier bags, etc.) divorced from and independent of the container per se.

B. *Vented Containers* are those which provide protection against many of the climatic elements (rain, snow, etc.) but are functionally open to the atmosphere and will not resist the penetration of moisture laden air. The vents perform to maintain pressure equalization between the interior of the container and the prevalent atmosphere. In addition, the vent holes usually located in the bottom of the container serve as drains through which any accumulated condensate may escape. When used, vents should be located to permit the unrestricted drainage of condensate and yet, not permit the penetration of rain, etc. In addition, drain holes should be screened or baffled to discourage the entry of rodents, snakes, etc.

C. *Free Breathing Containers* are in essence, vented containers having the additional capability of minimizing the amount of moisture vapor entering the container. This is accomplished by the use of vent tubes whose configuration functions to maintain the humidity level within the container once equilibrium has been established. Vent tubes provide an air passage and are open to the atmosphere but by their design function to impede the transfer of moisture vapor. This feature permits the container to breathe; to adjust to the variances in atmospheric pressure without exposing the contents of the container to the moisture prevalent under these conditions. Diffusivity of water vapor in air is so low that, for practical purposes, insignificant quantities of water vapor will pass through tubes of length ten times the diameter. If a tube is used which has a length determined from two components, i.e., a length sufficient to meet this criterion plus an additional length sufficient to contain the "slug" of air expelled from and later returned to the container, infiltration through the breather will be negligible. Tube length may become very great for large containers and thus be impractical. Tests conducted at the Naval Gun Factory have established an inside diameter of 1/4" as minimum for vent tubes to effectively drain any accumulated condensate.

Functioning as an air vent, the tube or tubes, must be of sufficient size to permit passage of the displaced air within a reasonable time. The descent of cargo aircraft (see Table 24) may subject the container to a rapid change of external pressure. It becomes imperative that the internal pressure of the container be equalized and maintained during the external pressure build-up. The ability to perform adequately is dependent upon the vent tube diameter. The following derivation is presented to acquaint the designer with the factors affecting the selection of the vent tube diameter.

a. A review of the data contained in Table 22 indicates that the most severe change in atmospheric pressure occurs in the first few thousand feet of altitude above sea level. The percent of change however remains constant at 4% and this value has been selected as the maximum rate for determining the flow through vent tubes.

b. As container breathing is most pertinent to the air transport environment it becomes essential to establish the rate at which the maximum pressure change will occur. The characteristics of Military Cargo Aircraft are contained in Table 24 and permits the selection of that rate of ascent or descent peculiar to the particular aircraft to be used during delivery.

c. A relationship has been established* between known factors which when presented in mathematical form will permit the designer to calculate the minimum flow through the vent tube to maintain the desired equilibrium.

$$F = (\Delta P)(R)(V)$$

F = flow rate in ft^3/min.

ΔP = Percent of change in pressure per 1000 ft of elevation

R = Rate of change in altitude in 1000's of ft/min.

V = Effective volume of the container in cubic feet (Use volume of empty container if reusable and subject to air transport in empty condition; otherwise, use effective volume by subtracting the displacement of the contents from the total volume).

Considering the maximum percent of change in pressure to be 4% per 1000 feet and the rate of change in altitude to be 2000 fpm (maximum rate of ascent for contemporary military cargo aircraft), the formula may be modified to show the relationship between the required flow rate and the effective volume of the container:

$$F = (\Delta P)(R)(V)$$

$$F = (.04)(2)(V)$$

$$F = .08(V)$$

**Arizona Gear Manufacturing Company*

d. The ability of a tube to satisfy the required flow rate is dependent upon its diameter. The flow rate within a tube with a comparatively small differential pressure between its two ends may be expressed mathematically by the formula:

$$F = 58\sqrt{\frac{pd^5}{WL}}$$

(See Machinery Handbook)

F = Flow rate in ft^3/min

p = pressure differential at the two ends of the tube in psi

d = inside tube diameter in inches

W = Weight of one cubic foot of the air entering or leaving the container in pounds

L = Length of the tube in feet

The basic formula may be modified to permit direct calculation of the minimum tube diameter. As the ratio of length to diameter has been established as 10 to 1; L may be expressed in terms of d and in the same units:

$$F = 58\sqrt{\frac{pd^5}{WL}} \qquad \left\{ \begin{array}{l} L = \frac{10d}{12} \\ L = \frac{5}{6}\,d \end{array} \right.$$

$$F = 58\sqrt{\frac{pd^5}{(W(5/6)d}}$$

$$F = 58\sqrt{\frac{6\ pd^4}{5W}}$$

$$d = \sqrt[4]{\frac{.000248\ F^2W}{p}} \quad \text{inches}$$

Example: Find the minimum diameter of a vent tube to effectively protect a container having a volume of 42.4 ft^3. The container will be reusable and will be returned by air transport empty of its contents. The cargo aircraft will be a C-133 whose rate of ascent is within the established 2000 ft/min.

1. Find the rate of flow necessary to maintain pressure equilibrium between the confines of the container and the prevalent atmosphere.

$$F = 0.08V = (.08)(42.4)$$
$$F = 3.39\ ft^3/min$$

2. The pressure differential at both ends of the vent tube may be assumed to be 1 psi (internal pressure of container at sea level and the pressure at 2000 ft of elevation (see Table 22).

3. The weight of one cubic foot of air is a variable, dependent upon the prevailing altitude, temperature and relative humidity. MIL-STD-210A assists in the selection of a suitable value: $W = 0.076\ lb/ft^3$.

4. Substituting these values in the formula:

$$d = \sqrt[4]{\frac{.000248\ F^2W}{P}}$$

$$d = \sqrt[4]{\frac{(.000248)(3.39)^2(0.076)}{(1)}} = 0.121"$$

5. The minimum tube diameter required has been calculated as 0.121 inches; however, it has been previously determined that to permit tube condensate drainage, the tube diameter can be no smaller than 1/4". Consequently a vent tube having an inside diameter of 1/4" should be used and applying the established 10 to 1 ratio, the length of the tube shall be no less than 2 1/2 inches. An additional length should be provided sufficient to contain the "slug" of air expelled from and later returned to the container as discussed above. A large increase in length necessitates the recalculation of the flow rate to insure that the diameter is adequate.

NOTE: Free breathing containers should be equipped with an effective seal to assure that the majority of displaced air will pass through the vent tube and be subjected to the dehumidification discussed in subsequent sections of this Chapter.

D. Controlled Breathing Containers are a sophisticated version of the free breathing container and the required rate of flow can be calculated in the same manner as previously discussed. The breathing of the container is accomplished by incorporating into the assembly, a precision valve or valves calibrated to open and/or close when subjected to a pressure differential. The state-of-the-art makes available an assortment of commercial valves rated according to their flow capacity and sensitivity to pressure change. MIL-V-8712 (ASG) classifies and establishes the performance characteristics of low pressure air relief valves; however, this document does not reflect the advance of this technology since 1954. Consequently, commercial breather valves must be qualified by test for each application until suitable specifications have been developed and hardware qualified.

There are valves available which will open or "crack" when subjected to a positive pressure. There are valves which will "crack" when subjected to a negative pressure or vacuum. In addition, there are combination valves (Figure 163) which "crack" under both conditions.

The valves or valve will when installed, function to regulate the internal pressure of the container by "cracking" to either exhaust or take-in air when a variance in pressure is experienced by a change in altitude or due to temperature fluctuation.

A container equipped with controlled breathing valves will, when closed and sealed at sea level, have an internal pressure of approximately 14.7 psi. When subjected to an air lift, and upon attaining an altitude of 4000 ft., it will be subjected to an external pressure of 12.7 psi. When exposed to

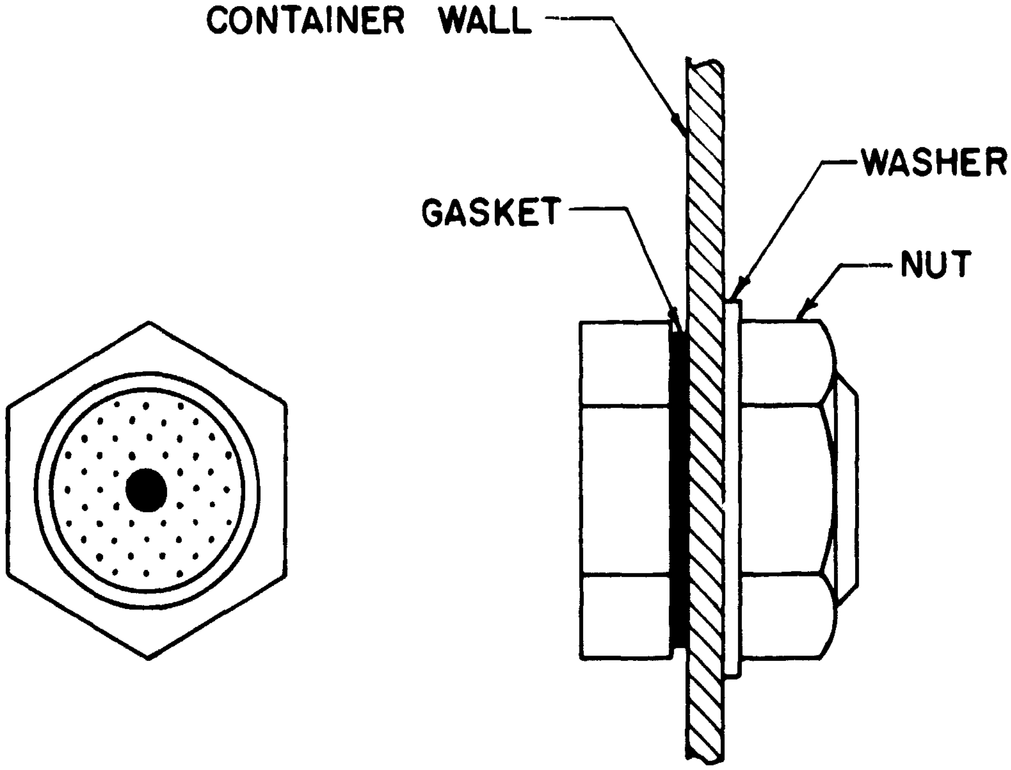


FIGURE 163. TYPICAL PRESSURE RELIEF VALVE

these conditions, the container is said to be under a pressure differential of 2 psi (14.7-12.7). The internal pressure variance causes the positive pressure breather valve to "crack" exhausting air from within the confines of the container. Upon discharge of air, the container experiences an internal pressure drop. The valve remains open until the internal pressure has stabilized to a level equal to or slightly less than the external pressure of the atmosphere, at which time it closes. Similarly, the negative pressure breather valve will function under the opposite conditions as experienced during descent of the aircraft. The atmospheric pressure at sea level is greater than the adjusted internal pressure of the container and the valve "cracks" to suck in air and maintain pressure equilibrium.

The sensitivity of the valve can be calibrated and set to respond to a particular range of pressure differential. The recommended setting has been found to be +2 1/2 psig and -2 1/2 psig. Exhaust valves should be set to "crack" when subject to a pressure variance of +2 1/2 psig. Intake valves should be set to "crack" when subjected to a vacuum of -2 1/2 psig.

As breather valves function to introduce new air into the confines of the container, a dehumidifier will be required to purge the new air of its moisture content.

The choice of a combination two-way valve or two one-way valves is a matter of economics; however, a manual release should be provided under either condition to bleed off residual pressure or vacuum prior to the opening of the container.

E. Sealed Containers refers to those purged of air by the introduction of pressurized dry gas. The effectiveness of pressurization is dependent upon the quality of the container seal and any protection provided is marginal. This technique results in a heavy structurally rigid container not compatible with the logistic requirements of a mobile Army. The sealed container is mentioned only for its historical significance and is not recommended for missile applications.

DEHUMIDIFICATION

Moisture laden air, encased or introduced to within the confines of a container must be purged of its moisture content. The air must be dehumidified to protect the contents from the corrosive effects of the condensate which will ultimately form when the container is exposed to the environment of its logistic pattern.

Dehumidification is accomplished by the use of a desiccant which, having an affinity for water, will extract the moisture from the air within its sphere of influence. Desiccants used for military packaging are usually chemical agents satisfying the performance requirements of MIL-D-3464B.

The performance of a desiccant is based on the principle of partial pressure. A volume of moisture laden air when confined, exerts a pressure comprised of the partial pressure of its dry air content and the partial pressure of its water vapor content. The affinity of a desiccant for water is due to the pressure differential of its water vapor content and that of its atmosphere. Water vapor will diffuse from the relatively higher partial vapor pressure of the moist air to the lower level of the desiccant until dynamic (psychrometric) equilibrium is attained and no further net transfer takes place. This phenomenon is known as adsorption, and results in a reduction in the moisture content of the air exposed to the action of the desiccant.

There are many compounds which will function as a desiccant; however, that used most extensively in Military packaging is silica gel. Silica gel is commercially available from numerous sources and its performance and application is effectively regulated by the following documents:

MIL-D-3464B	Qualification of Desiccants
MIL-P-116D	Quantity of Desiccant Needed
MIL-C-3263	Desiccant Containers

Silica gel is a granular, amorphous form of silica, made from sodium silicate and sulfuric acid. It has an almost infinite number of submicroscopic pores which attract water vapor, condense it, and hold it as a liquid by the physical phenomena known as surface adsorption and capillary condensation. It can adsorb approximately 40% of its weight of moisture at 100% relative humidity. The adsorption process is purely physical, therefore harmful compounds are not formed when water is adsorbed. The volume of silica gel remains unchanged as water is adsorbed. Saturated silica gel neither appears nor feels wet. It will however, dissolve if soaked and therefore should never be located in the container as to come into direct contact with any accumulation of condensate. Silica gel is available in a variety of particle sizes however under static equilibrium conditions the size and shape of particles is usually unimportant. A few properties of silica gel are shown in Figures 164 and 165.

The process of adsorption and activation are completely reversible, as a result silica gel can be reactivated an unlimited number of times without loss in efficiency or adsorption capacity.

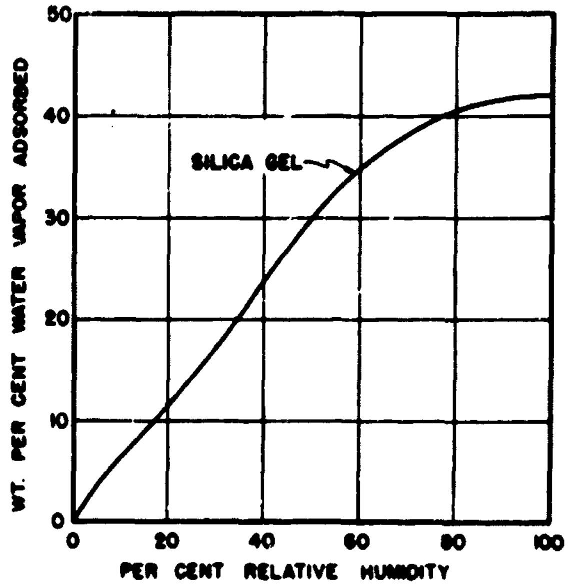


FIGURE 164. EQUILIBRIUM ADSORPTION CAPACITY OF SILICA GEL

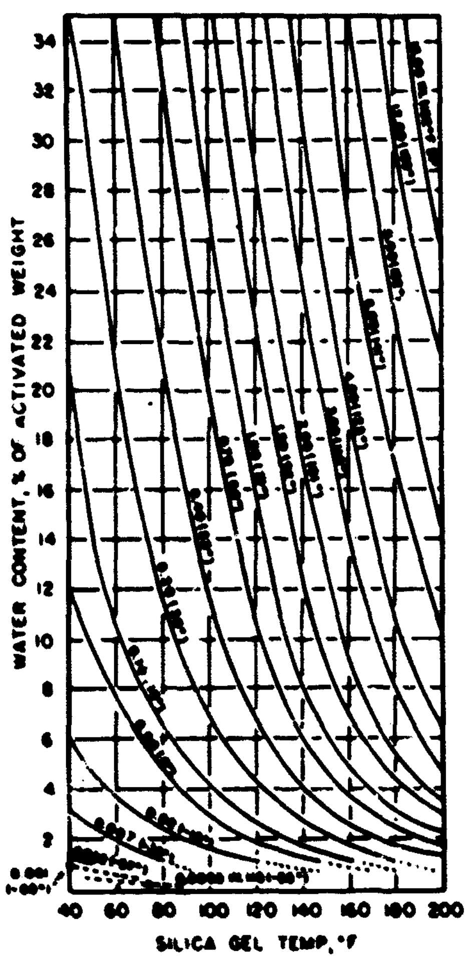


FIGURE 165. WATER CAPACITY OF SILICA GEL AS A FUNCTION OF TEMPERATURE AT VARIOUS PARTIAL PRESSURES (EQUILIBRIUM ISOPIESTICS). DEW POINTS CORRESPONDING TO PARTIAL PRESSURES ARE GIVEN IN PARENTHESES ON ISOPIESTIC LINES.

Desiccant dehumidification can be applied by static, automatic, or dynamic means. In *dynamic dehumidification* machinery is employed to remove excess moisture from an enclosure. Normally, the air to be dehumidified is drawn from the enclosure and forced through a bed of desiccant where it is dehumidified. The dried air is returned to the enclosure where after collecting additional moisture it is again recirculated through the machine. Generally, dynamic dehumidification is used in the dehumidification of large spaces, over 4000 cu ft in volume. As missile and rocket containers are well below this volume, they can be dehumidified using automatic or static dehumidification.

Automatic dehumidification refers to a solar radiation breather in which air drawn into an enclosure is forced to pass through a bed of desiccant, usually silica gel. Therefore, only dry air can enter during in-breathing. During out-breathing, solar radiation is utilized for the reactivation of the desiccant.

Static dehumidification utilizes a quantity of activated desiccant placed in the space to be dehumidified. The initial charge must be sufficient not only to reduce the relative humidity of the air, but also to remove any water which may be present in or on the item stored.

Containers equipped with either free or controlled breathing devices will require considerably more desiccant than those that are hermetically sealed and in addition, will require periodic inspection to assure effective performance of the desiccant. Indicators and detectors are available which will automatically register to show, by visual inspection, that the desiccant has become saturated and its affinity for moisture has been exhausted.

The procedure established to regulate the use of desiccants to assure effective application is adequately documented. Standards have been established and formulae developed to assist in the selection of the amount of desiccant required for the various conditions and amount of air to be dehumidified.

MIL-D-3464B defines the unit weight of a desiccant and specifies that it shall not exceed 50 grams. As the unit weight will vary with the capacity adsorption of the specific desiccant agent, general calculations must consider the maximum weight which may be used. Consequently, the subsequent formulae will consider a unit of desiccant as 50 grams.

DESICCANT REQUIREMENTS FOR SEALED CONTAINERS

MIL-P-116D presents two formulae which apply only to *sealed containers* where the vapor transmission rate of the barrier material used is so low as to be considered negligible. Under these conditions, the desiccant will be required only to dehumidify the encased air and will *not* be subject to any appreciable amount of additional moisture vapor introduced after sealing.

NOTE: When sealed containers are subjected to periodic inspection, or their seal is broken at any time, the initial desiccant charge must be replaced by either a new or reconstituted desiccant.

Formula No. I - To find the units of desiccant for use within *flexible sealed moisture barriers* other than rigid metal containers:

$$U = 1.6A + XD$$

Formula No. II - To find the units of desiccant for use within *sealed metal containers* functioning as *rigid* moisture barriers:

$$U = KV + XD$$

Where:

U = number of units of desiccant required

A = surface area of the moisture barrier in square feet

D = pounds of dunnage (cushions, braces, supports, etc.) other than metallic objects encased within the barrier.

V = Volume of the container in cubic inches or cubic feet

K = 0.0007 when volume is expressed as in^3

K = 1.2 when volume is expressed as ft^3

X = 0.5 for synthetic foam or rubber dunnage

X = 2 for glass fiber dunnage

X = 6 for bound fiber (hair) dunnage

X = 8 for felt, wood and cellulosic dunnage

DESICCANT REQUIREMENTS FOR FREE OR CONTROLLED BREATHING CONTAINERS

The desiccant used in conjunction with free or controlled breathing must have sufficient adsorption capacity to dehumidify not only the initial air encased with the container but also that additional air which will be introduced by the breathing process. The units of desiccant required to dehumidify the initial air can be determined by applying formula I or II.

Additional units of desiccant will be required to compensate for the breathing experienced during *long term storage* and/or the *diurnal cycle*. The additional units of desiccant required to protect under these conditions may be determined by the use of the following formula (see "Fundamentals of Guided Missile Packaging" - Klein):

Formula III (NOTE: Applies to silica-gel desiccant)

$$P = \frac{2VT_3\ (T_1 - T_2)\ DMR}{T_1T_2S_3E} \quad (1\text{-C})$$

Where:

P = Pounds of silica gel required

V = Volume of container in cubic feet

*T_1 = Average daily high temperature inside container, ^oR. Subtract low from high ambient values, multiply differential by 1.6 in spring, 2.0 in summer, 1.6 in fall and 1.2 in winter and add to T_2.

*Climatic extremes for military equipment may be found in MIL-STD-210A.

T_2 = Average daily ambient low temperature, ^oR

T_3 = Arithmetic average daily ambient temperature, ^oR

D = Storage time in days

M = Pounds of water to saturate one pound of dry air at temperature T_3

R = Average relative humidity of ambient air being drawn into container

C = Reactivation constant for silica gel. Determined as 0.312 experimentally

S_3 = Cubic feet occupied by one pound of dry air at temperature T_3.

E = Equilibrium percent water adsorption of silica gel in contact with air at average relative humidity during that part of the day when air is drawn into containers.

In equation III, the number 2 is an empirical factor of safety necessitated by the number of assumptions required. For outdoor storage under tropical conditions (T = 80° to 135°F, RH = 90%). It has been estimated that the quantity of silica gel should be 0.273 lb/ft^3 yr.

For complete protection encompassing all the environments peculiar to "worldwide distribution", the desiccant charge must include sufficient units to provide for the many changes of air which the container may experience when subjected to *rapid variations in atmospheric pressure* peculiar to the air transport media environment. The amount of additional desiccant required may be determined by estimating the number of flights that the container will experience during the delivery phase of its logistic cycle. As the container gains altitude, the pressure inside exceeds the external ambient pressure and the container exhales at intervals set by the sensitivity of the pressure relief valve if the container is of the controlled breathing type. If the container is free breathing, it will exhale constantly. When gaining altitude the container exhales dry desiccated air, however in descent, the container will inhale moist air. From MIL-STD-210A and similar data the external temperature at any altitude can be found. With a psychometric chart, the water content in weight per unit volume of air can be determined. Calculate the quantity of air inhaled by applying the general gas laws. Knowing the above, the amount of desiccant required to remove the water content of the inhaled air can be calculated. This desiccant should be added to that required for initial and storage desiccation.

In summation, one may consider the amount of desiccant used as a function of the container and its moisture barrier characteristics and as a function of the environment in which the container will operate. Overall, worldwide protection must consequently provide for either or all of the following:

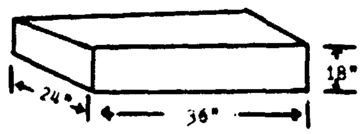
1. Initial desiccation, which is the removal of moisture present when the container is sealed.
2. Transportation desiccation; the protection needed during shipping.
3. Storage desiccation; the protection needed during container storage.

Illustrative examples of the procedures used in calculating desiccant requirements of containers:

Example I: A shipment is enclosed in a rectangular flexible sealed moisture barrier 24" x 36" x 18" and contains 10 pounds of wood dunnage.

Solution: The amount of desiccant required for this type package depends on the surface area of the moisture barrier and the weight of dunnage within the barrier. Using formula I:

$$U = 1.6A + XD$$



$$A = [2\,(24)(18) + 2(36)(18) + 2\,(24)(36)]\ \frac{in^2\ ft^2}{144\ in^2}$$

$$A = \frac{864 + 1296 + 1728\ ft^2}{144}$$

$$A = \frac{3888}{144}$$

$$A = 27\ ft^2$$

$$X = 8\ \text{(for wood)}$$

$$D = 10\ lb$$

$$U = (1.6)(27) + (8)(10)$$

$$U = 43.2 + 80$$

Answer: $U = 123$ units of desiccant

Example II: A modular aluminum container is hermetically sealed. It is 12 inches square and 4 feet long. It contains 7 pounds of fiber glass cushioning.

Solution: The amount of desiccant required for this type of container depends on the volume of the container and the weight of the enclosed dunnage. Using formula II:

$$U = KV + XD$$

$$K = 1.2$$

$$V = (1)(4) = 4 \text{ ft}^3$$

$$X = 2$$

$$D = 7 \text{ lb}$$

$$U = (1.2)(4) + (2)(7)$$

$$U = 4.8 + 14$$

Answer: U = 19 units of desiccant

Example III: A steel container 3 ft in dia and 6 ft long is to be stored for six months in a tropical atmosphere with 90% relative humidity, the temperature varies from 70°F to 85°F. The container is free breathing and is sealed in the field at the above conditions. Elastomeric mounts are used for suspending the packaged item. Find the amount of silica gel required to prevent corrosion.

Solution: Formula III can be used to find the amount of desiccant needed; however, this formula assumes that the container is dry when sealed. As this is not the case in this example, the amount of desiccant required as an initial charge to dry the container is calculated from formula II. The volume of the contained item is not subtracted from the volume of the container thereby providing an added factor of safety.

$$U = KV + XD \left\{ \begin{array}{l} K = 1.2 \\ V = \dfrac{\pi d^2 l}{4} = \dfrac{\pi (3)^2 (6)}{4} \\ V = 42.4 \text{ ft}^3 \\ D = 0 \\ \therefore U = (1.2)(42.4) + X(0) \end{array} \right.$$

***Initial Charge U = 51** units of MIL-D-3464B desiccant*

Using formula III:

$$P = \frac{2V\ T_3\ (T_1 - T_2)\ DMR\ (1-C)}{T_1\ T_2\ S_3 E}$$

$V = 42.4\ ft^3$

$T_3 = \dfrac{70 + 85}{2} = 77.5^{o}F = 77.5 + 460 = 537.5^{o}R$

$T_1 = 85^{o} - 70^{o}F = 15^{o}$; $2.0(15^{o}) = 30$; $530 + 30 = 560^{o}R$

$T_2 = 70^{o}F = 70 + 460 = 530^{o}R$

$D = 6$ mos. = 180 days

$M = 0.019$ Found from a psychrometric chart for air. Dry bulb temperature 77.5°F; wet bulb or saturation temperature 75°F

$R = 90\%$

$C = 0.312$

$S_3 = 13.8$ Found from a psychrometric chart for air

$E = 41\%$ Found by extrapolating Figure 165; using a temperature of 77.5°F for the silica gel and a wet bulb or dew point temperature of 75°F. This can be checked by using Figure 164; with a relative humidity of 90%. Figure 164 can be used because it was derived for a temperature of 77°F which by chance are the conditions of our problem.

Substituting into Formula III and solving:

$$P = \frac{2(42.4)(537.5)(560-530)(180)(0.019)(.9)(1-.312)}{(560)\ (530)\ (13.8)\ (.41)}$$

$P = 1.7$ lb of silica gel

DESICCANT HOLDERS

Standard commercial types of desiccant holders, usually cylindrical in configuration, are available. They consist of a perforated holder body, a cover with a sealing gasket, washer and a nut. Also provided is an "O" ring seal to be installed between the holder body and the outer container wall. This type of holder is adapted to the container by means of a hole in the container wall (Figure 166) and eliminates the need for opening the container to gain access to the desiccant.

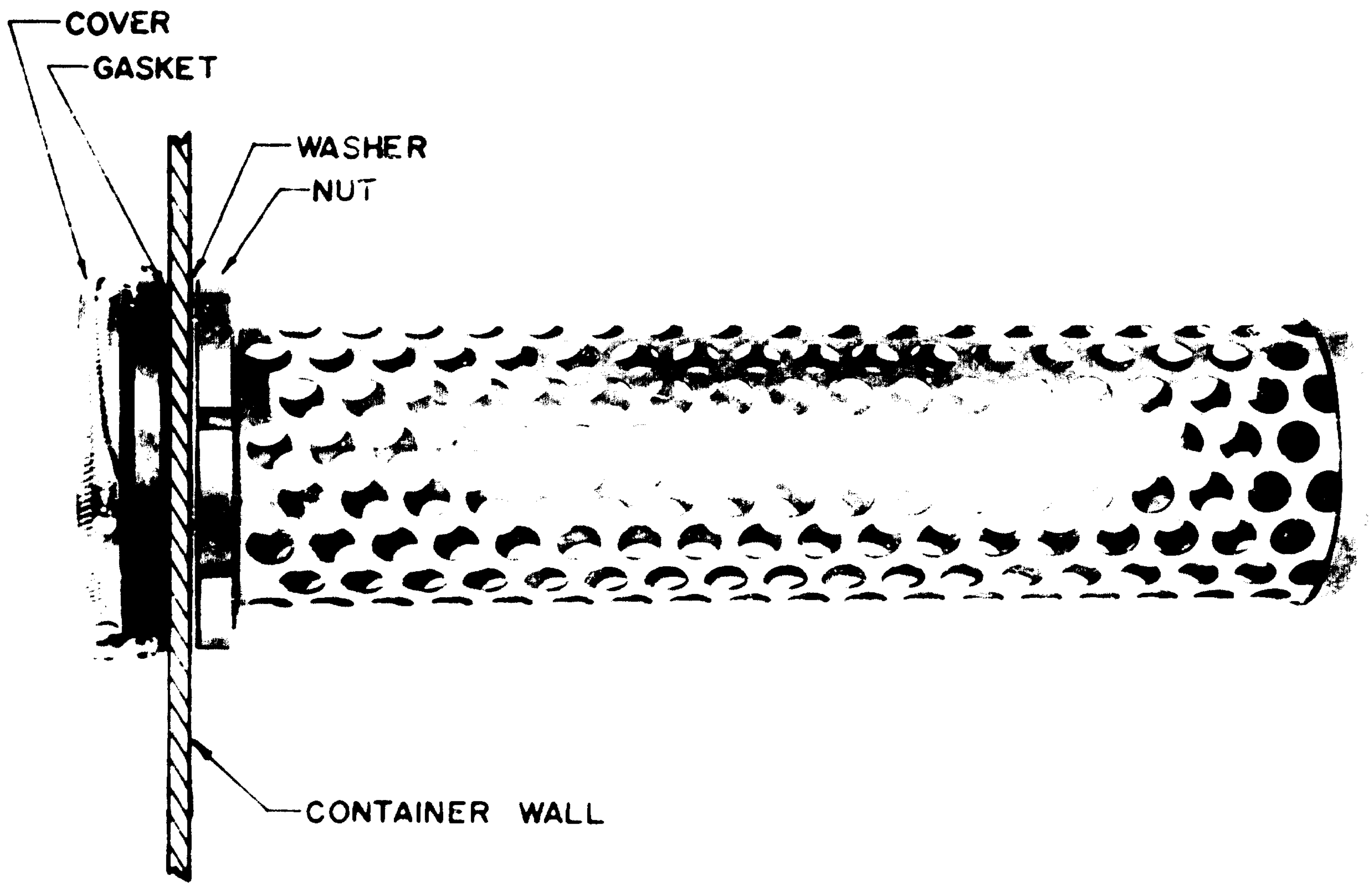


FIGURE 166. COMMERCIAL TYPE DESICCANT HOLDER

The addition of a boss or other modification to the container may be necessary in order to effect a seal when it is intended to install the desiccant holder in a curved surface.

The covers for these holders may be provided with various breather valves in their centers. This eliminates the need for an extra hole in the container body.

Custom designed baskets have frequently been used as desiccant holders. These vary in size and configuration, depending on capacity required, location, and the availability of space within the container. These baskets may be made of perforated metal (Figure 166), expanded metal (Figures 167 and 168), or of wire (Figure 169).

Whichever type of desiccant holder is used, it should be located at the same end of the container as the breather valve and the humidity indicator to facilitate replacing of the desiccant and allowing the containers to be stacked in storage with their ends against a wall thereby making optimum usage of the space available.

Studies have shown that the location of the desiccant, with respect to the humidity indicator, has no substantial effect on the relative humidity reading. Provision should be made for replacement of the desiccant without opening the container, by providing a sealed opening through which the desiccant basket can be reached. A typical example of such an access door is shown in Figure 170.

HUMIDITY INDICATORS

There are three general types of humidity indicators that have been used on missile containers. They can be classified as follows:

1. Hexagon head humidity indicator plug
2. Round head humidity indicator plug
3. Card type humidity indicator

The hexagon head humidity indicator plug is an externally mounted indicator which consists of a metal housing, a retaining gasket, and a washer and nut. A hole is drilled in the container and the nut is welded over the hole on the inside of the container. The plug is then threaded into the nut with the gasket providing a seal (Figure 171). The humidity card may be changed by using a standard adjustable or open end wrench to remove the plug from the container. An internal hex wrench is then used to remove an internal nut from the plug so that the card may be removed. A variety of humidity cards is available for use in the hexagon head plug (Figure 172). These indicators can be either "go-no-go" gauges (Figure 172a) or multiple range indicators (Figures 172b, c, d)

The availability of such cards and the need of only standard tools for removal and replacement makes the hexagon head indicator plug especially adaptable for use on missile containers.

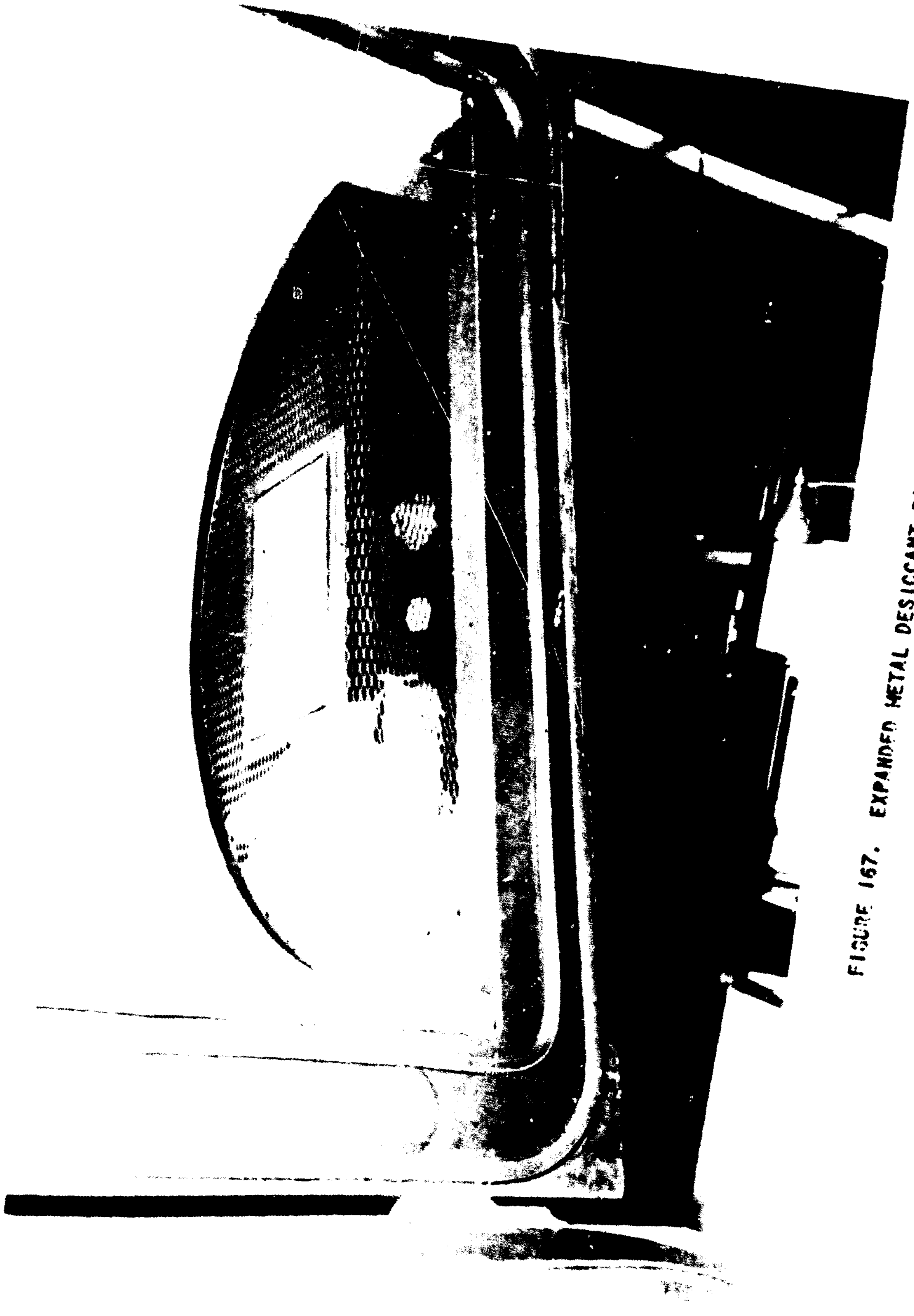


FIGURE 167. EXPANDED METAL DESICCANT BASKET

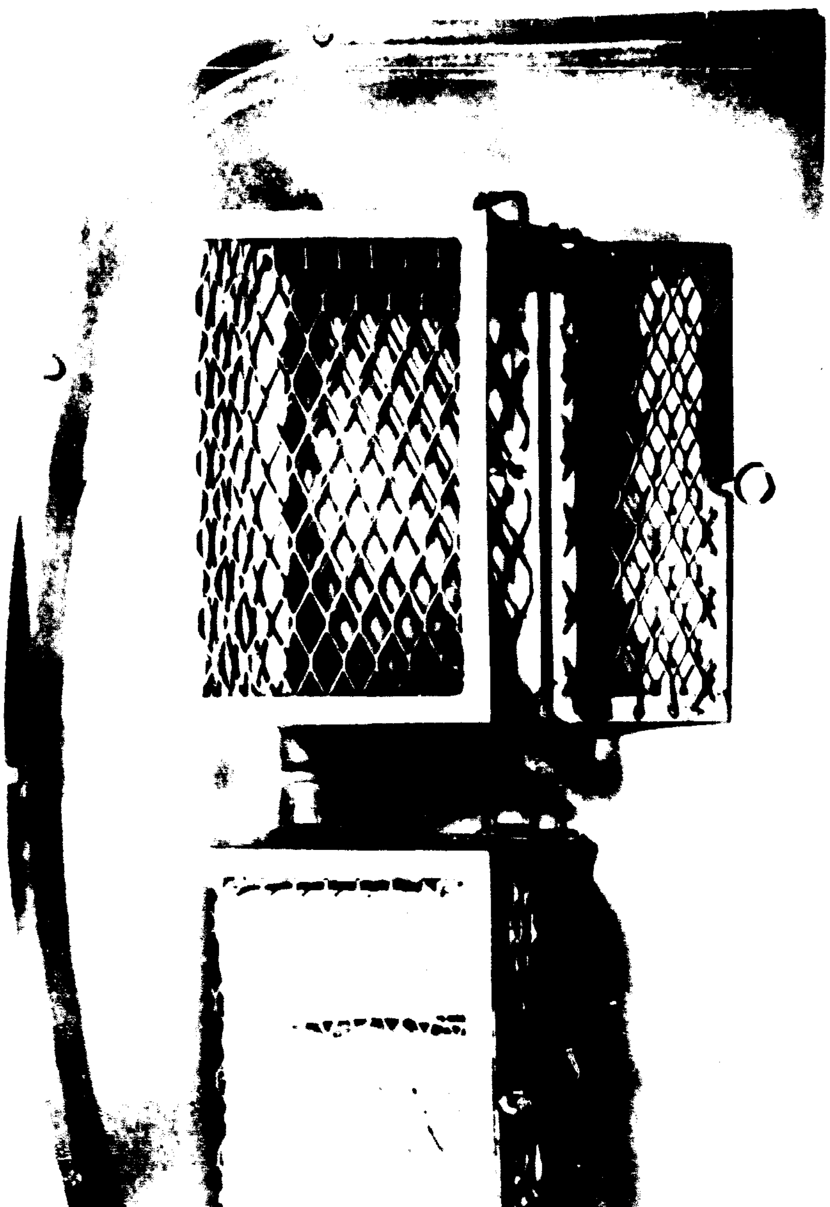


FIGURE 168. EXPANDED METAL DESICCANT BASKETS

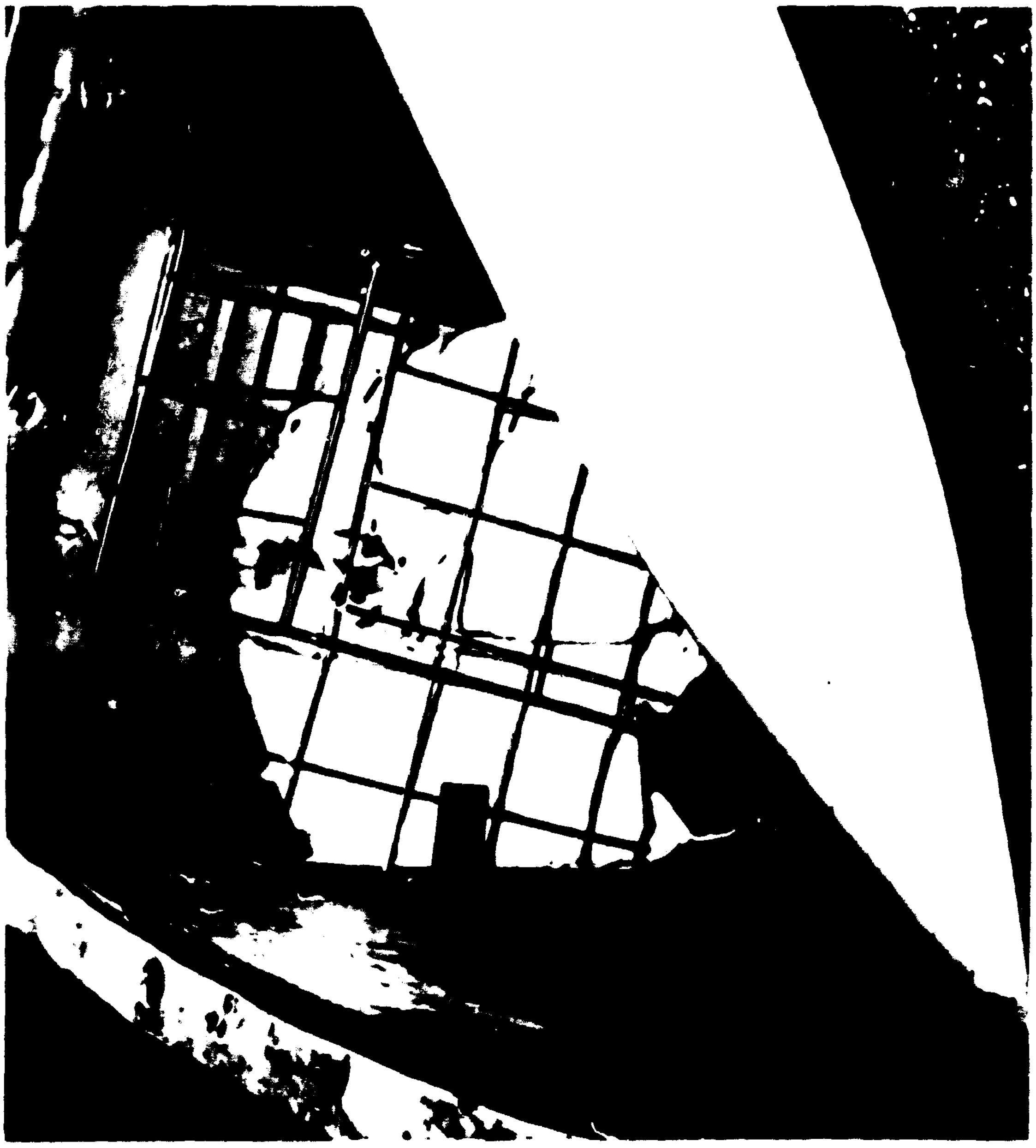


FIGURE 169. WIRE DESICCANT BASKET

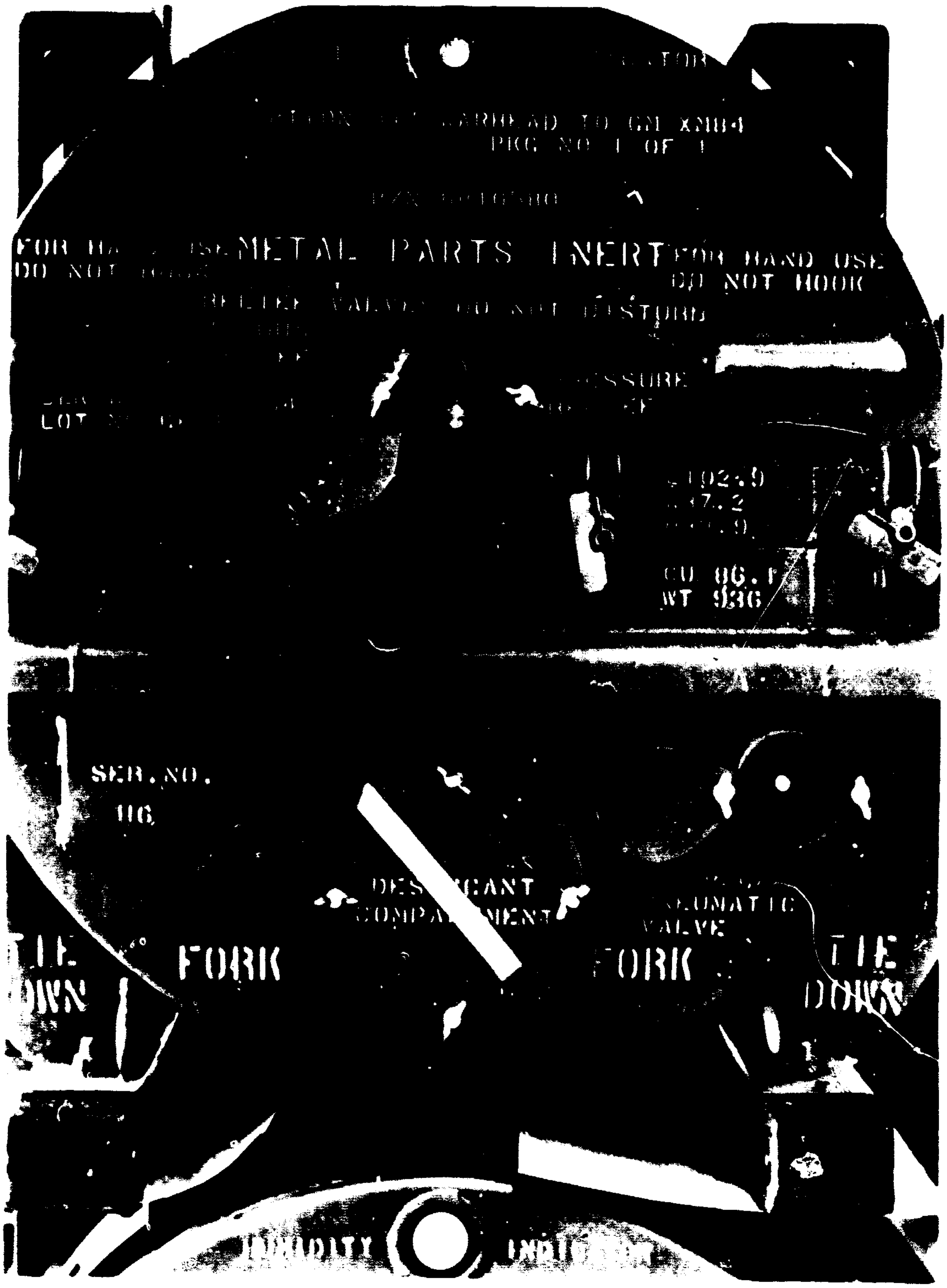


FIGURE 170. DESICCANT ACCESS DOOR

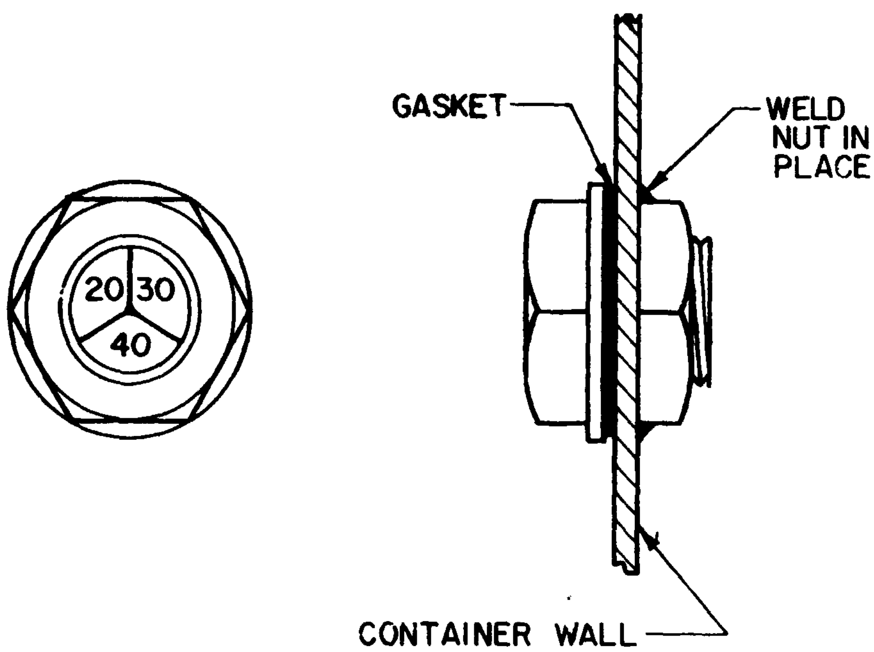


FIGURE 171. HEXAGON HEAD HUMIDITY INDICATOR PLUG

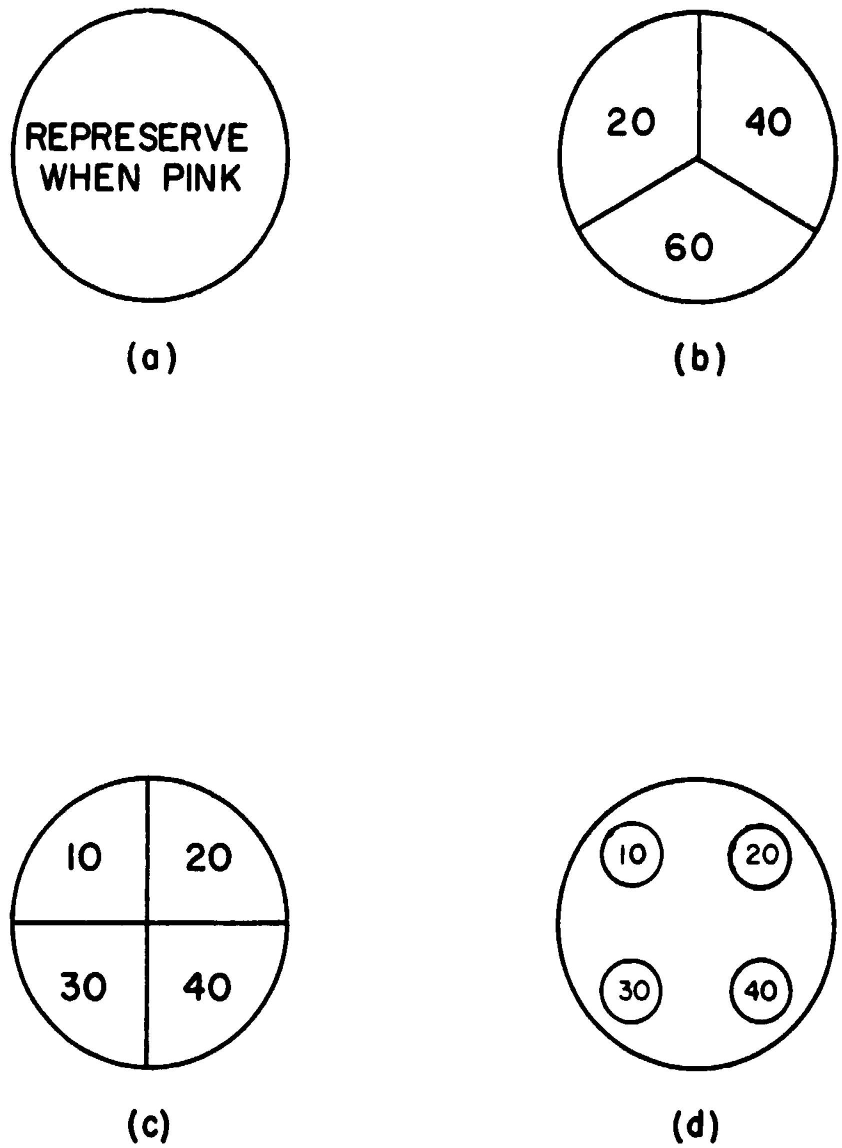


FIGURE 172. CARDS FOR USE IN PLUG-TYPE HUMIDITY INDICATORS. MULTIPLE RANGE CARDS SHOWN IN (b) (c) AND (d)

The round head indicator plug is similar to the hexagon head plug except that the head is round and slotted (Figure 173). This type, in addition to a standard adjustable or open end wrench, requires a special tool to remove the plug from the container (Figure 174). The tongue of the special tool fits into the slots and a wrench is then used to turn the tool. Removal and changing of the humidity card is then accomplished in the same manner as in the hexagon head type. This type of indicator is generally used when the humidity indicator is to be placed in a well in the container wall for physical protection (Figure 161). Need of a special tool for removal makes this type less desirable for use on containers than the hexagon type.

A card type humidity indicator has also been used on missile containers (Figure 175). This type consists of a paper or cardboard card with indicator spots impregnated on it. The card type indicator is hung inside the container and requires a window in order to be read without opening the container. When used in pressurized containers, this window would require a seal. In some instances, a light source would also be necessary to read the indicator. These requirements make the card type indicator the least desirable for use in missile containers.

A direct reading humidity indicator plug (Figure 176) is also available for use on missile containers. It incorporates the use of a sensitive bi-plastic element which bends in response to changes in relative humidity. As the RH changes, the end of the element moves across a scale printed on the face of the indicator giving a direct RH reading. The scale gives a continuous reading over a range of RH's within a temperature range of 32°F to 140°F. The readings are accurate to within ±5% and no temperature correction factor is needed. This scale can be calibrated to cover any range of RH desired. The response time of the element is short, requiring only minutes to register a change in RH. Instructions for represervation when a certain RH level is exceeded can be printed on the face of the indicator surrounding the dial or on the container itself. This indicator plug is a hexagon head type and is mounted in the same manner as the color change hexagon head type. Complete removal and changing of the element requires only a standard adjustable or open end hex wrench.

It is recommended that in order to standardize the use of humidity indicators, the general requirements of MIL-I-26860 be satisfied. This specification requires a plug type indicator which can be removed and replaced using only common hand tools. The hexagon head type best meets this requirement and the availability of multiple range cards or direct reading elements makes the hexagon head type adaptable to any RH requirements. Since the round head type requires a special tool for removal, it is recommended that the hexagon head plug be used as the standard humidity indicator. Choice of card or direct reading type depends on the individual requirements of the item being packaged.

The humidity indicator and desiccant basket should be located at the same end of the container in order to facilitate removal and servicing.

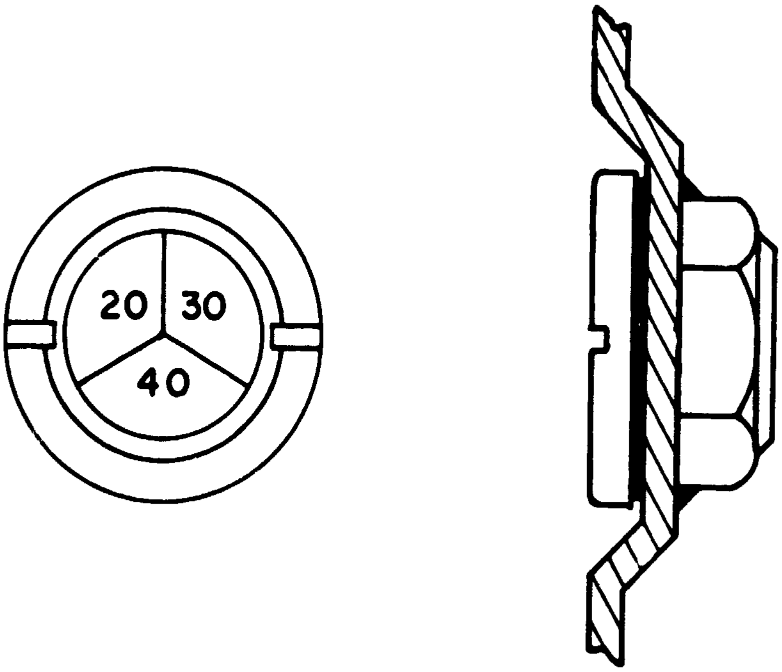


FIGURE 173. SLOTTED ROUND HEAD HUMIDITY INDICATOR PLUG

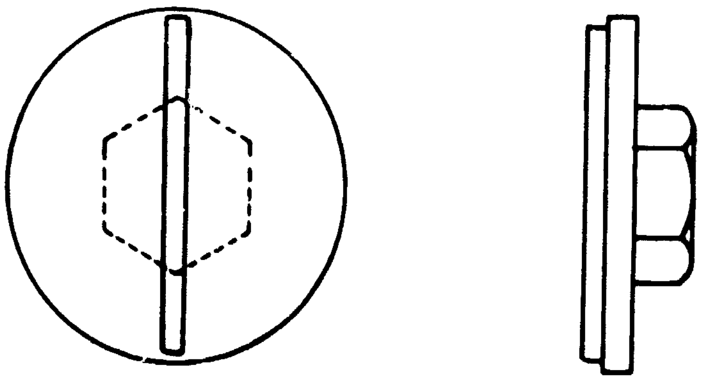


FIGURE 174. SPECIAL TOOL FOR INSTALLATION AND REMOVAL OF SLOTTED ROUND HEAD HUMIDITY INDICATOR PLUG

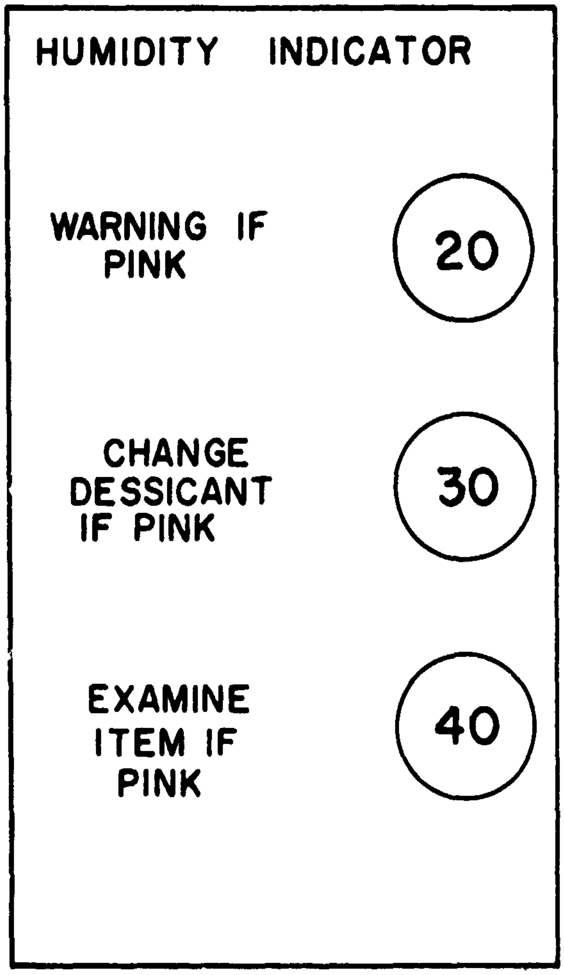


FIGURE 175. CARD TYPE HUMIDITY INDICATOR (MULTIPLE RANGE)

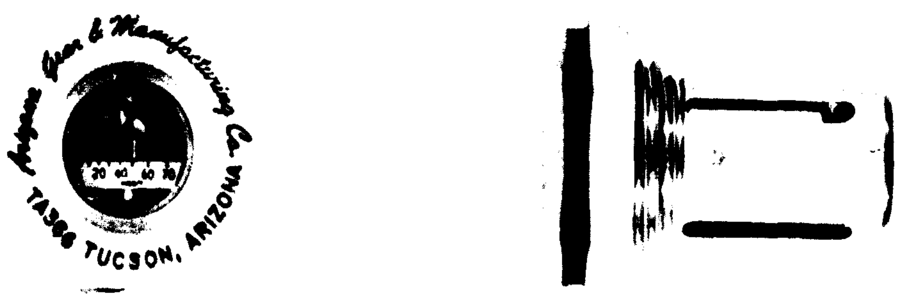


FIGURE 176. DIRECT READING HUMIDITY INDICATOR PLUG

Studies have shown that the indicator will not give erroneous results in this position since the vapor pressure of the air is eventually equalized throughout the container causing the RH to be constant throughout the container.

Typical humidity indicator plug installations are shown in Figures 177 through 179.

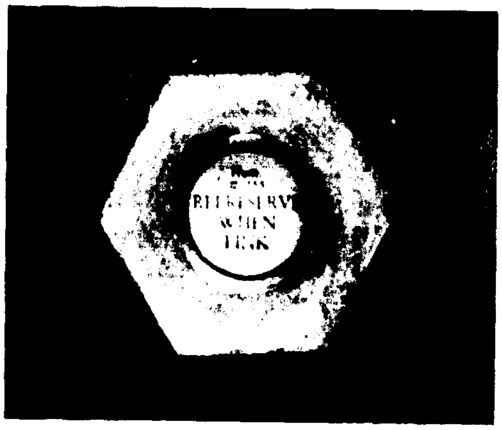


FIGURE 177. HEXAGON HEAD HUMIDITY INDICATOR PLUG INSTALLATION

FIGURE 178. CARD TYPE HUMIDITY INDICATOR INSTALLATION

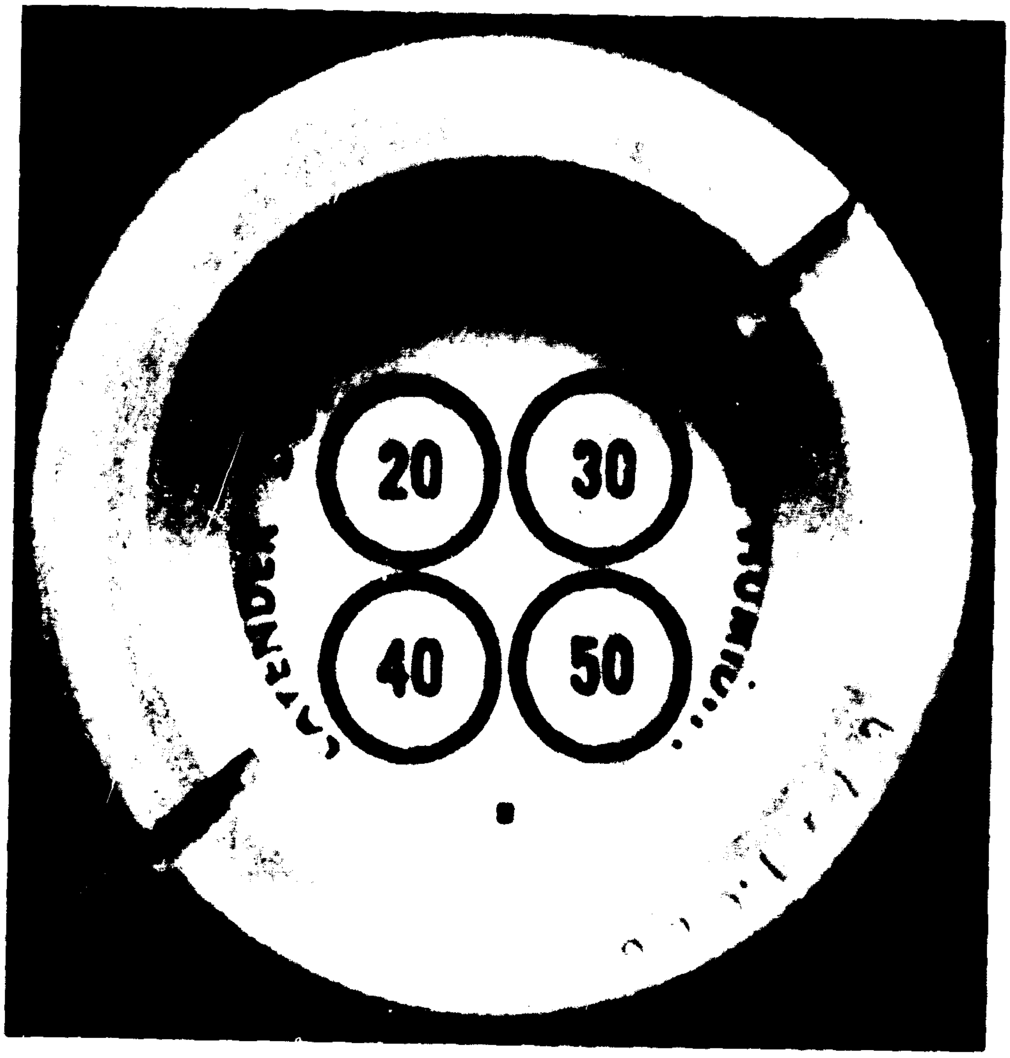


FIGURE 179. MULTIPLE RANGE SLOTTED ROUND HEAD HUMIDITY INDICATOR PLUG INSTALLATION

CHAPTER XI

FASTENERS AND SEALING

COVER FASTENERS

Fasteners on missile containers serve to secure covers, provide sufficient pressure on gaskets to effect a seal, and to secure auxiliary devices such as access holes, log receptacles and tool boxes. The number and type of fasteners should be commensurate with requirements of stress, bonding, sealing etc. Cover fasteners preferably should be of quick-acting, over center type. In the closed position, the fasteners should project as little as possible and should be completely within the container profile. On top-opening containers, the fasteners should be protected from handling damage by external flanges above and below the fasteners, forming a channel within which the fasteners are located (Figure 180). To permit the use of quick-acting fasteners on top opening containers, the sealing flanges on the container shell should be turned inward (Figure 180). On end-opening containers which open from both ends, quick-acting fasteners should be used only on the end from which the missile is removed. Less expensive, but equally effective, fasteners (normally bolts) should be used on the end which is used less frequently.

The fasteners used on missile containers can be conveniently classified as screw type, draw-pull type, or slide action type.

Screw Type Fasteners

The most suitable screw type fastener is the T-head bolt (Figure 181). This type permits unfastening without removal of the nut from the bolt, thus preventing loose parts from being lost. It also has the advantage of allowing individual tightening without prior adjustment. T-head bolts permit faster cover removal than regular nuts and bolts but if a large number of T-bolts are used, the total unlatching and/or reassembly time could become excessive.

Draw-Pull Type Fasteners

Many fasteners utilize different actuating principles yet fall under the general heading of draw-pull. They are quick acting, over center type fasteners which contain no loose parts when opened. This eliminates the possibility of losing part of the fastener when the container is open. Two types of commercially available draw-pull fasteners which have been used on missile containers are shown in Figure 182. Custom designed fasteners should not be used as they are more expensive than the standard commercially available fasteners. As can be seen, draw-pull fasteners can usually be obtained to meet any closure requirements. When used on top-opening containers, the fasteners should be strong enough to permit the container to be lifted from above by means of the cover. Although this is

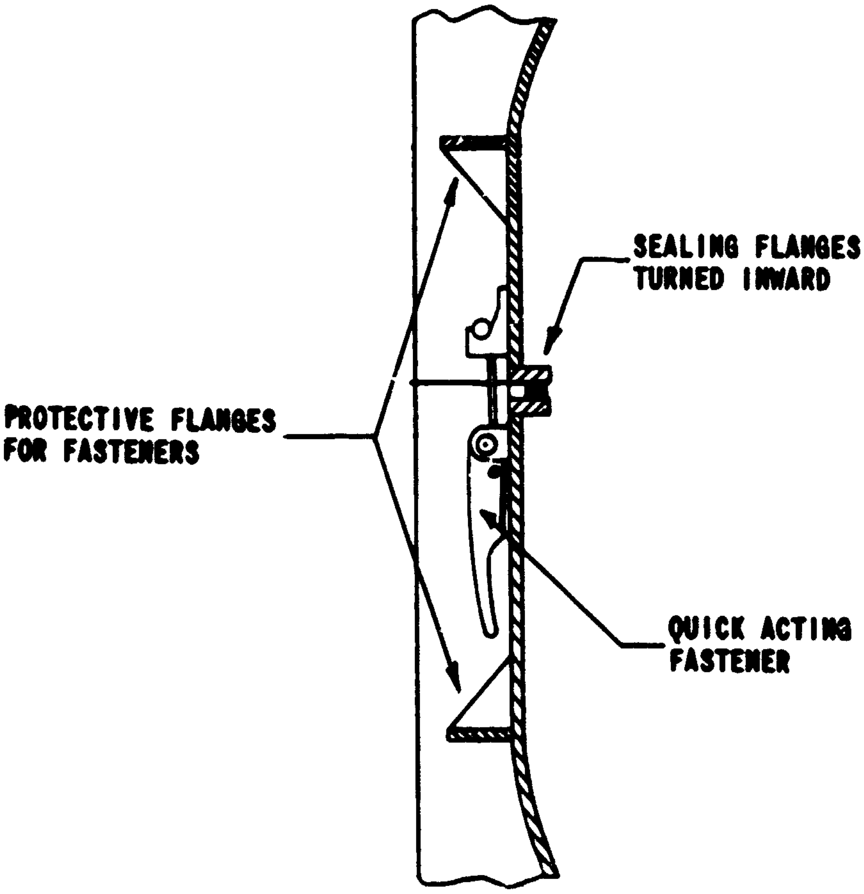


FIGURE 180. CONTAINER-FASTENER CONFIGURATION

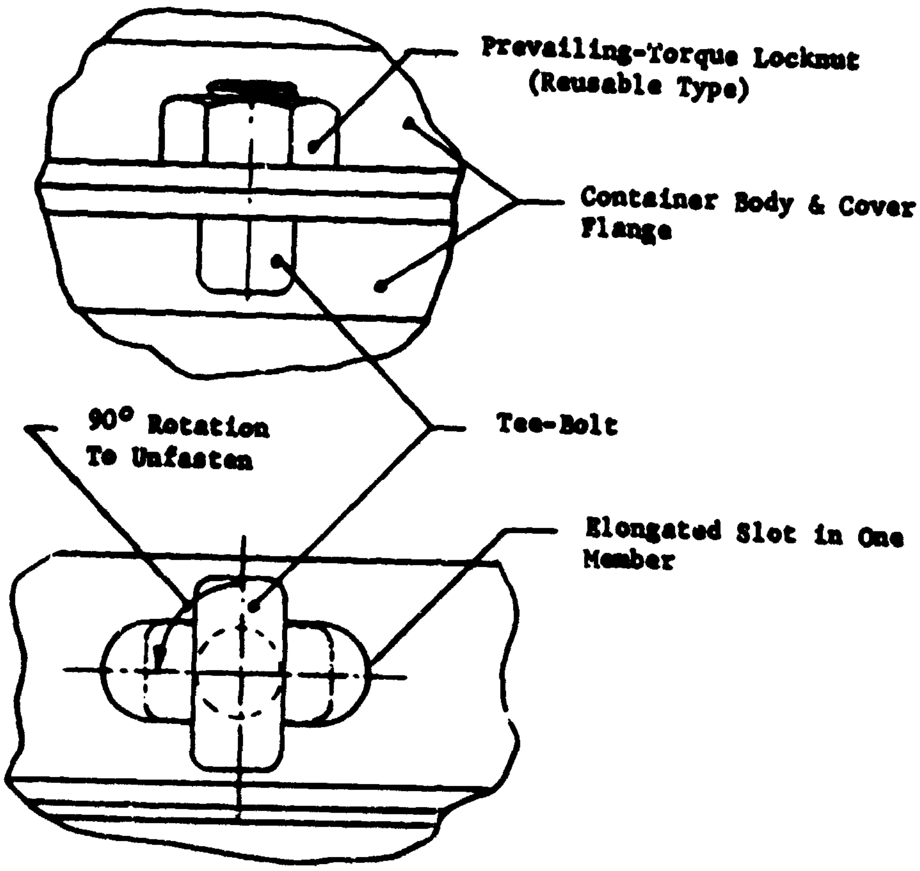
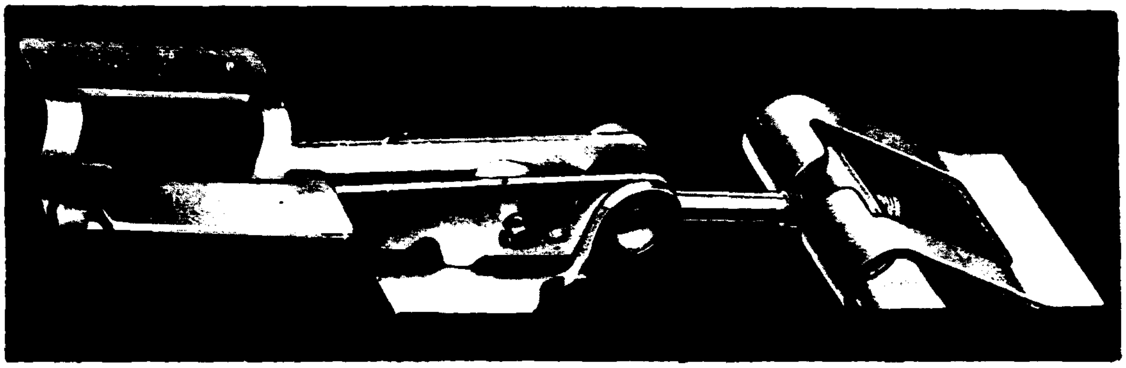
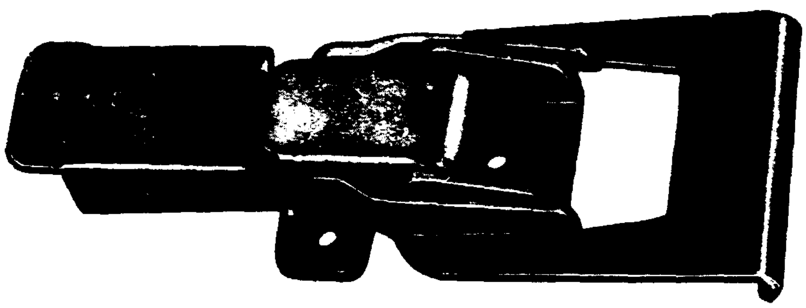


FIGURE 181. T-BOLT



(a)



(b)

FIGURE 182. DRAW-PULL FASTENERS

not the ideal way to lift a container, it is sometimes necessary when a fork-lift truck cannot be used, and when adjacent containers allow no space to reach the bottom of the container to be lifted.

Another type of draw-pull fastener is the compression spring fastener shown in Figure 183. These fasteners employ one or more springs to provide a given fastening tension. They are used to insure a constant closure force and also when accurate installation spacing is impractical. This fastener should not be used on containers stored outdoors due to the possibility of corrosion and during the winter, ice formations which will make the latch difficult to operate.

Slide Action Type Fasteners

This type of fastener employs a horizontal bolt-like member usually attached to or enclosed within a housing (Figure 184).The bolt-like member can be moved across the edge of the enclosure to engage within a keeper which is usually mounted on the frame or body of the container. This type latch is easily and quickly opened and closed and is ideally suited for use on containers that do not require a seal.

In choosing a cover fastener for use on a missile container, particular attention should be given to speed and ease of operation and to container sealing requirements. Fasteners must meet the following basic requirements:

a. Operable with arctic mittens unless definitely established that such conditions will not be encountered.

b. Rugged enough to absorb impact loads encountered in handling and in the removal of ice formations.

c. Capable of repeated use.

d. Operable by unskilled personnel.

e. No loose components after unlatching.

The following characteristics, though not essential, are desirable on container fasteners:

a. Adjustable fastening tension.

b. Lock in closed position.

c. Do not employ springs which are susceptible to failure due to ice formations or shock imputs.

d. Easily replaceable by depot personnel.

e. Recessed or protected by projecting channels if fasteners are susceptible to damage.

f. Commercially available where possible.

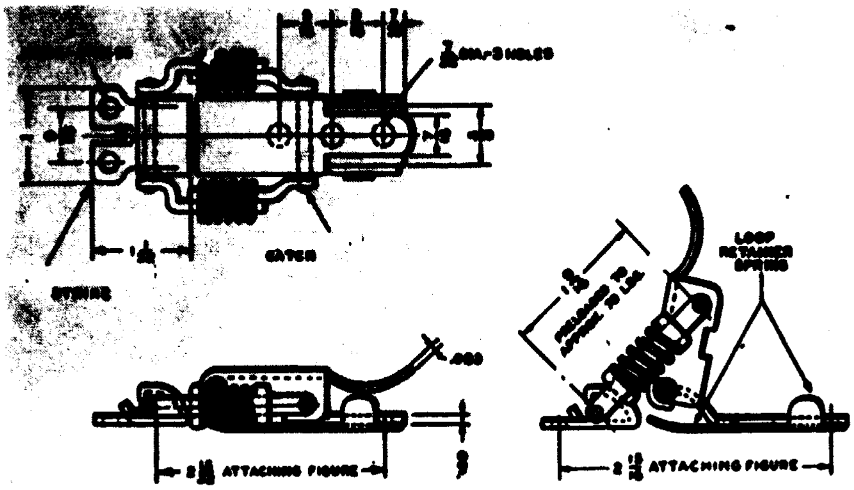


FIGURE 183. COMPRESSION SPRING FASTENER

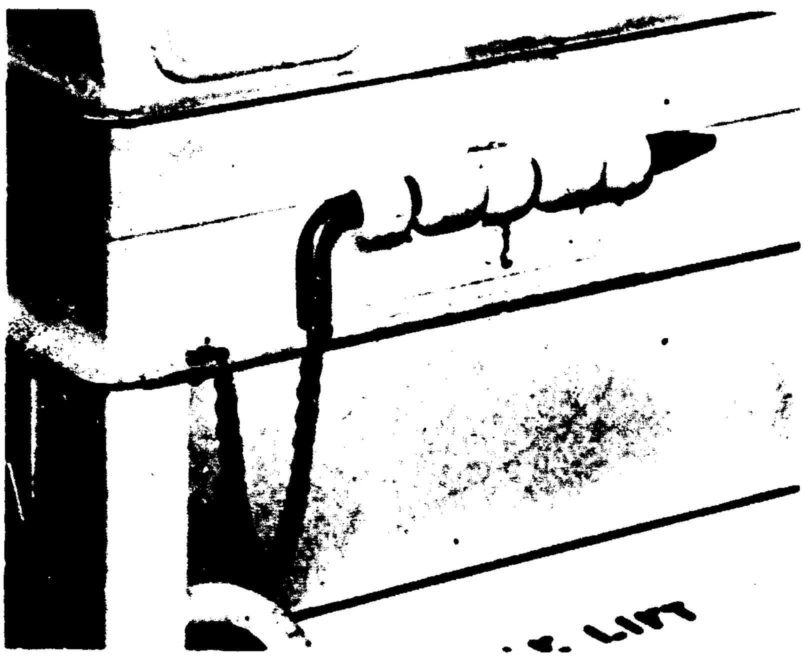


FIGURE 184. SLIDE ACTION FASTENER

SEALING

Gaskets on missile containers function to provide environmental seals to prevent the entrance, or exit, of undesirable foreign matter. Gaskets also serve to seal auxiliary equipment on the container body and often to provide shielding from electromagnetic interference. When designing a joint and choosing a gasket the following areas should be considered:

a. The pressure required to effect a seal under the anticipated environmental conditions.

b. The required joint surface finish.

c. The gasket material.

d. Is the gasket compressible or noncompressible?

e. Standard gasket shapes.

f. Ease of field replacement.

g. Compounds available for joining gasket materials to metal.

h. Compounds available to prevent gaskets from adhering to metal.

i. EMI shielding requirements (see Chapter XIII).

j. Cost.

Table 25 lists materials and their properties, suitable for container gaskets.

Joint Design - Design sealed joints on containers so that the cover and the body of the container meet in positive contact when the gasket is compressed a predetermined amount sufficient to effect a seal. When an incompressible gasket, such as rubber, is used the joint must be designed to allow for the side expansion of the gasket. A variety of joint designs limited only by the ingenuity of the designer can be employed; Figure 185(a) illustrates the desired condition.

As shown in Figure 185(a), a bead or spacer can be provided along the closure flange of the container. Before compression the gasket would extend above the bead. Fastening the cover would compress the gasket until the cover closure flange contacted the bead. Additional compression would not be possible.

A solution to joint design employing the principles outlined above is shown in Figure 185(b).

TABLE 25

GENERAL PROPERTIES OF NATURAL AND SYNTHETIC RUBBERS

	Natural Rubber[a]	SBR	Nitrile[b] Low Swell	Nitrile[b] Hi Swell	Neoprene[c]	Butyl[e]	Thiokol[f]	Silicone[g]	Poly-acrylates
Specific Gravity:									
Pure Gum	0.92	0.94	0.98	0.98	1.23	0.92	1.34	0.98	1.1
Tensile Strength, psi:									
Pure Gum	3000	400	600	600	3500	3000	300	200-450	—
Black Reinforced	4500	3000	3500	3500	3500	3000	1500	—	2500
Elongation, percent	700	500	600	600	600	700	400	300	500
Tear Resistance	G	P-F	F	F	G	G	P-F	P	F
Aging Resistance to:									
Ozone	F	P	P	P	E	E	E	E	VG
Oxidation	P-G	P-G	P-G	P-G	G-E	G-E	G-E	E	VG
Heat	F-G	F-G	G	G	VG	G	P	E	E
Shelf Life	G	G	G	G	VG	E	G	E	VG
Compression Set Resistance	G	G	VG	VG	d	P-G	P	E	P-G
Oil Resistance:									
Low Aniline Oils	P	P	E	G	F	P	E	P	E
High Aniline Oils	P	P	G	E	G	P	E	G	E
Gasoline Resistance:									
Aromatic	P	P	P	G	P	P	E	P	E
Nonaromatic	P	P	F	E	G	P	E	P	E
Acid Resistance:									
Dilute (Under 10%)	G	G	G	G	G	E	F	F	F
Concentrated (Except Nitric and Sulfuric Acids	F-G	F-G	G	G	F	E	F	P	F
Alkali Resistance:									
Dilute (Under 10%)	G	G	G	G	G	G	P	F	P
Concentrated	F	F	F	F	G	G	P	P	P
High Temperature Resistance (200°F or more)	F	G	G	G	G	G	F-G	E	E
Low Temperature Resistance (−67°F)	G	G	F	F	F	G	F	E	P
Impermeability to Gases	F	F	F	F	G	E	G	G	G
Water Resistance	G	VG	VG	VG	F	G	F	F	P

Note: E = Excellent, VG = Very Good, G = Good, F = Fair, P = Poor

[a] Swells in contact with turpentine, carbon bisulfide, chloroform, carbon tetrachloride, and vegetable oils. White glycerine, ethylene glycol, and water produce negligible swell. Functions best at temperatures under 160 deg. F., but can tolerate intermittent exposures to 250 deg. F.

[b] Resists swelling action of petroleum oils, fuels, and solvents. Usually will not adhere to metal flanges.

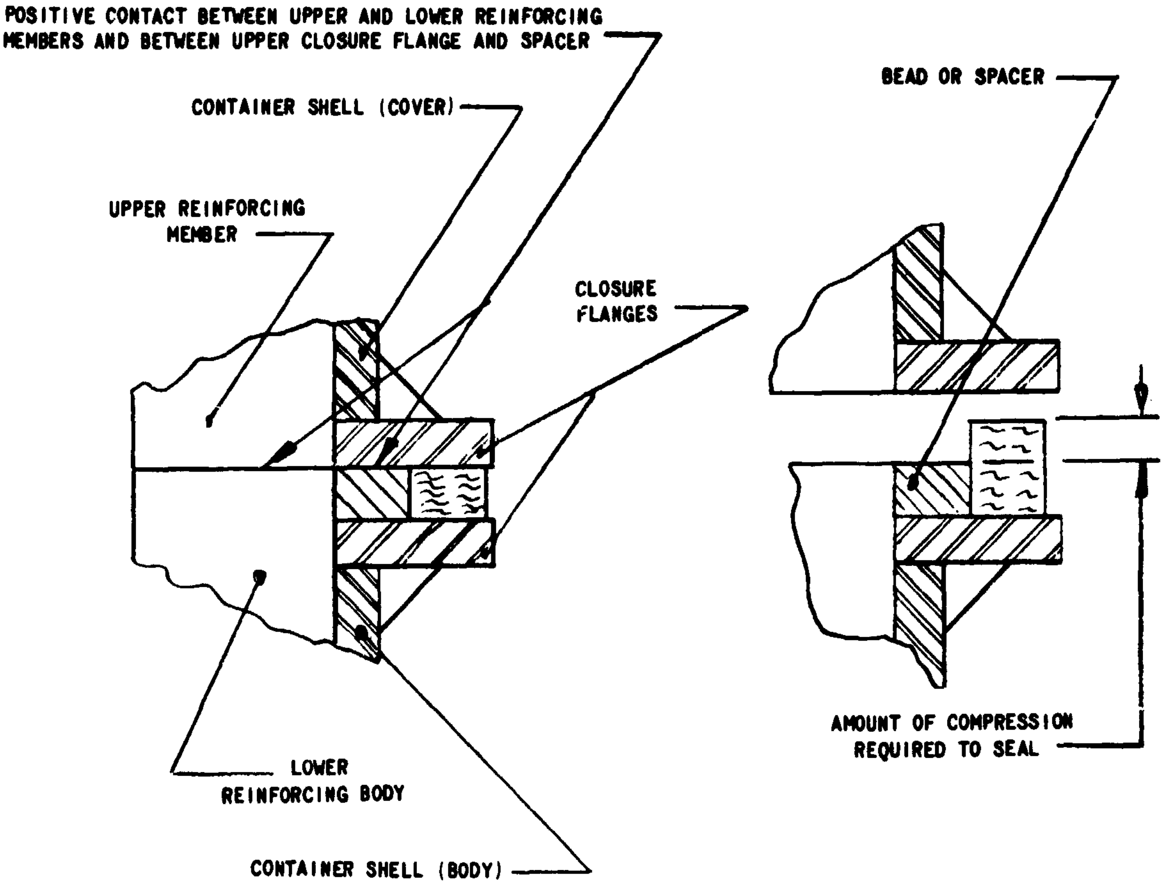
[c] Includes types GN and W.

[d] Resistance of type GN is fair; of type W, good.

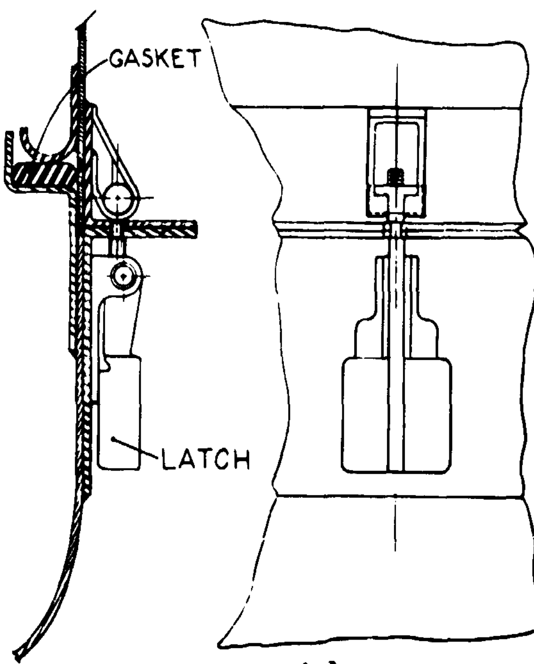
[e] Excellent resistance to vegetable oils, dilute organic acids, and alkalis. Poor solvent resistance. Poor compression set properties.

[f] Includes types PR-1 and ST. Excellent solvent resistance.

[g] Excellent dielectric properties, high and low temperature resistance, and resistance to tendencies to adhere at high temperatures. Good resistance to oxidation, weathering, high aniline point oils. Poor resistance to low aniline point oils, aromatic and nonaromatic gasolines. Low abrasion resistance. Deteriorates in contact with steam under pressure.



(a)



(b)

FIGURE 185. CONTAINER JOINT DESIGNS

In designing a joint the sealing obtained can be related to flange pressure, and the critical condition in achieving a seal can be expressed in terms of the initial unit load on the gasket. The least unit gasket load required to achieve a seal is called the minimum sealing stress. This is the key factor in designing a gasket. It has been found that with a rubber gasket and a zero internal pressure a seal can be created with a 50 psi flange pressure. However, even though a seal can be created at a low loading condition a flange pressure of at least 200 psi is required to maintain a seal after it is created, regardless of the type of gasket, assuming a nonporous or impervious material is used. Creating a seal is not sufficient; the seal must be maintained under operating conditions which include vibration, shock and temperature variations. To prevent these factors from opening a seal, initial flange pressures above those for creating the seal are required.

Flange surface roughness is of no consequence if minimum sealing stresses are achieved. With flange pressures of 200 psi or higher a surface roughness as high as 250 μ in. can be tolerated using rubber composition gaskets. Generally the thinnest gasket that will seal a joint should be used. If the minimum sealing stress is achieved a 10 to 20 percent compression in a rubber gasket is adequate for a gas seal. As there is considerable leeway in the choice of gasket thickness, whenever possible a standard commercial thickness and shape should be specified in the interests of economy.

HYGROSCOPIC MATERIALS

Most gaskets and packings used today are made of hygroscopic materials. These materials are susceptible to water intrusion and wicking, thereby providing a cause of corrosion. In order for the gasket to function as intended, it must be cut in a manner which will allow it to extend beyond the outer periphery of the flanged area. This will eliminate moisture traps which generally act as an origin for the formation of oxides which then propagate along the flange surface into the area that is being sealed.

If leather is to be used as a packing, the shaft which comes in contact with the leather should be chrome plated with a flash layer below .0001 inch or, for wear and corrosion resistance, a layer greater than .003 inch above the base metal.

CHAPTER XII

TEMPERATURE CONTROLLED CONTAINERS

GENERAL

More of today's equipment is becoming temperature-sensitive. This equipment may require precise temperature control or may only require such control so as not to be subjected to damaging temperatures. Items such as gyros, guidance systems, etc., must be kept at precise temperature levels with no more than one or two degrees deviation from their required temperature. This precise temperature control is often required from the time the item is manufactured until and during its use. The majority of temperature-sensitive items, however, will only require such temperature control so as not to be subjected to damaging temperatures. For example, a rocket motor must not be allowed to get so hot as to self-ignite, or so cold as to weaken the bond between the motor and the outer shell.

Some items do not require temperature control as such but are only sensitive to temperature shock (a fast rate of temperature change.) Temperature shock can be effectively controlled by insulation only, but temperature control is a great deal more complicated.

Methods of controlling temperature can be by either auxiliary power, batteries, thermophormic materials, or any combination of these.

AUXILIARY POWER

Auxiliary power used for controlling container temperatures may be obtained either from a plug-in source or from a portable power unit. These methods, however, lack the desired flexibility and require constant monitoring.

Carriers cannot always be relied on to supply power for these containers. Even when carriers are equipped with plug-in facilities, they are not necessarily always of the same voltage. A container designed to operate on one voltage may find itself in a carrier equipped with a different voltage.

A portable power unit often accompanies a container requiring auxiliary power and precludes the use of requiring the carrier to supply power. Portable power units also allow these containers to be stored at locations where there is no power available. The disadvantages of a portable power unit are: (1) it represents a fire hazard, 2) it requires maintenance and fuel, 3) it is usually large and bulky and 4) it must usually be manned at all times.

In order to achieve the flexibility of a portable power unit without all of its disadvantages, self-contained power sources such as batteries or self-contained heat sources such as thermophormic materials may be used in conjunction with auxiliary plug-in power. These self-contained power sources and heat sources will allow the container to be self-sufficient for a limited amount of time when required.

BATTERIES

Batteries have the advantage of being lighter and smaller than portable power units, are quiet and require no in-transit support. Some of the disadvantages of batteries are: 1) they use corrosive acids, 2) they are prone to deterioration from charging and discharging, and 3) they produce an explosive mixture of hydrogen and oxygen when they are used. Another disadvantage of batteries is that their efficiency decreases as the temperature decreases. Unfortunately, when batteries are used for temperature stabilization in containers under cold environment conditions, the time when power is needed the most, it is the least available.

Two containers utilizing battery power are shown in Figures 186 and 187. Although batteries are lighter and smaller than portable power units, they still utilize a large amount of space as shown in these figures.

THERMOPHORMIC MATERIALS

Thermophormic materials store heat by heat of transition or heat of fusion. These materials were developed to maintain fixed temperatures in containers during shipment with temperature tolerances as required. They have the ability to store the largest possible amount of heat in the smallest volume and weight, at well-defined temperatures, i.e., the melting points of the material. On a pound for pound, volume for volume, or dollar for dollar comparison, heat may be stored more cheaply and efficiently in a thermal battery than in an electric storage battery. Two containers utilizing thermal batteries are shown in Figures 188 and 189.

A thermal battery container consists of essentially four elements. These elements are the structural container, the insulation, the item, and the thermophormic material. These thermophormic materials are usually permanently encased in sealed containers to avoid any loss or contamination. An electric heater is placed in thermal contact with the thermophormic material so that the material can be fully charged prior to shipment and during storage. Figure 190 shows a schematic drawing of a typical container utilizing a thermal battery.

To better grasp the theory of thermophormic materials, a theoretical example may well be in order at this point. For an ideal case, assume that an item that will be damaged if it is exposed to a temperature below 25°F. If the shipping container for this item was expected to be exposed to an ambient temperature of -40°F, then a very good thermophormic material would be water. By having the water enclosed in its own cannister and being near the temperature-sensitive item, it will give up its stored heat as it is solidifying or cooling.

If the water (or heat exchanger as it should be called) is heated to 92°F and then subjected to a cold environment below 32°F, each pound of water will give up one BTU for each degree Fahrenheit drop in temperature until 32°F is reached. At this temperature the water solidifies giving off further heat without any further decrease in temperature. It is at this plateau that the term "heat-of-fusion" is applied. For water, this amounts to 144 BTU's per pound. Theoretically, each pound of water has given up 204 BTU's

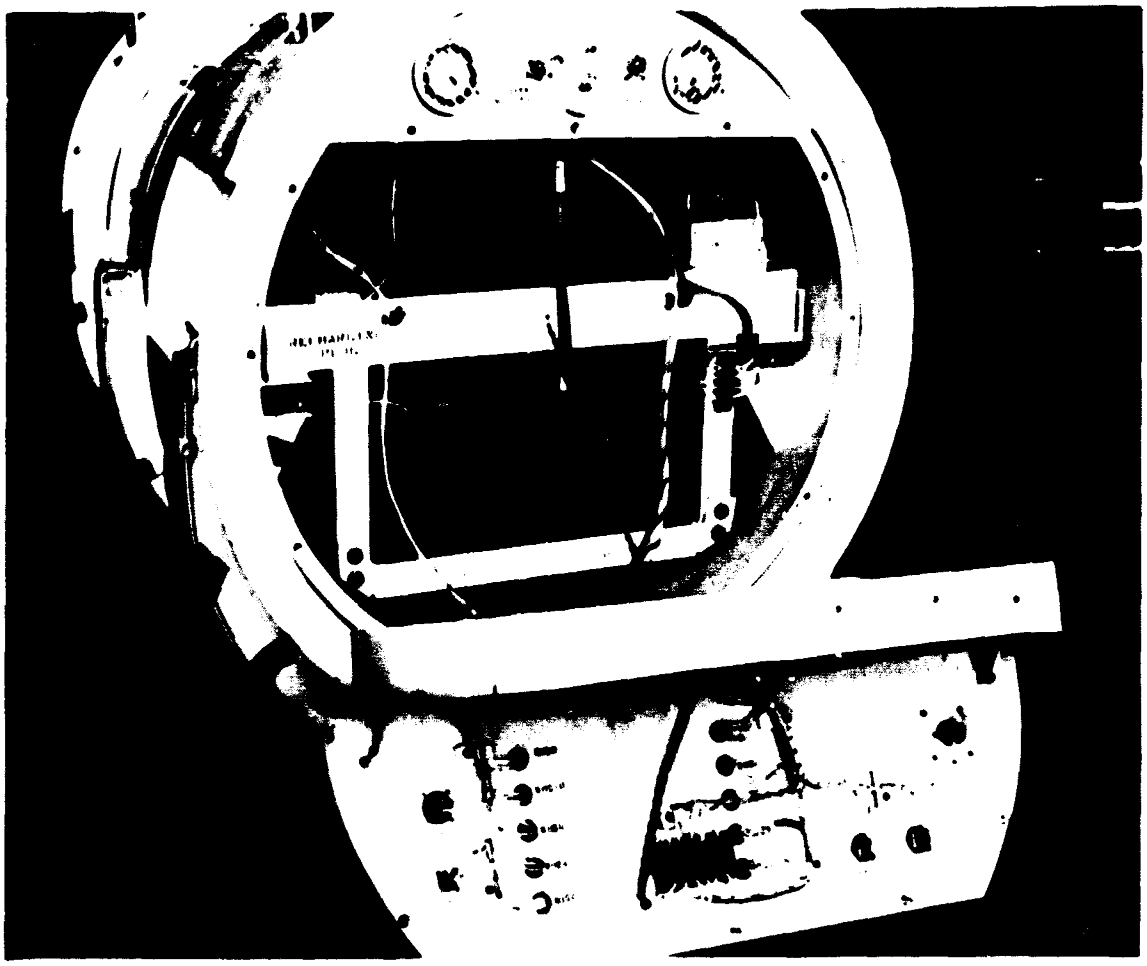


FIGURE 186. INTERNAL BATTERY POWER SOURCE FOR POLARIS GUIDANCE SYSTEM

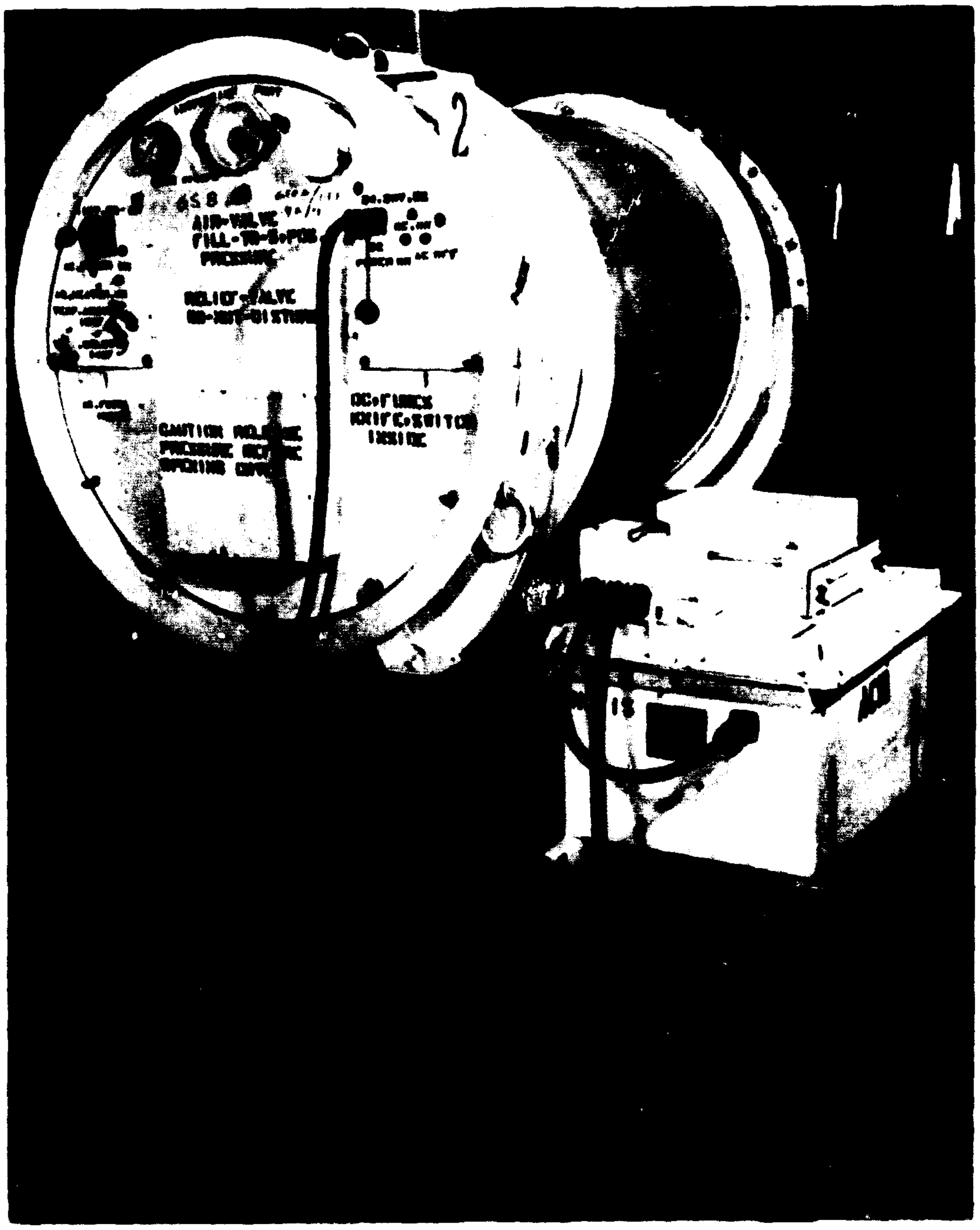


FIGURE 187. EXTERNAL BATTERY POWER SOURCE FOR POLARIS GUIDANCE SYSTEM

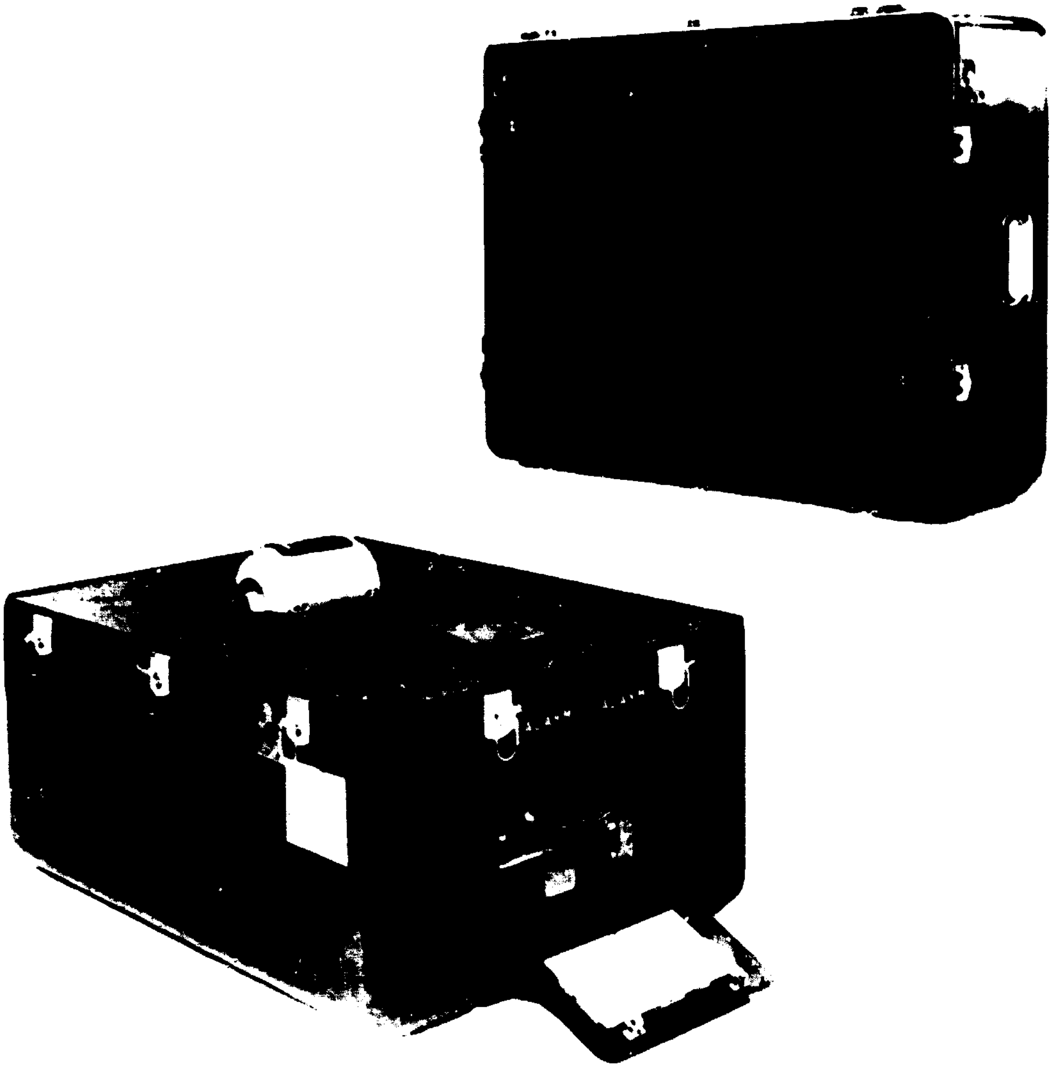


FIGURE 188. CONTAINER UTILIZING THERMAL BATTERY

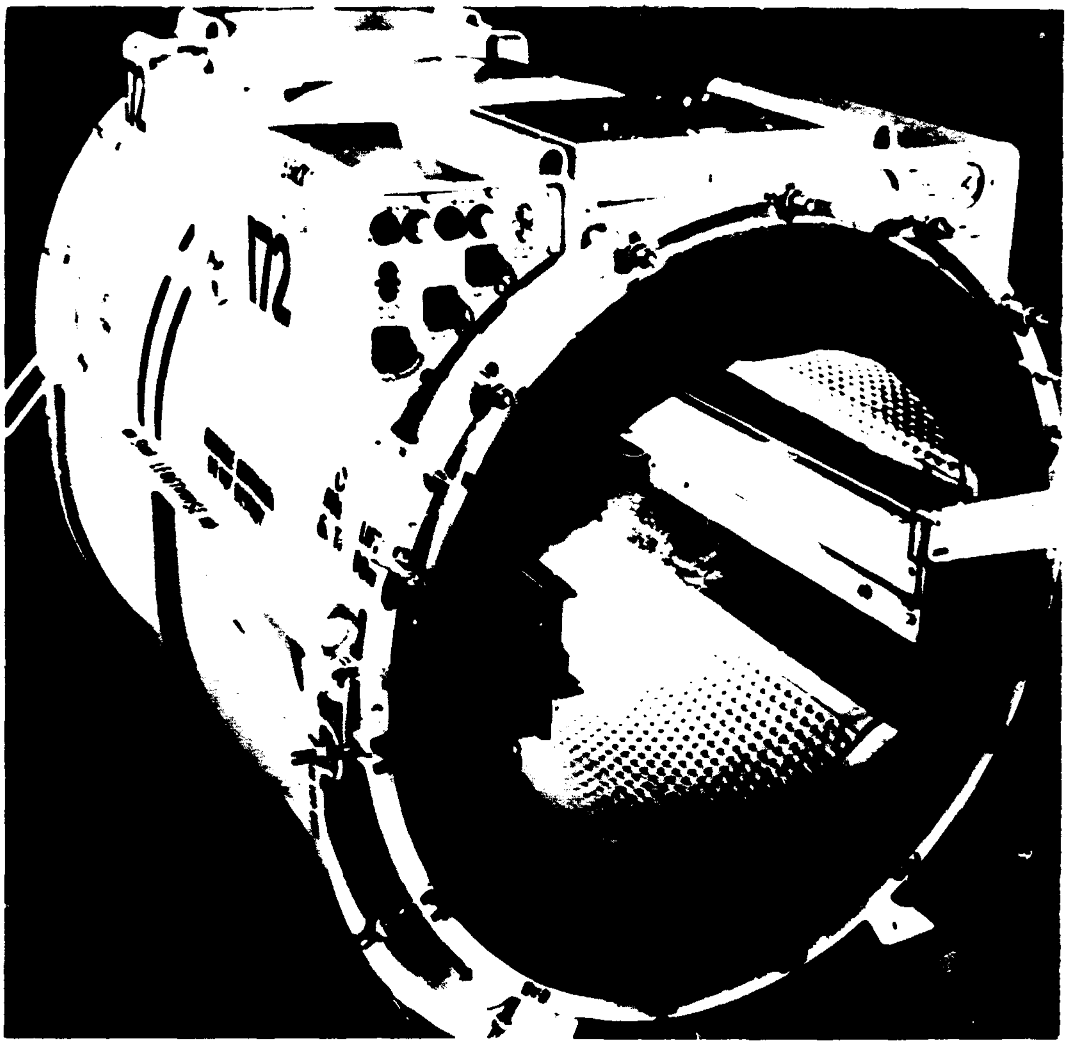


FIGURE 189. SHIPPING/STORAGE CONTAINER FOR MK I POLARIS GUIDANCE SYSTEM. MAINTAINS 137°F ± 5°F FOR 100 HOURS AT AN AMBIENT TEMPERATURE OF -20°F WITHOUT BATTERIES OR OUTSIDE POWER SOURCE.

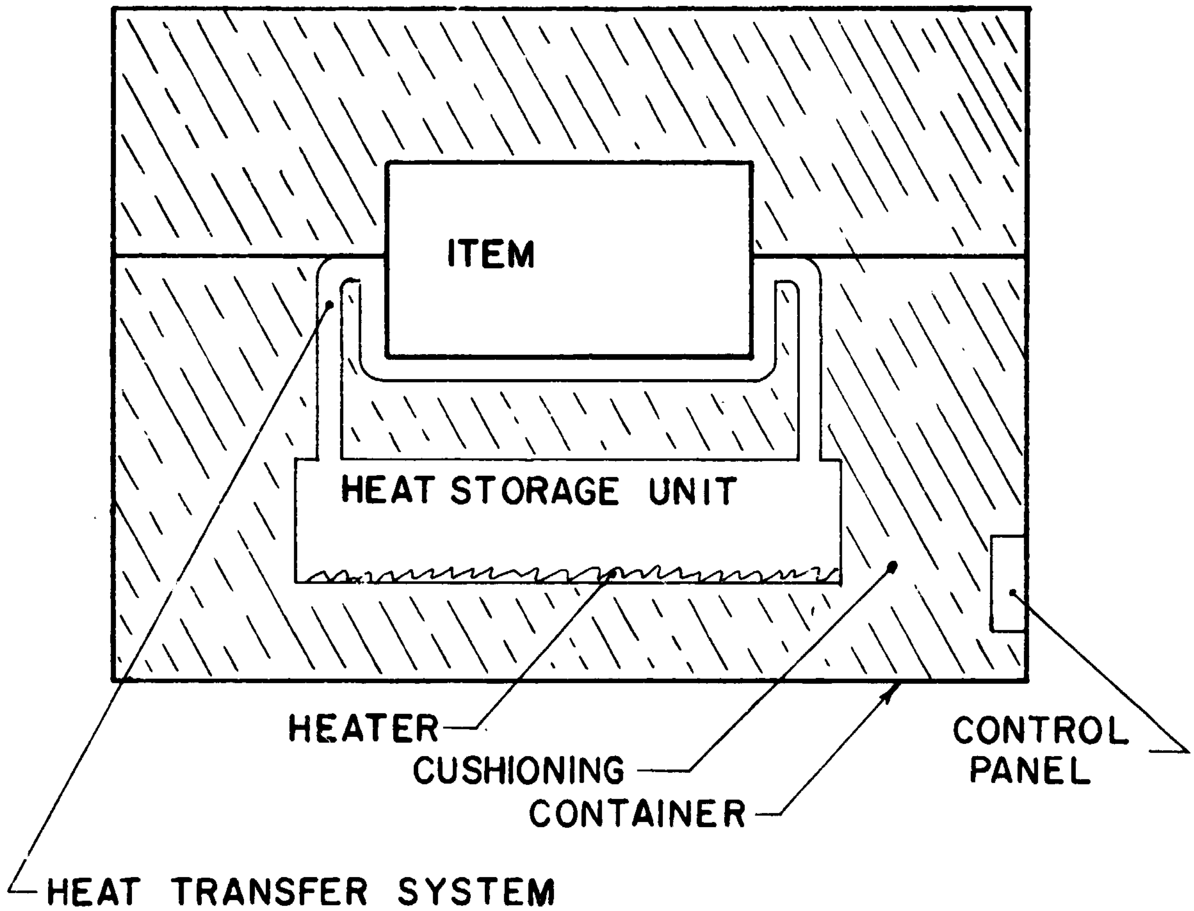


FIGURE 190. SCHEMATIC DRAWING OF A CONTAINER USING THERMOPHORMIC MATERIALS FOR TEMPERATURE CONTROL

(60 BTU's for the temperature drop from 92°F to 32°F plus 144 BTU's heat of fusion) and the temperature of the water has not gone below 32°F. This is shown graphically in Figure 191. Water, when solidifying, has a large expansion rate which may prevent its use since it may burst the closed system. Formulated thermophormic materials have very low expansion rates when solidifying.

By calculating our BTU per hour heat loss through the insulating material, the length of time the item will be protected can easily be determined. One major advantage of using this type of temperature control is that the thermophormic materials may be recharged by melting the material and elevating the temperature.

When selecting a material for use as a heat exchanger, the following factors should be considered:

1. What is the minimum temperature that must be maintained? The heat storing material should have a freezing point above the minimum required temperature.

2. Is the chemical composition of the heat exchanger material harmful to the container?

3. Is the material used for the heat exchanger toxic or harmful to humans?

4. Is the expansion and contraction of this material too great?

5. Will the continuous cycle of melting and freezing of this material change its chemistry? Is it possible for some materials to change their composition after repeated cycling and then not solidify at the required temperature.

6. Will the heat exchanger give up its heat rapidly enough to maintain the desired temperature level?

7. Does supercooling take place with this material? This is a characteristic of pure liquids that are motionless. The temperature may drop 20°F or more below the freezing point of the liquid before solidification takes place. Once solidification starts, the temperature of the liquid will jump almost immediately back to the freezing temperature. It is easy to see, therefore, that the temperature may have dropped below the damaging level before the heat of fusion is released. Supercooling can sometimes be prevented by adding certain impurities to the liquid or by having some mechanical means of tapping or disturbing the heat exchanger to start crystalization.

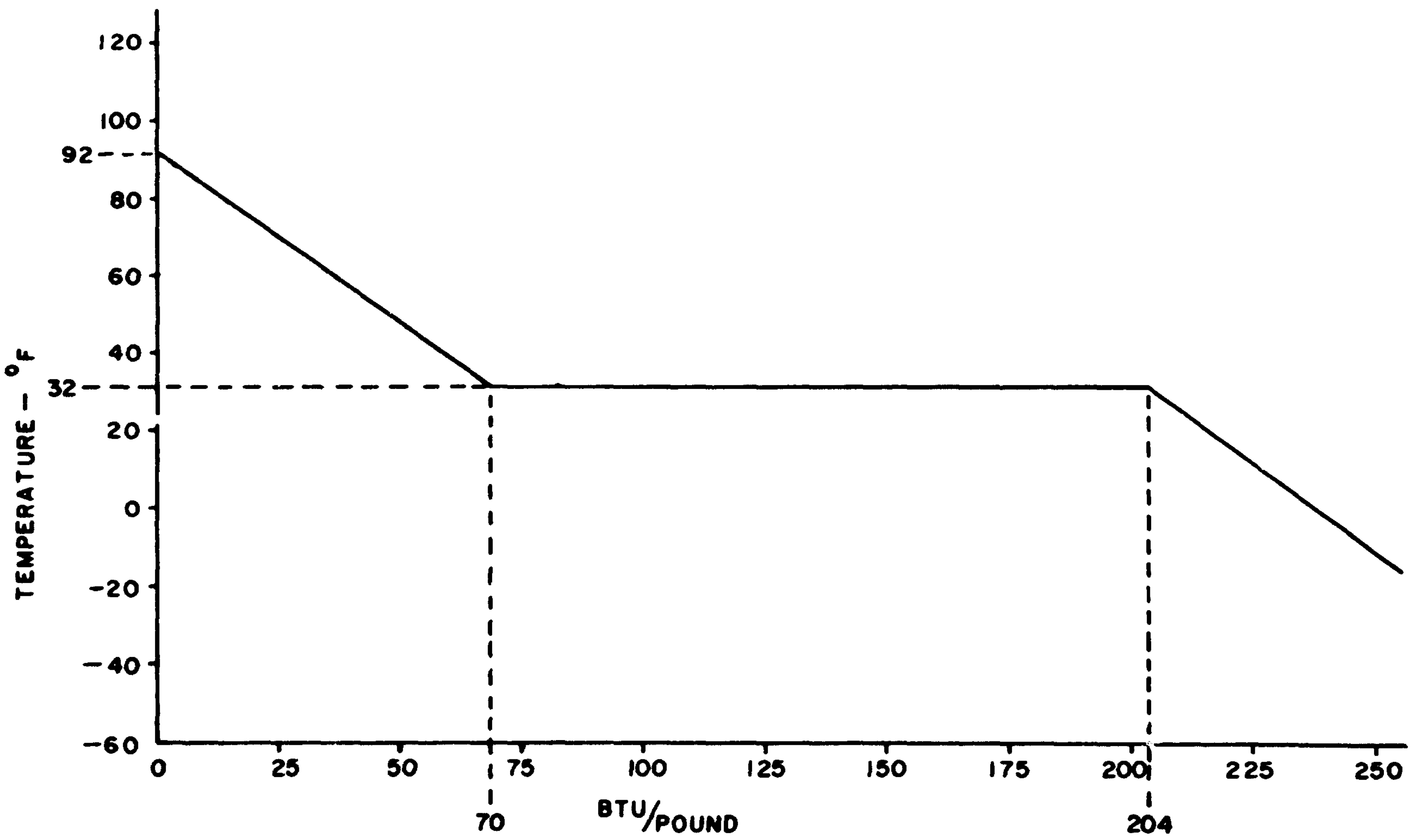


FIGURE 191. DISCHARGING CYCLE OF A HEAT STORAGE MATERIAL (WATER)

INTERNAL HEATERS

The conventional and probably the most widely used method of controlling temperature in a container has been by internal heaters. These heaters readily convert electric energy directly into heat energy by either electrically heated blankets which surround the item or by electric space heaters (Figure 192).

The electrically heated blanket consists of heating elements sandwiched between plies of the blanket material, usually just under the surface layer. These blankets usually consist of two halves, the top half and the bottom half. The larger covers are divided into various sections which are individually thermostatically controlled. This provides a more even temperature distribution over the item.

Electric space heaters incorporate a thermostatically controlled heating element and are usually of a forced, circulation type, i.e., they incorporate a fan for the circulation of air. In the larger containers, two or more fans are usually incorporated to maintain a more even temperature distribution.

The control panel and warning system for temperature controlled containers range from extreme simplicity to ones that are so complicated that training programs are required to be able to understand them. The degree of complication required for these control panels depends on the end usage and what information is required. A continuous temperature monitoring system may be required or desirable at times or a simpler method that indicates when the temperature has dropped below the critical level may be adequate. There should also be some means of indicating when the container is fully charged and ready for shipment. It must be remembered, however, that the distribution of most of today's equipment is worldwide, and that many different people will be handling the container and the design should, therefore, be kept as simple and foolproof as possible.

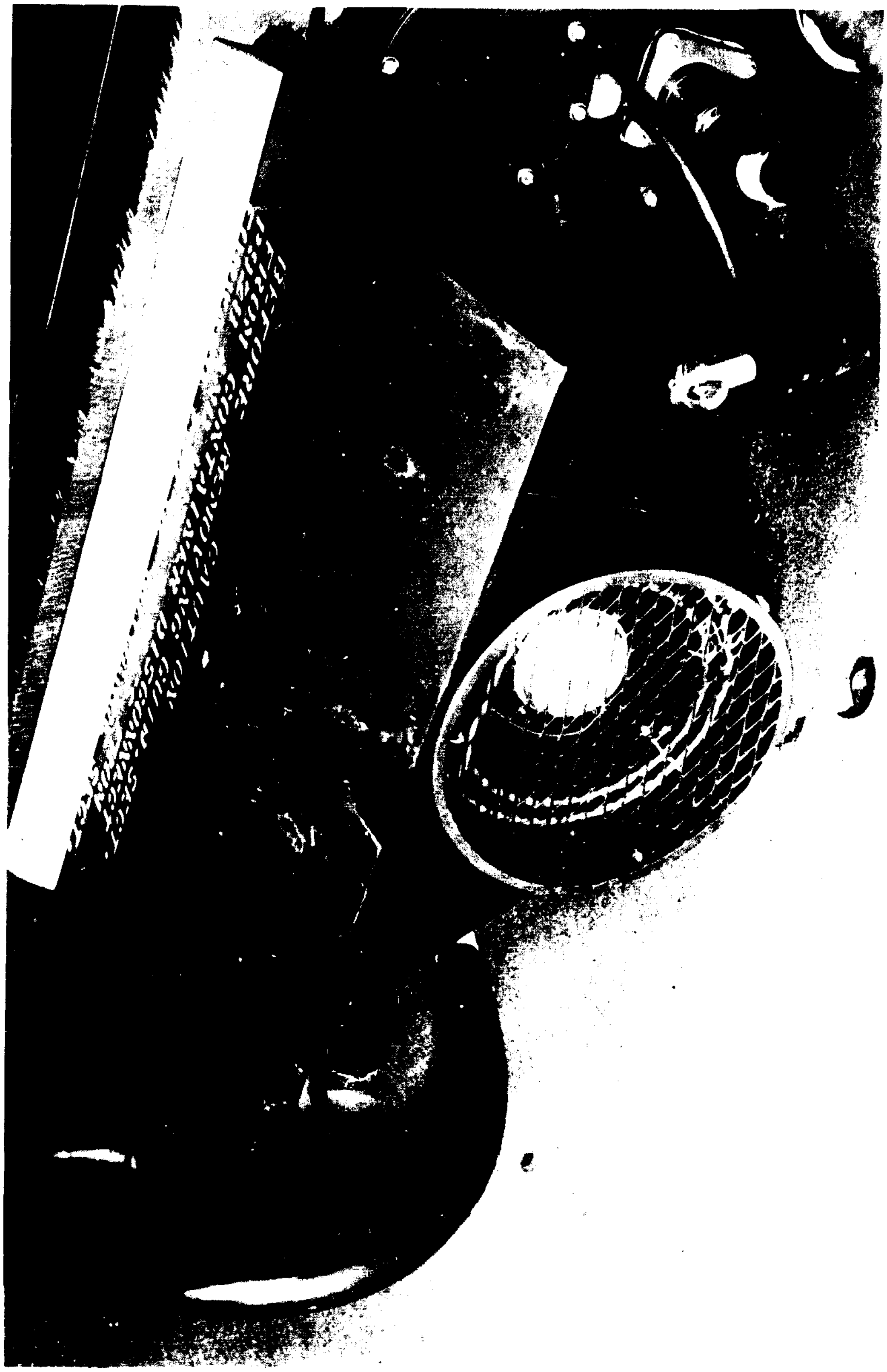


FIGURE 192. ELECTRIC SPACE HEATER INSTALLATION

CHAPTER XIII

ELECTROMAGNETIC INTERFERENCE (EMI)

THE HAZARD AND ITS SOURCE

The scope of the modern battlefield and its array of electronic systems and nuclear weapons present a new environmental hazard that was of little significance prior to World War II. The advent of radio and the subsequent development of radar provoked concern among the handlers and users of explosives; it was feared that the electromagnetic energy radiated by these and other electronic apparatus would cause accidental explosions. As most explosive devices are actuated electrically, the question naturally arose as to whether electrical currents generated by electromagnetic energy would set off these explosives. It was shown that, under the proper conditions, this could happen.

Radio transmitters, radar antennae, high voltage power lines, lightning, and nuclear explosions are all known to propagate a field of electromagnetic energy capable of transferring power from one point to another without the use of wire or other transmission lines. This radiated energy, traveling at the speed of light (186,000 miles/sec) has an intensity which varies inversely as the square of the distance from its source. The intensity of this electromagnetic energy can produce spectacular results--it has been reported that ordinary light bulbs have exploded and fluorescent bulbs have glowed when exposed to beams of electromagnetic energy.

Often the damage produced by exposure to an electromagnetic field is not evident and cannot be detected by visual inspection. Low voltage missile or rocket components (transistors, diodes, etc.) may be damaged when the induced voltage resulting from electromagnetic exposure exceeds the load capacity of these critical parts. Damage to components will result in a malfunction and must be considered with equal concern as that resulting in premature detonation. The assessment of damage to components can only be ascertained by a time-consuming, sophisticated check-out procedure.

Consequently, one must conclude that an electromagnetic hazard is said to exist in a given area when there is sufficient energy present to produce a physical effect such that a dangerous or destructive action is highly probable.

The hazard of EMI is not peculiar and cannot be limited to only the combat environment. The sources of EMI listed below may be found within any environment of "worldwide distribution" and protection must be afforded the missile or rocket throughout its complete logistic cycle:

a. lightning
b. solar and cosmic radiation
c. electric razors
d. power tools

e. fluorescent lights
f. automotive ignition systems
g. radio transmitters
h. high voltage power lines
i. highway radar speedometers
j. air traffic control radar
k. weather tracking radar
l. military surveillance radar

DETONATION

Electro-explosive devices (EED) such as the squibs used extensively in virtually every type of aerospace vehicle are, by definition, electrically activated devices which, when initiated, result in an explosive system. The most common EED is the wire bridge type, consisting of a fine wire bridge, a primary charge, and the main charge. Upon application of the input signal, the bridge wire heats rapidly, leading to the initiation of the chemical reaction in the primary charge which, in turn, detonates the main charge. The dangers of premature detonation of electro-explosive devices (EED's) caused by the pick-up of stray EM energy need not be elaborated. Although the causes of many accidents are readily traced, cases have been reported in which the suspected origins of interfering electromagnetic radiation defy reason. This fact, together with the almost endless array of complex manners in which energy may be coupled into the EED circuitry, makes the predication of radiation hazards to ordnance a difficult task.

The squib, which is used to fire explosives electrically, uses a "hot" wire which can be energized just as effectively by high frequency currents as by the direct currents for which it is designed. Squibs and fuzes have been actuated by being placed in a radar beam and by being fed currents from high frequency generators. A number of incidents of accidental firing of rockets have been reported in which electromagnetic energy was the suspected or the verified cause. In general, primary explosives may be initiated by heat, shock, light and ionizing radiation energy.

Most electro-explosive devices are shielded to prevent misfiring due to irradiation by undesired electromagnetic fields. The design engineer is, however, still confronted with the often complex problem of conducted RF energy and the multitude of paths which it may assume in coupling from the electromagnetic environment into the EED circuitry.

ELECTROMAGNETIC INDUCTION

When an object enters an electromagnetic field, much of the incident energy is absorbed by the object and the remainder is reradiated or scattered in many directions. The container and its contents, functioning as receiving antenna, may collect and amplify such energy to result in an induced voltage capable of detonating explosives or damaging low voltage missile components. Any metallic body may act as an antenna for receiving electromagnetic energy of a specific frequency if it's size is such as to make it resonant at that frequency. The phenomenon of electromagnetic induction as discovered by Faraday, and the resultant voltage induced in conductors within the sphere of influence of EMI constitute the additional hazard against which the container must protect its contents.

A fundamental problem is to devise procedures and criteria by which the degree of hazard may be estimated. This problem is complicated by the wide range of frequencies involved, and the complex geometrics associated with the weapon and its transportation, storage, training operations and ultimate deployment and utilization.

Every type of electro-explosive device (EED) has a nominal fire-energy level, usually expressed in millijoules or ergs. However, individual EED's of one type will have fire-energy levels which deviate from the nominal level by as much as 50%. Statistical data have been accumulated on many EED's by various commercial and military laboratories throughout the country. Additional, but rather limited, data have been collected on the susceptibility of these various devices to RF fields. Experimentation has been done both with the EED alone and the EED installed in normal fashion with firing circuits attached. The results of this work indicate rather clearly that EED's are susceptible to low frequency and high frequency RF energy and thus must be protected from it. Data lacking to date is a spectrum analysis of each type EED, showing its susceptibility, as installed with firing circuitry, to radiated frequency, power or field intensity, and modulation of the radiated energy. Considerable effort is being expended by military and commercial laboratories to get this kind of information; however, progress is slow because of the complexities involved with the selection or development of acceptable measurement instrumentation.

HAZARDS FROM COMMUNICATIONS TRANSMITTERS

By far, the greatest threat of RF hazards to ordnance results from the use of electro-explosive devices (EED) in close proximity to high frequency communications transmitters and not from microwave radars as it is sometimes thought. This is not to imply that microwave radars do not or cannot cause hazards but instead, it is intended to emphasize that at most locations where hazards occur, the measured field strengths in the high frequency regions (2-30 mc) are usually of much greater magnitude than those from microwave radars. This, of course, is not true if the main radar beam of a very high powered radar is pointed directly at an exposed EED.

Many cases have been found where the presence of a human body was sufficient to complete a path to ground through the EED for high frequency RF energy and cause a premature explosion. The question is often raised as to how a small device such as a squib can have enough capture area to collect sufficient energy to cause ignition. This is readily answered when the large area of the device to which the EED is usually attached is accounted for. When this is done, it will be found that, on occasion, astonishingly high voltages or currents are built up between ground and the body of the EED. As an example of how sufficiently large currents may pass through an EED, consider the following: an efficient pickup (for its size) in feeding low-resistance devices is a loop antenna. A loop of 0.1 wavelength on a side has a radiation resistance of 3 ohms and one of 0.05 wavelengths has less than 1 ohm. Thus 10 volts/meter at 10 mc (a field strength readily obtainable near the antenna) will drive better than 1 amp through a 1.5 square meter loop. Since loops are nonresonant below 0.1 wavelength on a side, they act as wide band pickup devices over the entire low frequency range.

HAZARDS FROM MICROWAVE RADARS

While it has been demonstrated that a relatively low powered microwave radar can set off an EED which is in the open and unshielded, it is more difficult to prove from theoretical calculations and measurements that radars have, in fact, caused premature detonation under field conditions. In many instances, radars are prohibited from illuminating a missile when the EED is being installed and this is undoubtedly a wise procedure. Present radars are unlikely to cause malfunctioning of an EED when the missile is airborne.

Radars planned for the future especially those of the phased array type will, if they actually deliver the power proposed, constitute an RF hazard of considerable magnitude since the field strength even at appreciable distances from the antenna will be very high. In this case, it will be necessary to make calculations, and measurements at reduced power, in the Fresnel region of the antenna where complicated phase and spatial relations exist. This means that simple estimates of the RF hazard threat will not be possible.

MISCELLANEOUS HAZARDS

In addition to obvious hazards to personnel and ordnance, intense RF fields can also create other hazardous effects, some of which probably have not yet been traced to the presence of intense electromagnetic energy in the area. One of the most serious of the miscellaneous hazards is the explosion of fuel, such as gasoline or kerosene, during refueling operations around aircraft or missiles. The aircraft makes an excellent pickup antenna and intense fields can be generated between the fueling nozzle and the aircraft. Obviously, any sparking between these points is quite likely to result in a very disastrous explosion.

Another hazard which is more dangerous because of possible secondary reactions is the setting off of photographic flash bulbs by intense RF fields. Ignition of a large quantity at once could cause a fire but solitary ignition would probably be more of a nuisance than a danger.

Good design practices are the key to interference suppression. Electromagnetic capability must be given as much consideration in initial design as other important considerations.

Some consideration should be made between what normally is referred to as electromagnetic radiation (up to infra-red) and all frequencies above this which, while technically electromagnetic radiation, have effects quite different from the lower frequency energy.

Any frequency which is well enough matched to the (lossy) material to cause appreciable heating must be considered as a possible hazard.

CHECK ON SIGNIFICANCE OF MEASUREMENTS DB

The establishment of an RFI measurement capability is a complex and costly operation. Unless a small specialized program is being considered, the establishment of anything short of broadband coverage is not recommended. Near-field measurements for specification compliance or for certification of shielded enclosures may require a frequency coverage of about 10 kc to 40 kmc.

Often the designer is influenced by availability of materials in the design of suppression devices to attenuate or eliminate radio interference.

Since it is necessary to consider weight, size, and materials in the functional design of equipment, as well as the problems of EMI, the designer must choose a compromise which will permit satisfactory system operation. This implies EMI suppression to a degree rather than complete elimination.

Containers which must operate in an environment of heavy interference must be well shielded to reduce pickup. Consequently, the missile or missile component to be protected must be evaluated to determine its susceptibility to EMI. Unless the item has been determined to be inert to EMI or provision has been made by the missile manufacturer to resist the phenomena of EMI, the container must provide for this protection.

Shielding the container will provide an electric shield around its intended load to prevent damage by ac or dc disturbances. The shield should limit the magnetic field intensity at the surface of the load to 100 oersteds when the container with the load installed is subjected to a uniform dc magnetic field of 500 oersteds, or an ac magnetic field of 500 oersteds from 0 to 1 megacycle. The container should protect the memory unit from radio frequency interference in accordance with specification MIL-I-6181 for Class Ib equipment.

When an object is illuminated by an electromagnetic wave, a portion of the incident energy is absorbed as heat and the remainder is reradiated (scattered) in many different directions. That portion of reradiated energy reflected (electromagnetic echo) is of chief interest in radar; heat absorbed is of concern to container design.

Antenna reflecting surfaces may be made of a solid, short material but it is often preferable to use a wire screen, metal grating, perforated metal or expanded wire mesh.

An RF hazard is usually caused by one of two effects: 1) heating from RF currents caused by the magnetic component of the field, and 2) sparking due to the electric component of the field. The H field is the oscillating magnetic field which generates circulating currents in objects or loops and may result in heating. The E field is the oscillating electric field which is perceived when areas are drawn from an object engaged or disengaged in an RF field.

SHIELDING

Since it has been shown earlier that EMI may be found almost anywhere in the world at one time or another, items susceptible to damage from EMI must be shielded. Both the interference source and the susceptible device may be thought of as antennae, one transmitting and one receiving. A representative shielding configuration is shown in Figure 193.

A perfect shield is not possible. Some of the factors contributing to interference influence of external fields are holes for component mounting, ventilation, etc., and joints in the container. Attenuation of the signal through the material of the container itself, however, may sometimes be less than through these alternate paths.

The shielding effectiveness of a container or enclosure is reduced as the number and size of openings increase. These openings should, therefore, be kept to a minimum and their diameters kept as small as feasible. A small opening is defined as one which is small in dimension compared to the wavelength of the interference source. A large hole should be covered by a fine mesh (22 mesh, 15 mil) copper screen. Since effective mesh for shielding purposes rarely contains more than 50 percent area, the size of the ventilation hole must be increased accordingly. If the mesh is to be removed easily, it should be attached, with enough screws or bolts to maintain continuous electrical contact completely around the edge.

When an opening is covered with screening material, the attenuation obtained depends on the following factors: 1) Size of aperture relative to the container, 2) Mesh or perforation dimensions relative to cabinet dimensions and 3) impedance and distribution of exciting fields. A graph showing the attenuation of various screening materials is given in Figure 194.

Wave guide attenuators may be used to shield large holes. These attenuators will pass all frequencies above a certain frequency and actuate all below that frequency.

When meters and other gages and dials are installed on the outside surface of the container, they should be sealed in a shielded enclosure with proper filtering of the connecting leads. The meter or dial face can be sprayed with an electrically conductive finish which also provides shielding. Other openings such as fuse receptacles, valves, etc., could be covered with spring loaded caps or screening material. Where gaskets are required, they should be of the conductive type.

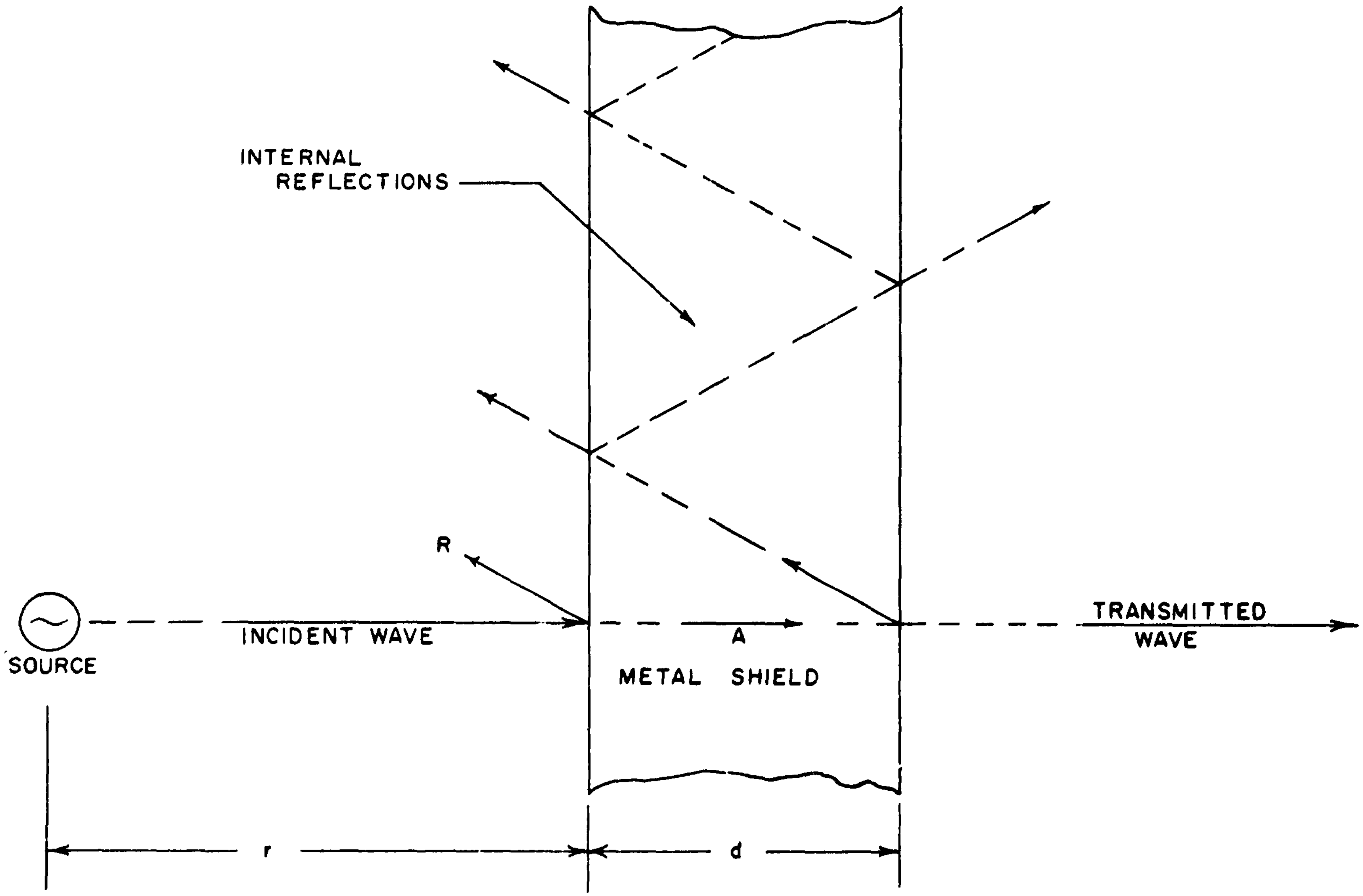


FIGURE 193. REPRESENTATIVE SHIELDING CONFIGURATION

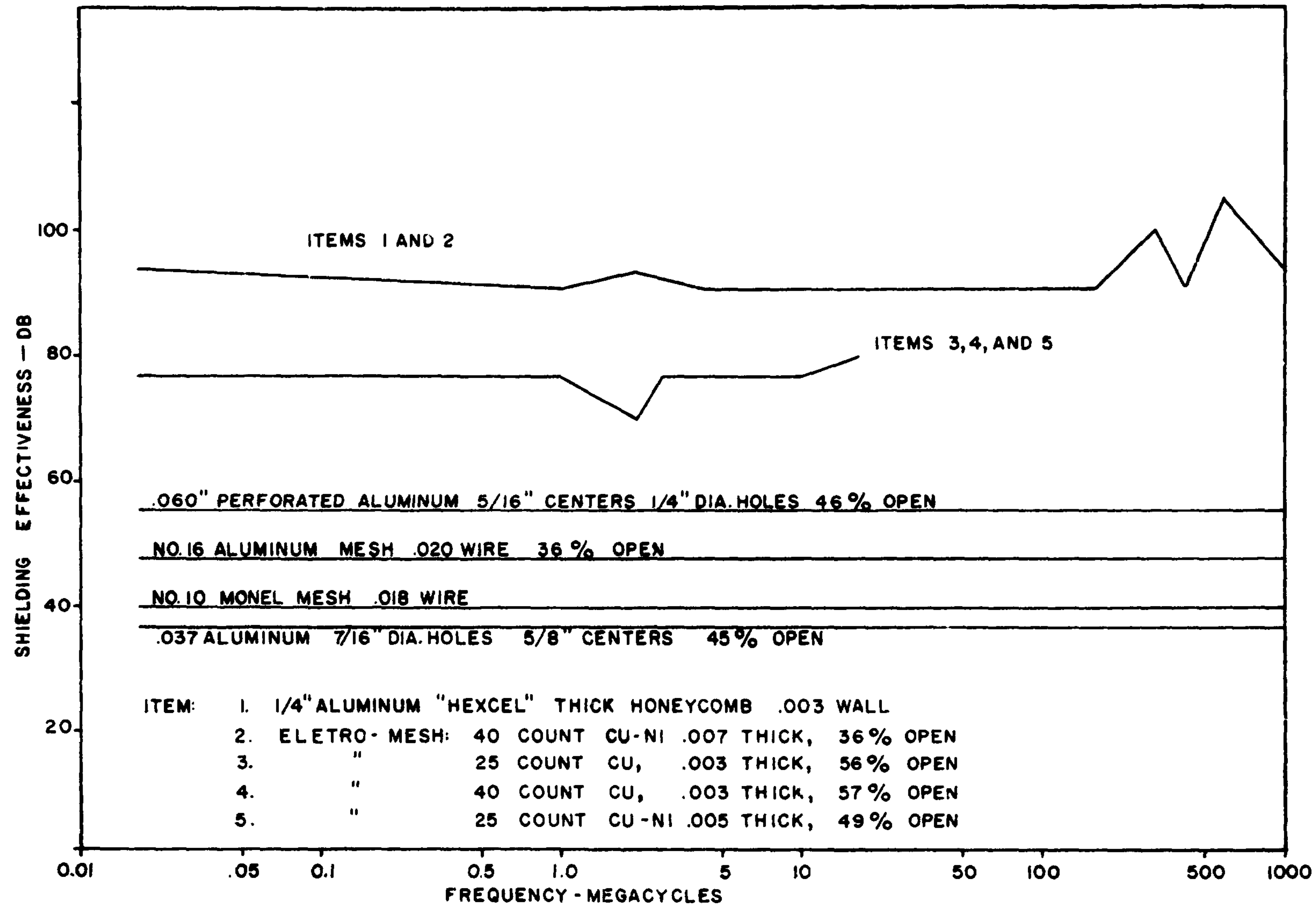


FIGURE 194. ATTENUATION OF VARIOUS SCREENING MATERIALS

Shielding efficiency is measured in decibels and describes the fraction of impinging energy which penetrates the enclosure and is given as

$$S = 20 \log \frac{E_1}{E_2} \tag{25}$$

where

S = shielding efficiency, db.

E_1 = impinging field intensity, μv/meter

E_2 = exiting field intensity, μv/meter

For analytical purposes, shielding efficiency is given as

$$S = R + A + B \tag{26}$$

where

R = total reflection loss, db.

A = penetration or absorption loss, db.

B = internal reflection loss, db.

The factor B may be neglected for an electrically thick barrier. Equation 26 now states that the effectiveness of a conducting shield in reducing the energy of an electromagnetic field is the result of the absorption loss incurred in passing through the conducting plane, and the reflection losses occurring at each surface of discontinuity.

The absorption loss or attenuation is given as

$$A = 3.338\, t\sqrt{fG\mu} \tag{27}$$

where

t = thickness of barrier, inches
f = frequency, cps
G = conductivity relative to copper
μ = magnetic permeability relative to vacuum

The reflection loss can be calculated from either equation 28, 29, or 30 and will depend upon the original impedance of the wave. For a plane electromagnetic wave of 377 ohm characteristic impedance, the reflection loss is given by

$$R = 108.2 + 10 \log \frac{G \times 10^6}{\mu f} \tag{28}$$

377 ohms is the wave impedance of a space at a great distance from radiators.

The reflection loss for high impedance waves or an electric field is given as

$$R = 353.6 + 10 \log \frac{G}{f^3 \mu r^2} \quad (29)$$

r = distance from source to barrier, inches

The reflection loss for low impedance or magnetic waves is given as

$$R = 20 \log \left[(0.462/r)\sqrt{\frac{\mu}{fG}} + 0.136\, r \sqrt{\frac{Gf}{\mu}} + 0.354 \right] \quad (30)$$

A high shielding efficiency for electric fields or high impedance waves may be obtained by using shields of high conductivity such as copper and aluminum. Equations 28 and 29 show that the reflection loss is infinite at zero frequency and decreases with increasing frequency. It can be seen from equation 30, however, that magnetic (low impedance) fields are more difficult to shield since the reflection loss may approach zero at certain combinations of materials and frequencies. It is very difficult to shield against magnetic fields using nonmagnetic materials.

As an example, assume that a ground-level nuclear detonation produces a broadband electromagnetic pulse with most of its energy distributed in the 10-15 kc band. Specify the thickness of aluminum required to provide 300 db isolation at 10 kc.

G for aluminum = .61
$\mu = 1$
$f = 10^4$ c/s

$$R = 108.2 + \log \frac{.61 \times 10^6}{(1)\ (10^4)} = 193.17 \text{ db.}$$

Assuming that B is equal to 0, then A must equal 300 - 193.17 or 106.83 db. Equation 27 has been rearranged in terms of thickness t to show

$$t = \frac{A}{3.338 \sqrt{fG\mu}}$$

Substituting in the values for A, f, G and μ the equation now reads

$$t = \frac{106.83}{3.338\sqrt{(10^4)\ (.61)\ (1)}} = .41 \text{ inches}$$

A simpler and quicker method for determining the various unknown quantities is to use the graphical method. From Figure 195, Zm is indicated as being about 55 microhms. Using Figure 196 and the value of Zm obtained from Figure 195, the far-field reflection loss R is equal to about 130 db. Assuming B is O, A must equal 170 db. Figure 197 shows that A = 170 db, $Gt|Zm|$ = 18 inch-microhms and t is, therefore, equal to .54 inches

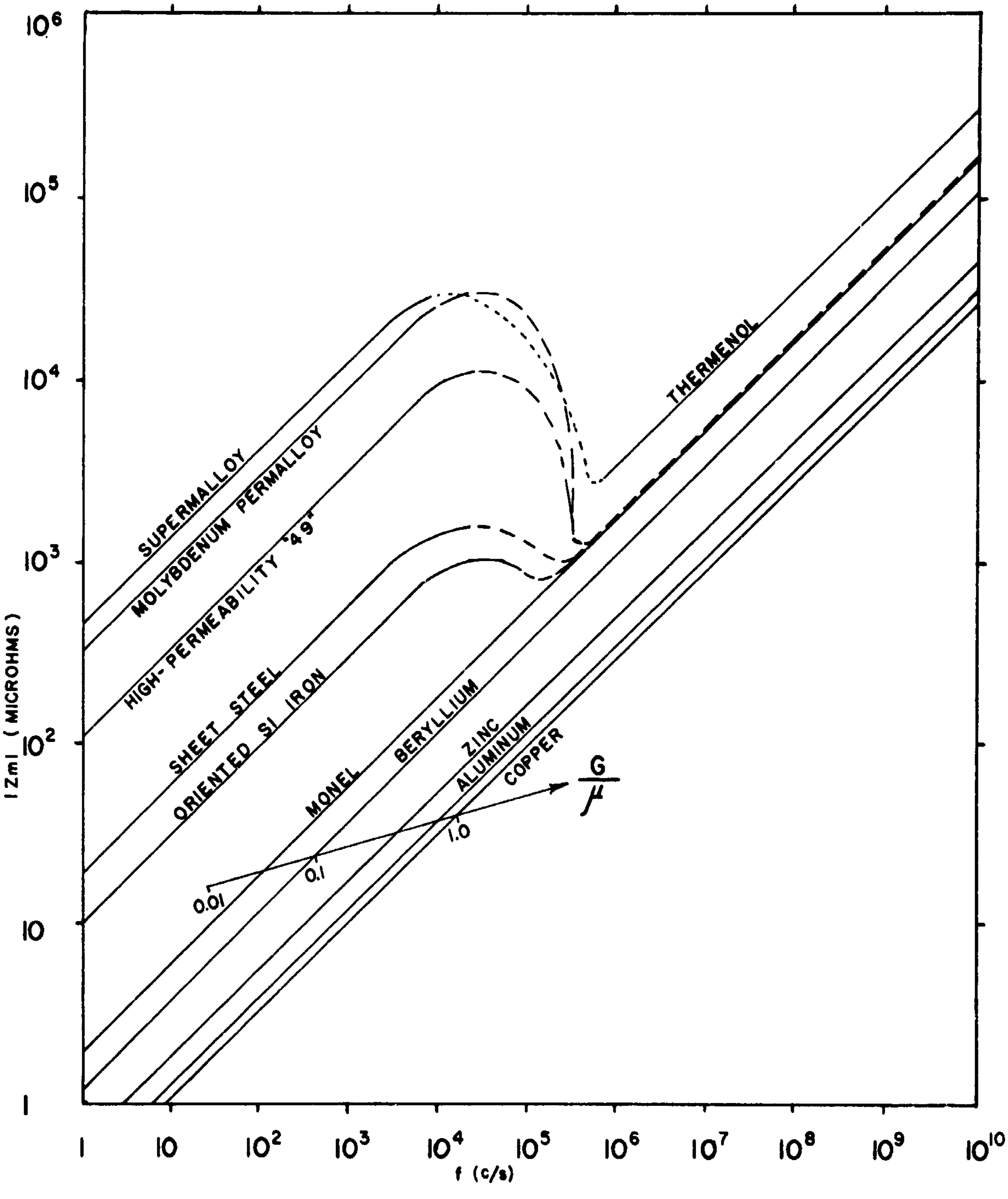


FIGURE 195. INTRINSIC IMPEDANCE OF COMMON SHIELDING MATERIALS

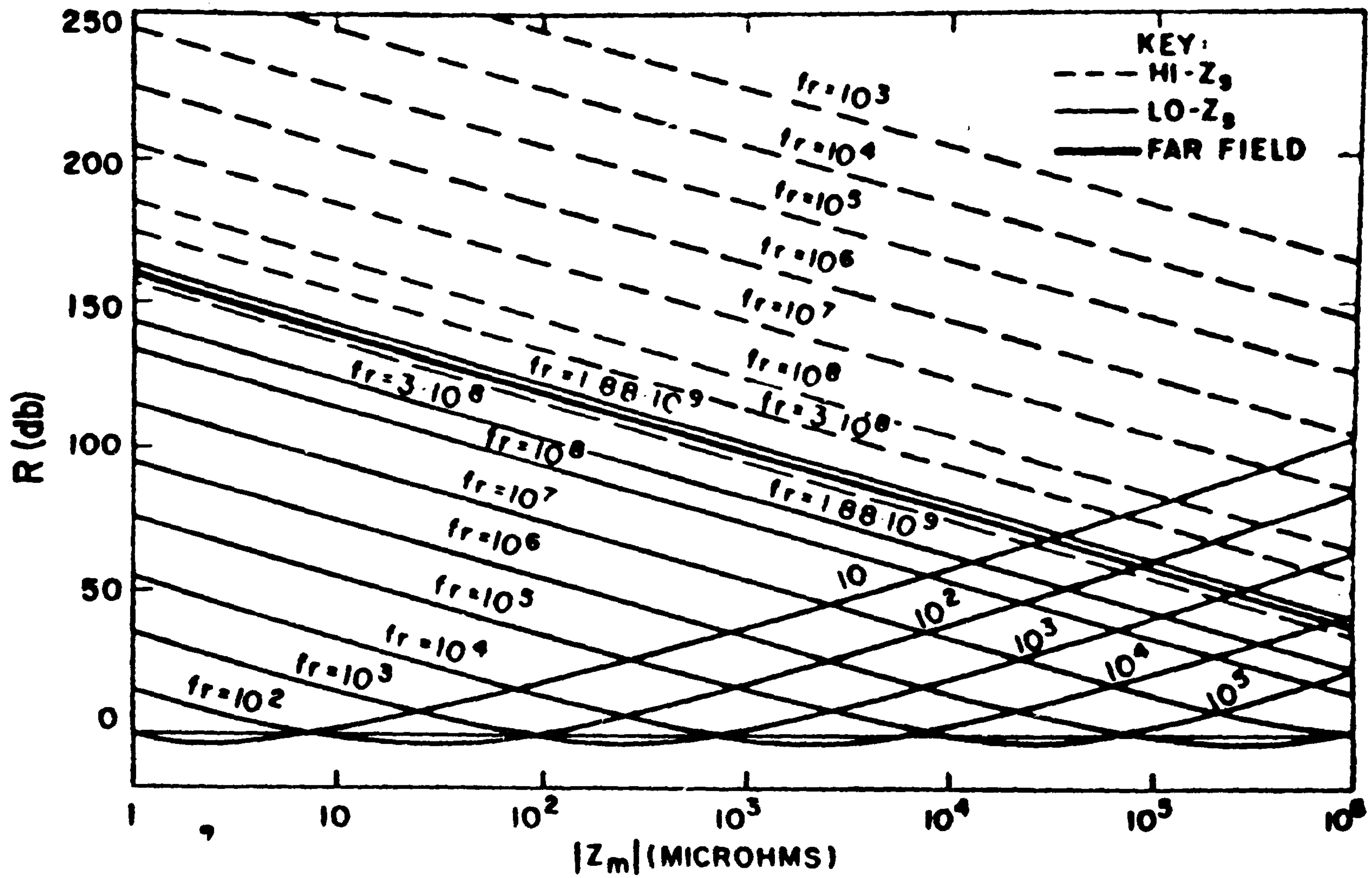


FIGURE 196. REFLECTION LOSS FOR A SINGLE SHEET

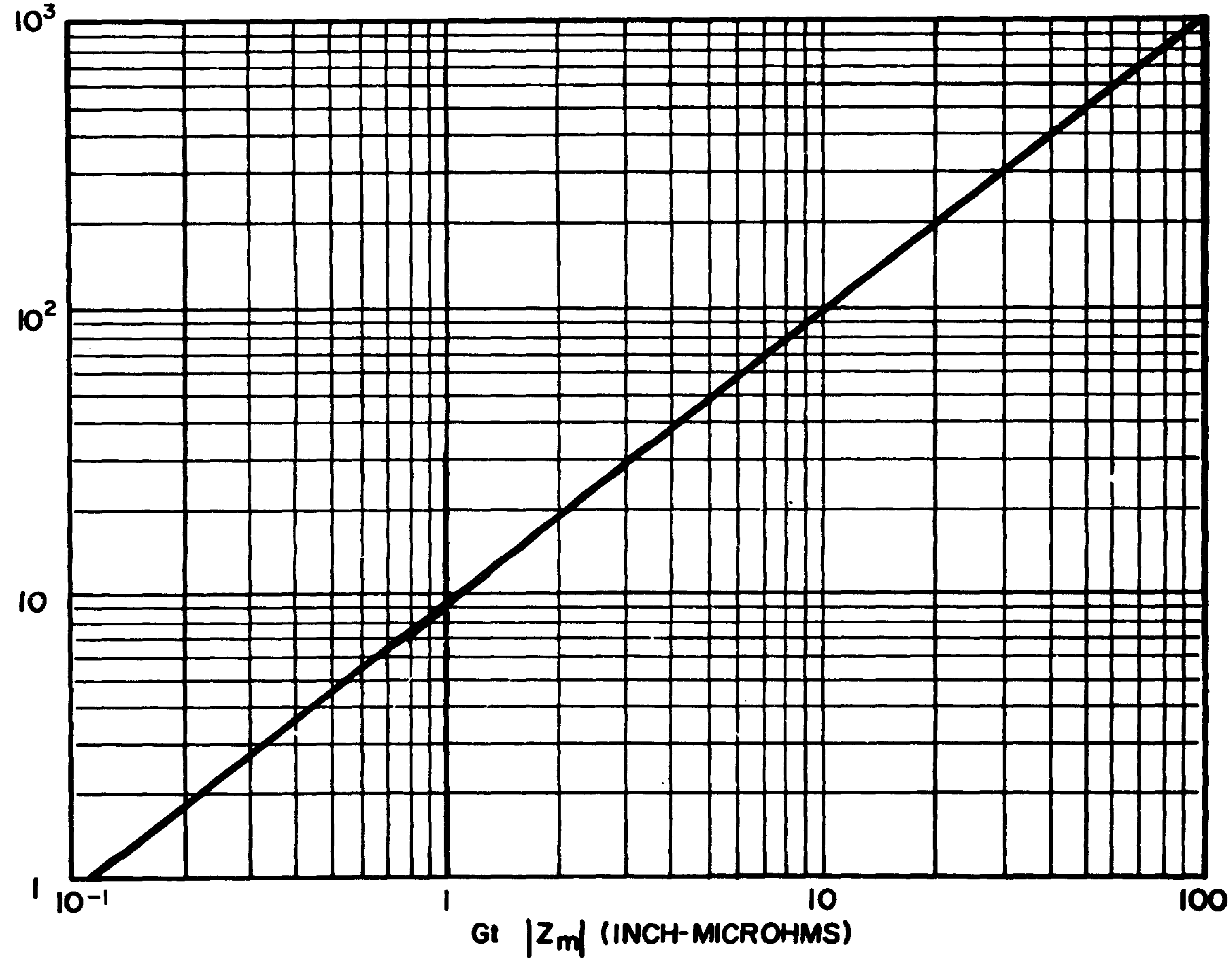


FIGURE 197. ABSORPTION LOSS PER LAYER

NOTE: Zm is the impedance of the material dependent upon the conductivity and permeability of the metal.

There will be slight discrepancies between the analytical and graphical methods. The main reason for these discrepancies is that the graph for the reflection loss R is based on a single formula for both high impedance and low impedance waves instead of the individual formulas.

The above equations are for the theoretical value of shielding efficiency but in actuality, such levels are seldom achieved, particularly at low frequencies.

In general, for plane waves, magnetic materials provide better penetration loss, whereas good conductors provide better reflection loss.

Recently new materials have been developed for shielding against magnetic fields. These materials have been named Netic and Co-Netic alloys. Netic is a specially formulated, non-retentive alloy, non-shock sensitive and made specifically for high field intensity shielding. Co-Netic is a special, high permeability alloy, non-shock sensitive, developed for shielding the lower intensities. When either of these materials are grounded, they also provide electrostatic shielding.

A Netic alloy sheet may also be used with a Co-Netic sheet. This laminated combination shields against both high and low field intensities. The Netic side should always be placed nearest the field source.

JOINT AND GASKET DESIGN FOR ELECTROMAGNETIC INTERFERENCE SHIELDING

When designing containers embodying EMI shielding the number of openings should be kept to an absolute minimum. The most desirable joint consists of metal-to-metal contact along a continuous line, with welding affording the ideal condition. This idealized solution is, of course, not practical for removable container covers. A continuous metal-to-metal contact maintained along a continuous line by means of screws or bolts require surface finishes, container body stiffness, and a number of fasteners which are incompatible with the economic and logistic requirements of today's missile containers. Failure to provide EMI shielding using metal-to-metal contact at all mating surfaces has led to the introduction of conductive gaskets.

Gaskets for EMI shielding applications fall into two categories, the multiple-contact type or the continuous-contact type. Conductive gaskets in use or proposed for use are:

1. Metal screen impregnated with Neoprene (excess Neoprene removed from wire-mesh surface by use of abrasives).

2. Compressed knitted wire mesh of copper, monel or other metal

3. Aluminum tubing filled with a Neoprene core (used in slotted flange and cover-plate designs).

4. Metal foil over Neoprene core.

5. Wire sleeving over Neoprene core (used in slotted flange and cover-plate designs).

6. Sprayed-metal Neoprene gaskets.

The first three gaskets listed above are the most promising for providing interference-free service.

Metal-foil covered gaskets, 4, are suitable for use on flat surfaces, but are found to cause trouble on curved surfaces due to buckling or breaking of the foil. Sprayed-metal gaskets, 6, have been found to be inferior to other gaskets because of the porosity of the coating. The knitted wire mesh, 2, is far superior to any gasket made of woven mesh. It is combined with a sealing medium such as Neoprene when hermetic sealing, as well as shielding, is required.

Conductive gaskets can be made in practically any size or shape to fit the container with which it is to be used. The resiliency and density of the gasket material can also be varied according to the requirements of each application. A well designed gasket insures good all around contact even with appreciable unevenness of the mating surfaces or warping, with special machining for a close fit unnecessary. Consideration should also be given to the compatibility of the gasket material with the mating surfaces from the viewpoint of corrosion.

Gaskets are always used in compression and are held in place by friction, soldering, glue, or mechanical means. When a glue or epoxy is used, it should be applied at intervals instead of continuously so that electrical continuity is not impaired.

Another method often used to provide shielding at joints is the use of spring contact fingers. These can provide good shielding against EMI at much lower joint pressures. These fingers, however, are fragile and are more often used in hinged doors where a wiping contact is desired.

Other places where conductive gaskets should be used are under meter faces and around shafts which penetrate the container.

ELECTRICAL BONDING

Electrical bonding is the process in which the various components or modules of an assembly are electrically connected by means of a low impedance conductor. The purpose of bonding is to make the structure homogenous with respect to the flow of radio frequency currents and, therefore, reduce the possibility of developing electric potentials between metallic parts which can produce radio interference. When the dimensions between two joints are on the order of magnitude of a wavelength, a potential difference will exist in the presence of an electric or magnetic field. At lower frequencies, however, the potential difference between the two joints will be proportioned to the impedance between those joints. Reducing this impedance will reduce the potential difference. When the potential difference between different parts of a structure is high, spark discharges in the strong electric field that is built up are possible. When these two joints are bonded by a low impedance path, a conduction current will exist with a comparatively weak electric and a stronger magnetic field. The magnitude of this conduction current is usually negligible but, in any case, the magnetic field is preferable to the possible generation of spark discharges from between unbonded members. Poor bonds can produce interference due to varying impedance under shock or vibration.

A low impedance path is possible only so long as the dimensions of the bonded members are small as compared to a wavelength of the interference being considered. At high frequencies, the members can be considered as transmission lines whose impedance can be inductive or capacitive of varying magnitude, depending upon geometrical shape and frequency.

The best type of bond is a permanent, direct, metal-to-metal contact accomplished by either welding, brazing, sweating, or swaging. Although soldered points are adequate for most purposes, they do have an appreciable contact resistance and therefore cannot be dependent upon to provide the most satisfactory type of bonding. Bolts and rivets can provide effective bonding of joints, but care must be taken that relative motion between the joined members does not reduce the bonding effectiveness by introducing a varying impedance. Some type of star or lock washers should be used with bolt or lock thread bonding devices to ensure against loosening of the bonded joint. Star washers are also effective for cutting through protective or insulating finishes on metal.

Pre-fitted joints and joints fastened by self-tapping or sheet metal screws are not always reliable as low-impedance radio frequency paths. Where relative motion is required between members that should be bonded, as in the case of shock mounts, a flexible metal strap can be used as a bonding agent. Solid straps are preferred to braided straps due to the lower self-inductance of the solid strap. These straps should also be thin, wide, and as short as possible in order to minimize the self-inductance. A typical bonding strap would be 1 or 2 thousandths of an inch thick, one or more inches wide, and 1 to 5 inches long. The dc resistance of such a strap would be negligible but would have a resistance of about 0.1 ohm at 10 mc and about 15 ohms at 1,000 mc. This impedance is high for the frequencies given and illustrates the point that there is no adequate substitute for direct metal-to-metal contact.

CORROSION OF BONDED JOINTS

Corrosion may take place between two metals in a bonded joint in the presence of moisture through either of two processes. The first process is called galvanic corrosion, and the degree of corrosion is dependent upon the relative positions of the contacting metals in the electromotive series with the metals at the top of the series corroding more rapidly than those at the bottom. The farther apart these metals are in this series, the greater the resultant corrosion will be, with the more active metal (high in the series) tending to go into solution.

The second process is called electrolytic corrosion and requires two metals in contact through an electrolyte, the metals not necessarily being of different electro-chemical activity. The corrosion of the metals in this process is attributed to the presence of local electrical currents such as may be flowing when using the structure as a power system ground return.

Since the mating of bare metal to bare metal is essential for a satisfactory bond a frequent conflict often arises between the bonding and finish specifications. There are, however, certain conductive coatings such as alodine, iridite, Dow #1, and certain protective metal platings such as cadmium, tin, and silver that are conductive and usually do not have to be removed before bonding.

Another method of combating corrosion is to use metals low in the activity table. This is not generally practical where weight is a consideration; and it is imperative that the more active, lighter metals are used. In any case, all joined bare metals should be close together in the activity table if excessive corrosion is to be avoided.

Any corrosion that is anticipated should be designed to occur in easily replaceable items such as washers, straps, etc., rather than in main structures. Only in rare instances will it be more efficient to have the corrosion take place in the more abundant member.

Tight and well-coated joints will prevent the entrance of moisture into the joint and the resulting corrosion that is likely to take place.

MAGNETIC COUPLING

Currents flowing in a grounding device or a ground plane can introduce a voltage in adjacent conductors which is very difficult to remove. These voltages are produced by a change in flux linkages within a loop of finite area. The reduction of magnetically induced voltages can be accomplished by the following methods:

1) Separating the circuits, 2) reducing the area of the pickup loop, 3) using twisted-pair wiring and 4) shielding.

Twisted-pair wiring reduces magnetic coupling by inducing equal and opposite self-cancelling voltages in the circuit. At frequencies below 5 kc, a twisted pair will provide over 20 db of magnetic coupling reduction. Copper braid shielding provides very little shielding at frequencies below 5 kc but its effectiveness is increased as the frequency is increased above 5 kc. Ferrous shielding is more effective than copper braid at frequencies below 5 kc but does not equal copper braid at frequencies above 5 kc.

For the most effective magnetic decoupling throughout the spectrum, twisted-pair conductors enclosed by copper braid shielding is usually employed. The effectiveness of twisted-pair wire depends a great deal on the uniformity and tightness of the twist employed, with the tighter twist being more effective.

The largest reduction in pickup for twisted-pair wires is realized when one wire is used as the low side signal return path. Which of the two wires is to be used as the low side can only be determined by trying one side and measuring the pickup and then trying the other side while measuring the pickup.

Single-ended circuits used in the audio range should not have their shields used for a ground return. A separate wire should be used to complete the ground return between pieces of equipment, and a single ground point tied to the ground plane should be provided for the interconnected equipment. Three or more pieces of equipment should be grounded to a single point which is, in turn, grounded to the ground plane. Insulation should be used over all shields and wires to prevent intermittent grounding to the ground plane or other shields.

Power that is transferred through magnetic coupling will usually be decreased as the signal circuit impedance is increased. The susceptibility to electrostatic coupling, however, will be increased. The optimum value of impedance will be the lowest value for which the magnetically coupled power is made small. Since the optimum value is dependent upon the circuit wiring and it is not always possible to calculate or measure the effective pickup loop internal impedance, an average circuit impedance level of 300 to 600 ohms for low impedance signals is used. This value will usually result in minimum magnetic and electrostatic coupling.

Another method of reducing magnetic coupling in wires is by shield grounding. At values above 1 kc, double-end shield grounding was found to be more efficient than single-end shield grounding and at values below 1 kc, there was no difference between single-end and double-end shield grounding.

It is thus concluded that twisted-pair wires with double-end shield grounding is the preferred wiring for reduction of magnetic and electrostatic coupling.

ELECTROSTATIC COUPLING

No appreciable electric field effects appear on closed loop secondary lines, but great changes can occur on high impedance lines or under open circuit conditions. Two parallel conductors, with the voltage of one higher with respect to the other, will have a capacity between them. This capacity is a function of 1) the conductor size, 2) the distance between the conductors and 3) the dielectric constant of intervening material.

The voltage appearing on the circuit of high impedance will be a result of 1) the voltage division between the source impedance of the first circuit,

2) the capacity existing between the conductors and 3) the impedance of the second circuit.

The coupling capacity between the two conductors may be divided into two parts by surrounding one of the conductors with a shield which becomes low impedance by connecting it to the reference point for both circuits, in this case, ground. Now, the voltage from the unshielded circuit is coupled through the capacity between this conductor and the newly inserted shield on the other conductor. With the shield impedance to ground nearly zero, little voltage will be developed across it. Further improvement could be made by also surrounding the first conductor with a shield, breaking up the original coupling capacity into three parts.

Ground or low impedance connections at radio frequencies cannot be obtained by use of pigtail or wire connections that are too long in length. A one inch length is desirable with three inches as the maximum allowed. A shield over a few feet in length should be grounded at both ends if it is to be kept at a low ground impedance for high frequencies.

Low frequency conductors, which do not normally carry radio frequency currents, may conduct interference because of pickup from adjacent hot cables.

Pulse cables should, therefore, be separated from low level cables and separately shielded. The cables should also be terminated at both ends in a good ground connection. Grounding at both ends of randomly selected conductors in a cable have displayed an electrostatic shielding effectiveness averaging 12 dbs. Unused conductors in harnesses grounded at both ends will therefore gain an increase in electrostatic shielding. These closed loop conductors may, however, carry circulating currents and thus create magnetic fields within the cable bundle. This method should be used with caution.

SHIELD GROUNDING

Grounding of the shields, when used, may be accomplished as single-point or multi-point grounding. The use of single or multiple grounding on shielding will depend greatly on 1) The interference signal frequencies involved, 2) the length of the transmission line and 3) the relative sensitivity of the circuit to high or low impedance fields. The most difficult decision to make in determining whether to use single-point or multi-point grounding exists when ground currents are flowing. These currents can cause a voltage drop to exist between two points in a ground plane depending on the magnitude of the current and the impedance of the ground plane. If a shield is grounded at these two points of different potential, a current can flow through the shield, enabling coupling to take place between the shield and the center conductor. Large ground currents or large ground path impedances cancel the shield effectiveness and the shield becomes a detriment. The ground currents must be very large in a good ground plane, however, before an appreciable potential difference exists between two ground points.

Shielding a wire and grounding the shield at each end may make the system susceptible to magnetic fields due to the currents that can be induced in the shield which may couple to the center wire because of its high inductance or capacitance to the shield. The natural solution to this problem is to ground the shield at only one point, but such grounding will not offer satisfactory electrostatic field protection to the wire.

To obtain a current-free ground, the following recommendations are given: 1) do not use a grounding device as a circuit conductor, but as a reference point only and 2) supply return current leads for all circuits.

In general, single-point grounding is most effective when only for short shield lengths. Single-point grounding is ineffective in reducing magnetic or electrostatic coupling when conductor-length to wave-length ($</\lambda$) ratios are greater than 0.15, where the wave-length is that of the highest frequency to be used on the wire or in the system.

For $</\lambda$ ratios greater than 0.15, multi-point grounding at intervals of 0.15λ is recommended, for the shield can act as an antenna which is relatively efficient at $</\lambda$ when one end is grounded. The coupling or radiation would be increased at lengths when the shield approaches $\lambda/4$. As the circuit length is increased, multi-point grounding will be required for successively lower frequencies. For example when L = 10 ft., f = 14.8 Mc; when L = 100 ft., f = 1.4 Mc, etc. Multi-point shield grounding solves most electrostatic coupling problems, but in audio circuits or where large ground currents exist, single-point shield grounding may be more effective.

FILTERS

Filters have the same two basic functions as shielding, i.e., to isolate a sensitive area from environmental interference fields and to confine internal interference fields to prevent their interaction with the environment. Filters have one basic difference from shields in that filters are used to isolate interference voltages on conductors rather than fields. Since any shield which confines a field or isolates a sensitive area from environmental fields must be penetrated by electrical connections, it is necessary to use a filter on each lead to prevent the field from being guided outside or inside the shield by the lead.

A filter must be installed in the correct manner to obtain maximum efficiency. This consists of installing the filter in a metal-to-metal contact on its ground plane and, in some cases, isolating the leads to avoid contaminating filtered lines. The shields of shielded wires should be terminated within an inch of the filtered lugs to keep a high degree of shielding effectiveness. Also, the use of paper or plastic capacitors should be avoided unless they are of special interference-reducing design. Capacitors of the ceramic type, which have a low inductance, are effective at RF.

APPLICATION GUIDELINES

DC Power

To minimize the possibility of the supply lines coupling interference to other circuits and to protect them from receiving interference from other lines, the best procedure is to use twisted-pair for the supply line and its return. Shielding offers little advantage on lines of this low impedance. The routing should be away from ac power and control lines.

AC Power

Alternating current of comparatively high amperage, characteristic of most ac power lines, makes them potential sources of interference coupling to adjacent lines. Transposed or twisted lines should be used for all ac power circuits. The routing of these lines should be away from susceptible lines. Ac power circuits in which switching transients are expected, may beneficially use shielding to contain the higher frequency components of the transient. Such shielding should be over the entire power wiring bundle and should be grounded at both ends.

Low Level Signals of Low Impedance

Where the distance between input connector and circuit input is small, i.e., an inch or two, the use of a twisted-pair alone may prove adequate. For long runs, the use of twisted-pair shielded wire is mandatory; this is true with unbalanced as well as with balanced output devices. In the balanced case, there is no grounding except for the shield; in the unbalanced case, it is often necessary to ground one of the conductors as well as the shield. The shield and conductor should preferably be grounded at the same point. When going through a conductor, three pins should be made available on the connector to provide insulated passage of the two signal leads and the shield. Grounding of the shield may be at one end of the total run for short runs or both ends or multi-point for long runs, depending on ground current considerations.

Low Level Signals of High Impedance

Where signals from high impedance output devices must be transmitted over any appreciable distance, an impedance transforming device such as a transformer, cathode follower, or transistor should be used to lower the transmission circuit impedance to 500 ohms or lower. However, the use of high impedance signals for transmission of information should, in general, be scrupulously avoided, whether high or low level. Where the use of such signals cannot be avoided, the interconnecting lead must be shielded and the shield grounded at each end. In some cases, the use of a double or triple shielded cable, grounded at each end, may be required if the cable is in an intense electrostatic environment.

High Level Signals

Signals of high level will, in general, not be bothered by susceptibility of circuits. Rather, it may be a source of interference to lower level signal lines. For this reason, and dependent on other characteristics of the signal, either a twisted-pair or a shielded lead should be used. Multiple shielding may be required if the signal is of sufficient level. Grounding should be at both ends to prevent electrostatic radiation from the cable.

Reference Voltages

Care should be taken to minimize the possibility of introducing dc as well as ac voltages. Grounding, where required, should be only at one point. Treat the reference voltage as a circuit, always including its return lead either in the form of a twisted-pair or a shielded or coaxial lead.

The use of twisted-pair and/or shielding for the reference voltage lead and its return will minimize the pickup from sources of electromagnetic radiation. In the case of ac reference voltages, this treatment will also minimize the interference effect that the reference voltage might have on other circuits. Shielding of the twisted-pair may be helpful, especially when the circuit impedance is not held to a low value; however, filtering of the reference voltage inside the using equipment is to be preferred over the use of shielding. The source impedance of the voltage should be maintained as low as possible in order to minimize electrostatic pickup. In any case, the using element should see only the reference voltages, and not the reference voltage plus small components of other signal and power voltages due to common impedances.

Control Voltages

The control of various functions is usually accomplished with the use of voltages of either ac or dc which are switched on or off in a step manner. Lines carrying such voltages are potential interference generators; they should be of a nature that will hold coupling to other circuits at a minimum. Separation and shielding is thus indicated.

RF Signals

RF signals within a unit should be routed in such a way that cross coupling between input and output circuits is held to a minimum. Outside the unit, shielding should be used if necessary to prevent excessive radiation from the wire or excessive pickup on the wire. Grounding of such shields should be multi-point for RF signals.

SUMMARY OF CABLING FACTORS

Magnetic fields appear as low-impedance interference sources at low (audio) frequencies. Conventional copper braid is of negligible effect in containing these fields. Use of twisted wire is the principal means of

reducing the effects of flux linkage in the pickup circuit. The loop area of the pickup circuit must be made as small as possible in order to decrease the number of flux linkages within the magnetic field; this is done by always including the return with the current wire. Such circuits should not have the signal return grounded at more than one point. Use of ferrous shielding (Mu metal, Co-Netic foil, iron pipe, etc.) can be used to concentrate the flux linkages in a low permeability path, thus avoiding flux linkages with the pickup circuit. Magnetic waves of higher than audio frequencies appear as relatively higher impedance interference sources and larger shield reflection losses occur, thus increasing conventional shielding effectiveness. Electric fields appear as high-impedance interference sources, and highly conductive copper braid shielding is effective in providing attenuation. To be effective, however, the shield needs to be at the potential of the ground plane, and the use of long shields grounded at only one end makes it highly improbable that the entire shield will be at ground potential. In this case, since shield reflection loss depends on mismatch between the intrinsic impedance of the shield and the field, there will be little shield reflection loss and the shield will be of little effect. The remedy is to ground the shield at each end, and for longer cables, at each 0.15λ distance.

SPECIFICATIONS AND STANDARDS

All equipment and systems subject to electromagnetic interference should conform to Military Specification MIL-E-55301. This specification covers the electromagnetic interference reduction design requirements, emission and susceptibility limits, and test procedures for assuring electromagnetic compatibility of all equipment and systems. It includes all items that are capable of generating or being adversely affected by electromagnetic interference.

MIL-STD-826 (USAF) establishes uniform test methods for testing equipment, systems and subsystems to determine their electromagnetic interference and susceptibility characteristics. These test methods are to insure that interference control design is incorporated into equipment, systems and subsystems and that applicable limits are not exceeded by performing tests under simulated situations obtainable in the laboratory similar to those existing in the actual environment.

CHAPTER XIV

LOGISTICS

Transportation Limitations

The limitations imposed upon containers by trucks, railroads, ships, aircraft, and special transporters for overseas areas and the continental United States will be described in this section. The designer will usually find that the regulations and dimensional limitations in overseas areas are more restrictive than the continental United States.

Wherever it appears container dimensions will approach the limitations specified in this section, or specific problems arise that cannot be resolved by reference to this section, then a detailed transportability study should be made for the mode of transportation under consideration. Transportation publications are referenced in this section which will aid the designer in solving transportation problems. Transportation problems should be coordinated at the local Transportation Office.

Truck

Each state in the United States has placed upon its highway system limitations affecting the size of loads that can be legally transported over these highways. Although these limitations can be exceeded, to do so would cause considerable difficulty and would, in all probability, require special permits, special routing, police escorts, etc. This would, of course, add to the in-transit time and consequently the transportation costs. Since these limitations vary according to states, the designer must be aware of the highway limitations. A summary of highway size limitations for individual states is shown in Table 26.

Containers should be designed to permit versatility of transporting through any state without first having to obtain special permits, routing, etc. Generally speaking, the maximum width and height for over-the-road equipment which will meet the general requirements of all states is 8' wide and 12' 6" high. Maximum length of vehicles authorized in all states range from 35' for single units to 50' for tractor-semitrailer units. The floor height of trailers will usually vary from 4' 1" to 5' depending on the size of the tires used. For flat bed trailers, this leaves a usable stacking height ranging from 7' 6" to 8' 5". This is assuming a 12' 6" maximum road height limitation. Since truck-full trailer units are not allowed in certain states, this type of vehicle should only be considered in special cases. Dimensions of standard military vehicles are contained in data sheets which are available at U. S. Army Tank-Automotive Center, Warren, Michigan 48090.

Overseas highway limitations are generally more restrictive than those found in the United States; consequently, the carrier and container should not exceed 11 feet in height, 8 feet in width, and 16,000 pounds axle load.

TABLE 26
TRUCK AND TRAILER LIMITS BY STATES

State	Height	Width	Length (ft)				Axle Load Limits		Maximum* Gross Weight in Pounds			Formulae ** and Tables (.)
			Single Unit	Tractor Semi-Trailer	Truck Full Trailer	Tractor Semi & Full Trailer	Single	Tandem 4' Apart	Tractor & Semi-Trailer Single-Axle	Tractor & Semi-Trailer Tandem	Other Combinations	
Ala.	12'6"	96"	35'	50'T-S	N.P.	N.P.	18,000	36,000	45,000	64,650	N.P.	Table
Alaska	13'	96"	35'	60'	60'	60'	18,000 S-7	32,000	45,000 N	75,200	76,800	Table
Ariz.	13'6"	96"A	40'	65'	65'	65'	18,000	32,000	45,000	68,000	76,800	Table
Ark.	13'6"	96"	35'	50'T-S	50'	50'	18,000	32,000	45,000	56,000*** P	56,000 P	....
Calif.	13'6"	96"A-1	35'	60'T	60'U	65'D	18,000	32,000	45,000	68,000	76,800***	Table
Colo.	13'6"D	96"	35'	60'T-S	60'	60'	18,000	36,000	45,000	67,200***	75,200	Formulae (1)
Conn.	12'6"	102"	50'	50'T-S	N.P.	N.P.	22,400	36,000	50,000 Z-1	60,000	N.P.	....
Dela.	12'6"	96"	40'	50'	50'	60'	20,000 S-1	36,000	40,000	60,000	60,000	Table
D.C.	12'6"	96"	35'	50'T-S	50'	N.P.	22,000	38,000	56,400	63,890	65,400	Table
Fla.	12'6"	96"	40'	50'T-S	50'U-1	N.P.	20,000	40,000	49,000	66,450	66,450	Table
Ga.	13'6"	96"	30. 35'	50'T-S	50'	N.P.	20,340	40,680	61,020 D	63,280 D	63,280	....
Hawaii	13'	108"	40'	55'	65'	65'	24,000	32,000	57,000	67,200	81,600	Formulae (2)
Idaho	14'	96"	35'	60'T-S	65'	65'	18,000 S-3	32,000	45,000	68,000***	76,800	Table
Ill.	13'6"	96"	42'	50'	50'	50'	18,000 S-3 D	32,000	45,000	72,000	72,000	....
Ind.	13'6"	96"	36'	50'T-S	50'	50'	18,000 S-3	32,000	45,000	72,000***	72,000	....
Iowa	13'6"	96"	35'	50'T-S	N.P.	N.P.	18,000 M-3	32,000 M-3	45,000 M-3	72,634	N.P.	Table
Kan.	13'6"	96"A	35'	50'T-S	50'	N.P.	18,000	32,000	45,000	63,890***	63,890	Table
Ky.	13'6"D	96"	35'	50'T-S D	N.P.	N.P.	18,000 S-M-4	32,000 S M-4	42,000 S M-4	59,640 S-F	N.P.	....
La.	12'6"	96"	35'	50'T-S	60'	N.P.	18,000 S-6	32,000	36,000 P	64,000*** P	68,000 P	....
Maine	12'6"	96"	50'	50'T-S	50'	N.P.	22,000 S	32,000	50,000	68,000	60,000	Table
Md.	12'6"	96"	35'	55'T-S	55'	55'	22,400	40,000 I	53,800	65,000	65,000	Formulae (3)
Mass.	N.R.	96"	35'	50'T-S	65'U-2	N.P.	22,400 S-3	36,000	60,000	60,000	N.P.	Formulae (4)
Mich.	13'6"	96"	35'	55'T	55'	55'	18,000 S-1	26,000 J	45,000	68,000*** D	111,000 D	(3 Tables)
Minn.	13'6"	96"	40'	50'	50'	N.P.	18,000	32,000	45,000	72,500***	72,500	Table
Miss.	12'6"	96"	35'	50'T-S	50'	N.P.	18,000 S-4	32,000 D	45,000	55,650	59,000 D	Table
Mo.	13'6"T	96"	35'	50'T-S	50'	50'	18,000 S	32,000	45,000	63,890***	64,650	Table
Mont.	13'6"	96"	35'	60'T-S	60'	60'Z-2	18,000	32,000	45,000	68,000***	76,800	Table
Neb.	13'6"	96"	40'	60'T-S	60'U-1	60'	18,000	32,000	45,000	67,333	71,146	Table
Nev.	N.R.	96"	N.R.	N.R.	N.R.	N.R.	18,000	32,000	45,000	68,000	76,800	Table
N.H.	13'6"	96"	35'	50'T-S	50'	50'	22,400 S	36,000	52,000	66,400	66,400	Table
N.J.	13'6"	96"	35'	50'T-S	50'	N.P.	22,400 S-3	32,000	52,400 G	60,000	60,000	....
N. Mex.	13'6"	96"A-2	40'	65'T-S	65'	65'	21,600 S	34,320	52,200	75,600***	86,400	Table
N.Y.	13'	96"	35'	50'T-S	50'U	N.P.	22,400 S-3	36,000	53,800	65,000	65,000	Formulae (5)
No. Car.	12'6"	96"	35'	50'T-S	50'U	N.P.	18,000 S-M2	36,000 M-2	46,200	62,000 M-4	62,000 M-4	....
No. Dak.	13'6"	96"	35'	60'T-S	60'	60'	18,000 S-2	32,000	45,000	62,000	73,280 C-Y	Formulae (6)
Ohio	13'6"	96"	35'	50'T	60'U	60'	19,000 S-5	24,000 W	47,000	72,000*** W	78,000 W	Formulae (7)
Okla.	13'6"	96"	35'	50'T-S	50'	N.P.	18,000 S-5	32,000	45,000	73,280***	73,280	Table
Oregon	13'6"T-D	96"A-1	35'	60'T-S-D	60'U-4D	65'Y-D	18,000 S-2	32,000	45,000	68,000	76,000 L-D	Table
Penn.	12'6"	96"	35'	50'	50'	N.P.	22,400 S-3	36,000	50,000	60,000	62,000	....
R.I.	12'6"	102"	40'	50'	50'	N.P.	22,400	44,000	50,000	60,000 Z	88,000 E	....
So. Car.	12'6"	96"	40'	50'	50'U-1	N.P.	20,000 M-1	32,000 M-1	49,000 M-1	63,890 M-1	68,350 M-1	Table
So. Dak.	13'	96"	35'	50'T-S	60'	60'Y	18,000 S	32,000	45,000	72,110***	73,280	Table
Tenn.	12'6"	96"	35'	50'T-S	50'U-1	N.P.	18,000	32,000	45,000	61,580	61,580	Table
Texas	13'6"	96"	35'	50'T-S	50'	N.P.	18,000 S-5	32,000	45,000	58,420	72,000 [illegible]	Table
Utah	14'	96"	45'	60'	60'	65'Y	18,000	33,000	45,000	76,500 C	79,900	Table
Vt.	12'6"	96"	50'	50'T-S	50'	N.P.	N.S. S	N.S. S	50,000	60,000	60,000	....
Va.	12'6"	96"	35'	50'T-S	50'	N.P.	18,000 M-4	32,000 M-4	45,000 M-4	56,800 M-4	56,800 M-4	Table
Wash.	13'6"	96"	35'	60'T	60'	65'D	18,000 S-7	32,000	45,000	68,000*** L-2	72,000	Table
W. Va.	12'6"	96"	35'	50'	50'	N.P.	18,000	32,000	45,000	63,890	73,280 L-1	Table
Wisc.	13'6"	96"	35'	50'T-7	50'U	N.P.	19,500 X	32,000	40,000 X	73,000*** X-1	73,000 X-1	Table
Wyo.	13'6"	96"	40'	60'T-S	60'	60'	18,000	36,000	45,000	72,110***	73,950	Table

TABLE 26
TRUCK AND TRAILER LIMITS BY STATES (cont)

FOOTNOTES

(.)	- Tables may be obtained from State Motor Vehicle Administrators.	G	- Vehicles registered before March 1, 1950 exempt.	T	- Semi-Trailer limited to 40'; T-5: not restricted, T-6: Semi-Trailer 40' with permit. T-7 - Measured from rear of semi-trailer to rear of tractor.
*	- Maximum Practical Gross (see third paragraph General Remarks).	I	- 36,000 lb. if axles spaced less than 48" apart.	U	- Full trailers limited to 35'; U-1 35' unless 3 axle, then 40'; U-2: 33'; U-4: 40'
**	- Formulas. 1 - 800(L + 40). 2 - Group of Axles less than 18', 700(L + 40). Group of Axles more than 18', 800(L + 40). 3 - 850(L + 40). 4 - 1000(L + 24). 5 - 34,000 + (L x 850). 6 - 750(L + 40). 7 - 900(L + 42 2/9).	J	- On designated highways one tandem per combination permitted 32,000 lb.	W	- 31,500 with tandem axles spaced more than 4' apart.
***.	3-axle tractor with tandem axle semitrailer.	L	- Permit required for gross weight over 60,000 lbs.; L-1 Permit required over 63,840 lbs.; L-2 - 72,000 lbs. with permit on main highways.	X	- Includes 1,500 lb. tolerance single axle; X-1 - Includes all tolerances.
A	- 102" across tires. A1 - 100" across tires; A2 - 102" on designated highways.	M-1	- Plus 10% tolerance.	Y	- With permit.
B	- Semi-Trailer length controlled by single unit length except where footnote appears.	M-2	- 1000 pounds tolerance on 1 axle; M-3 - Plus 3% Tolerance. M-4 - Plus 5% tolerance.	Z	- Not less than 10:00 x 20 tires; not less than 27' between extreme axles.
C	- With Proper Equipment.	N	- Maximum 47,000 lbs.	Z-1	- Subject to tire size requirement.
D	- On designated highways.	N.P.	- Not Permitted. (N.R. - No Restriction)	Z-2	- At discretion of Highway Commission, may be permitted.
E	- 3-axle truck with 3-axle trailer.	N.S.	- Not Specified.	#	- Effective Jan. 1, 1960.
F	- No tolerance allowed.	P	- Plus weight on front axle.		
		S	- Subject to 600 lb. per inch tire requirements; S-1: 700 lb.; S-2: 550 lb.; S-3: 800 lb.; S-4: on tires 9:75 and larger; S-5: 650 lb.; S-6: 450 lb.; S-7: 500 lbs.		

(Courtesy of: Truck-Trailer Manufacturers Association, Inc.)

Since the American Trucking Association has no published rules for loading, blocking and bracing of commodities for highway transportation, missile and rocket equipment should be loaded in accordance with the applicable approved Army loading drawings.

Railroad

To promote maximum efficiency of railroad transportation, railroad equipment and loaded rail cars should be within the clearance limitations published by the Association of American Railroads. Since many of these limitations are dependent on bridges, tunnels, telephone poles, etc., and are subject to change, special equipment and cars with loaded dimensions should not exceed the published limitations without obtaining clearance of the Association of American Railroads. Loaded rail cars which exceed the minimum limitations usually will require special routings at restricted speeds.

To aid the designer in developing a container for North American and European railroad transportation, a standard railroad clearance chart is shown in Figure 198. It should be noted that the North American rail clearances are applicable to cars having dimensions up to 50' 6" inside length, 54' 8 1/2" coupled length, and 41' 3" between truck centers. If it is necessary to use longer cars or cars exceeding the other dimensions given above, then a special study of clearance limitations should be initiated.

Longer loads may be transported on open top cars not exceeding the above dimensions by overhanging the load on one car or utilizing idler cars. Loads transported by this method must conform to the criteria governing overhanging loads and use of idler cars as given in the Association of American Railroads Regulations.Containers up to 120' may be transported over conventional routes using this method if all other critical criteria are met.

Loading, blocking and bracing drawings, for each missile system to be transported by rail, are prepared by the Army Missile Command in accordance with the rules set down by the Association of American Railroads. These rules state permissible weight distribution, location of loads, types and sizes of material to be used for blocking and bracing, etc. For open top cars, sections 1 and 6 of the "Rules Governing the Loading of Commodities on Open Top Cars" should be consulted. For closed type cars, pamphlets 27, 41 and 42-B of the "Rules Covering Loading of Carload Shipment of Commodities in Closed Cars," should be consulted. Proposals for deviation from these rules must be submitted to the Defense Traffic Management Service, Washington 25, D.C., through the appropriate channels, for referral to the Mechanics Division of the Association of American Railroads.

When designing containers with a specific car size in mind, allowance must be made for blocking and bracing material as specified by the Association of American Railroads. Flat cars require a 6-inch clearance on each side and a 28-inch clearance on each end to allow blocking of the container base. The upper part of the container is restricted to the length of the

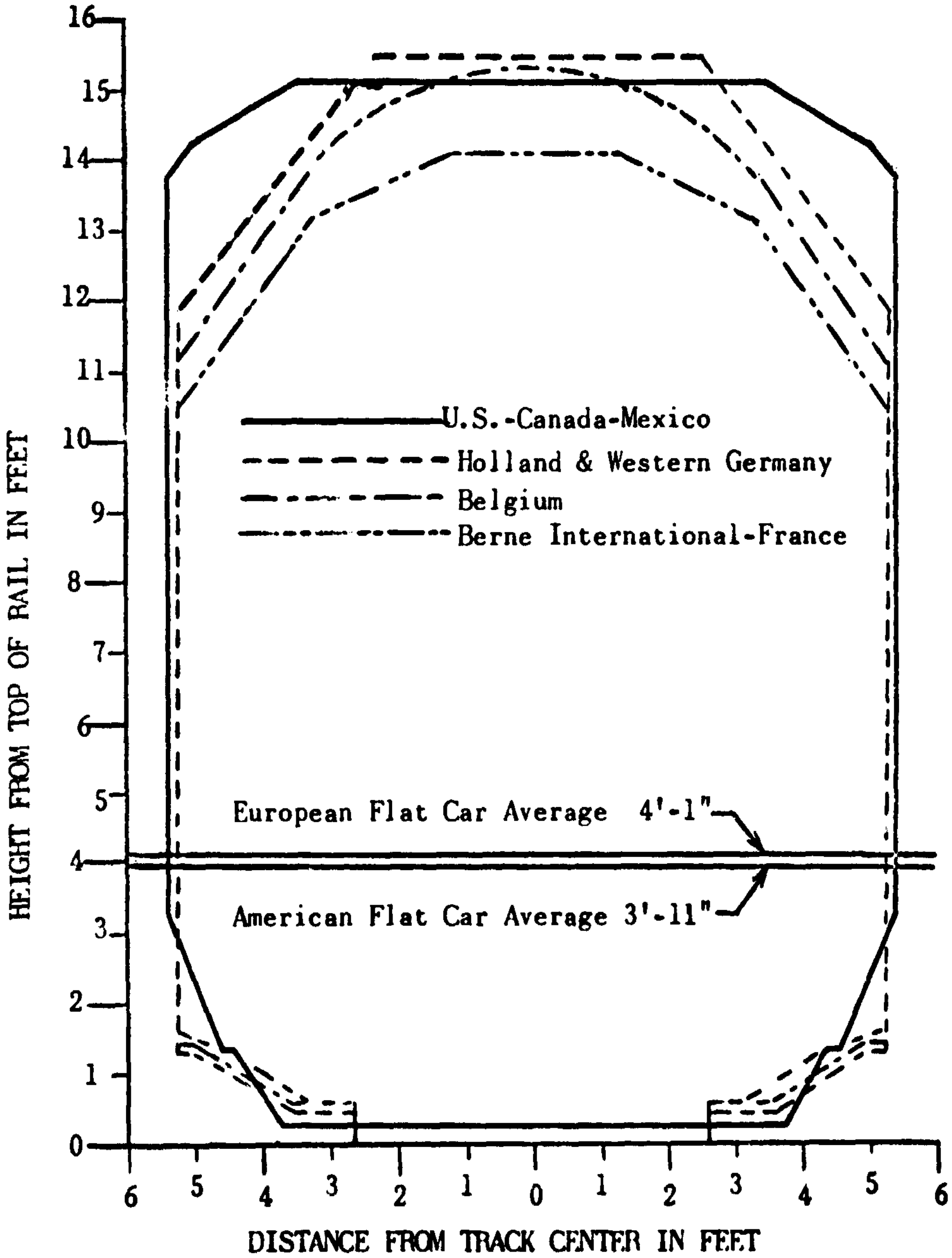


FIGURE 198. RAIL CLEARANCES

car used except for those clearances required for the brake wheel (see Figure 199) and to the height and width limitations specified in the clearance diagram shown in Figure 198. This allows a 10' 8" maximum width with the height varying from 9' 10" to 11' 2", depending on the width of the container.

Containers with a greater height may be loaded on depressed floor or well hole cars. The average height of the car floor above the top of the rail is 2 feet for depressed floor cars and 10 inches for well hole cars. This is compared to 3 feet 11 inches for the American flat car. Due to the limited quantity of depressed floor and well hole cars, it is recommended that containers be designed for use on standard railroad equipment.

When loading gondola cars, no clearance is required between the load and the sides and ends of the car for blocking except in the vicinity of the brake wheel where the minimum brake wheel clearances will govern, as shown in Figure 199. Anti-chafing material should be placed between the load and the sides and ends of the car to prevent damage to the container.

When loading containers in box cars, the dimensional limitations placed upon the container will usually be dictated by the door size. Although there are special box cars available with removable sides and ends for ease of loading, their limited quantity and availability should be a deterrent factor in container design and use.

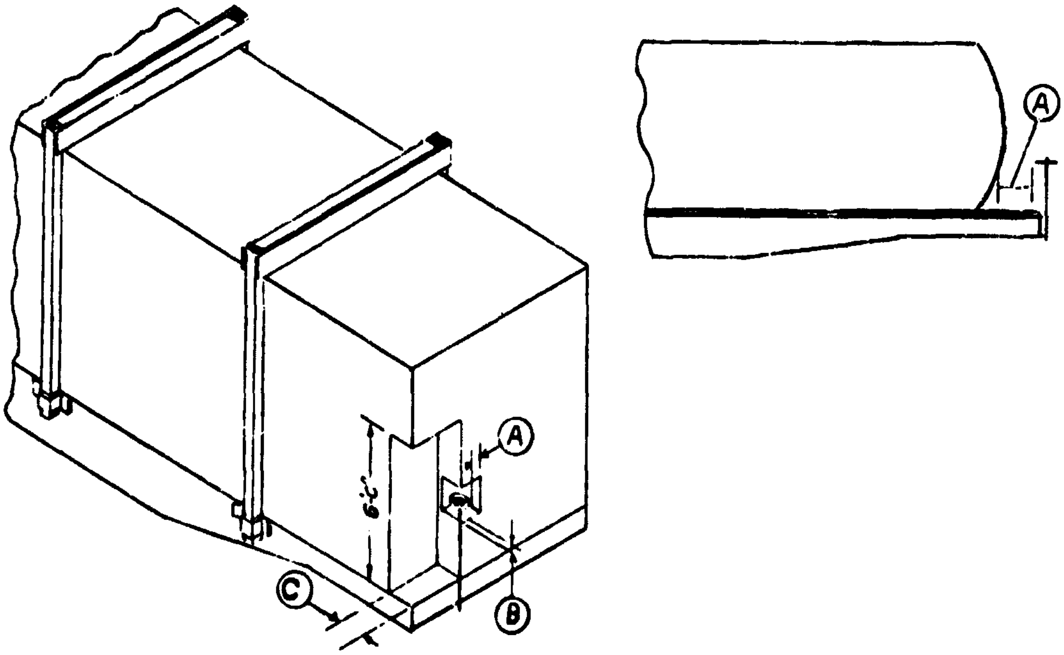
Standard rail equipment commonly used for transportation of missile containers is shown in Table 27.

For further information on the sizes of all available rail equipment on the North American continent, the Official Railway Equipment Register should be consulted.

Flat cars or open top cars are preferred because of their ease of loading and unloading. Closed cars will be more difficult to load, block and brace, especially where larger type containers are involved. It must be noted, however, that open top cars offer no protection against the elements and it may be more advantageous to employ closed cars, especially if secrecy is desired.

Ship

Any container that can be transported to dock side can be handled and loaded on board ship. While special handling equipment can be made to load any given weight a ship can carry, the container designer should endeavor to limit the weight of individual containers and their contents to the boom capacity of the vessel in order to permit loading and unloading without use of shore equipment. Since all cargo ships are equipped with at least a 5 long ton boom (long ton equals 2240 pounds), it may be assumed that this weight limit could be loaded and unloaded anywhere by any type of vessel. In certain instances, it is feasible to double this capacity by utilizing



Brake Wheel Clearance. The brake wheel clearance must not be less than requirements shown in drawing, above, and should be increased as much as consistent with proper location of load.

A 6 in. clearance in back, on both sides of, and above brake wheel, except as shown for tanks and similar shapes in one piece.

B 4 in. clearance underneath brake wheel.

C 12 in. minimum clearance from end of car to load, extending from center of brake wheel to side of car and 6 ft. above car floor. On gondola cars this space may be utilized from floor of car to 4 in. below bottom of brake wheel, Item "B."

In the loading and hauling of long commodities requiring more than one car, handbrakes may be omitted on all save one of the cars while they are thus combined for such purpose. (See Supplementary Act No. 133 Approved April 14, 1910, Federal Statute reference 36 Stat. L., 298, of the current edition of the U.S. Safety Appliances.)

Brake wheel clearance should be increased as much as consistent with proper location of load.

FIGURE 199. BRAKE WHEEL CLEARANCES

TABLE 27
DIMENSIONS OF COMMONLY USED RAILROAD CARS

Type of Car	Nationality	Inside Length	Inside Width	Inside Height	Weight Capacity (lbs)	Side Door Width	Side Door Height
Open	N. American (flat)	41' 6" 42' 6" 45' 0" 49' 0" 50' 0" 52' 0" 52' 6" 53' 6"	* * * * * * * *	--	80, 000 140, 000	--	--
	N. American (gondola)	41' 6" 46' 0" 48' 6" 52' 6"	9' 6" 9' 6" 9' 1" 9' 5" 9' 6" 9' 6"	--	Up to 140, 000	--	--
	Turkey and Greece (flat)	60' 9" 49' 4"	8' 9" 8' 9"	--	70, 000 80, 000	--	--
	Turkey and Greece (gondola)	24' 7" 26' 9"	8' 10" 8' 10"	--	30, 000 30, 000	--	--
	Japan	18 - 42'	7-1/2 - 8-1/2'	--	N. A.	--	--
	Britain	17 - 20'	7-1/2 - 8-1/2'	--	N. A.	--	--
	France	20 - 25'	7-1/2 - 8-1/2'	--	N. A.	--	--
Closed	N. American	40' 6" 50' 6"	8' 6" 9' 2" 8' 6" 9' 2"	9' load height	75, 000 100, 000	8' 8" 10' and 15'	10'
	Turkey and Greece	24' 7" 32' 10"	8' 10" 8' 10"	N. A. N. A.	30, 000 31, 500	N. A. N. A.	6' 10"
	Japan	17 - 23'	7-1/2'	6-1/2 - 7-1/2'	N. A.	N. A.	N. A.
	Britain	17'	7-1/2'	6-1/2 - 7-1/2'	N. A.	5'	6'
	France	30'	7-1/2'	6-1/2 - 7-1/2'	N. A.	N. A.	N. A.

*Inside widths for each length listed are: 8'6", 9'2", 9'6", 10'2", and 10'6".

two 5-ton booms in parallel, but this would limit the area of the ship to which items could be stowed. For containers containing explosives, the Coast Guard has placed various weight limitations on all hoisting equipment according to the class of explosive. These limitations may be found in paragraph 146.29-41 of CG 108.

Length and width limitations of containers for in-hold storage can be derived from the hatch sizes given in Table 28. Containers longer than the dimensions given in Table 28 can sometimes be stored below deck by slightly tipping the container, assuming that the height of the container does not exceed the height of the hold or compartment in which it is to be stowed. The heights of tween deck holds* will range between 6 feet to 12 feet while the heights of the lower holds will vary between 7 feet to 25 feet.

TABLE 28

HATCH SIZES OF SOME CARGO SHIPS (AR 705-8)

	Smallest	Largest
Mariner Class	20' 3" x 18' 6"	40' x 30'
Victory Class	24' x 22' 4"	36' x 22' 4"
Liberty Class	20' x 20'	35' x 20'

Containers are not restricted to in-hold stowage, but may utilize "on deck" stowage in accordance with CG 108. While "on deck" stowage will lift the restrictions placed upon containers by hatch and hold sizes, other size limitations will be placed upon the container depending upon the type and size of vessel to be used. The "on deck" stowage limitations in most cases will be less restrictive than those for below deck stowage. If this type of stowage is used, the container will be afforded very little protection against the elements during its voyage. In any case, regardless of "on deck" stowage or in-hold stowage, the weight limitations placed upon the container in loading will remain the same.

For easy stowage aboard most vessels, the container dimensions should not exceed 35 feet in length, 20 feet in width, and 11 feet 4 inches in height. To permit container loading and unloading by the smallest type of vessel utilizing only the ship's facilities, a weight limitation of 11,200 pounds for non-explosive items and 7,467 pounds for containers containing complete missiles with high explosive warheads and solid or liquid propellant motors, must be adhered to. If two 5-ton booms are hooked in parallel or one 10-ton boom is used, then these weight limitations will be doubled. For weight limitations of other types of explosives, preparation of holds and compartments, and other stowage limitations, "Rules and Regulations for Military Explosives and Hazardous Munitions - CG 108" should be consulted.

*Tween deck hold (a space located between the weather or main deck and lower hold)

If containers exceeding the above limitations are offered for water shipment, then reference to AR 705-8 is recommended for guidance.

Aircraft

When designing containers for the required degree of air-transportability, careful consideration must be given to the limitations imposed by the characteristics of the aircraft involved. The most important of these characteristics are:

a. Maximum allowable aircraft payload.

b. Size, location and configuration of door openings.

c. Size and configuration of cargo compartments to include limiting features that may prevent full utilization of available space.

d. The strength of the aircraft floor and loading ramp.

e. Number, location and strength of tie-down fittings.

f. The forward and aft aircraft center of gravity limits.

Containers designed for air transportation should be designed to be transportable in the maximum number of types of available aircraft and alleviate the possible shortage of a particular type.

The outside dimensions of containers for air transportation in Air Force aircraft, the Army H-37 helicopter, and the Army YAC-1 airplane must be such as to permit loading and unloading with a 6-inch vertical clearance after loading and a 5-inch lateral clearance on each side during and after loading. Containers which are to be transported in Army aircraft, other than the H-37 helicopter and the YAC-1, must be capable of being loaded and unloaded through side cargo doors to provide a 1-inch vertical and lateral clearance at the doors and inside the cargo compartment during loading and 6 inches vertical and 5 inches lateral clearance after loading. Consideration must also be given to clearance requirements for aisle space and access to controls and auxiliary equipment. For items that will restrict easy passage through the aircraft, the transportation officer should be contacted for guidance. Dimensional and ramp loading criteria for Army and Air Force aircraft are shown in Table 29. Container size limits for some other aircraft are contained in Tables 30 through 34.

When considering weight limitations for air-transportability, caution must be exercised on problems of floor loading. The designer must allow sufficient bearing area at the surface of contact between the container and the aircraft floor to remain within the floor loading limitations. This limitation will usually vary between 100 to 500 pounds per square foot, depending on the type of aircraft used. To help guide the container designer in selecting maximum payloads for air-transportability, payload distance

TABLE 29

DIMENSIONAL CRITERIA FOR SOME ARMY AND AIR FORCE AIRCRAFT

Airplane	Type	Cargo Compartment (Usable Space)			Loading Aperture		Ramp Data			Cargo Hook Capacity (lbs)
		Length	Width	Height	Width	Height	Length	Ground Angle	Floor Angle	
C-119G	Fixed Wing	36'11"	9'2"	7'8"	9'2"	7'8"	16'0"	14°	14°	(1)
C-123B	"	28'9"	9'2"	8'2"	9'2"	8'2"	8'3"	15°	15°	(1)
C-124A	"	77'0"	11'3"	11'6"	(5)	11'8"	28'4"	17°	11.5°	(1)
C-130A	"	41'0"	10'0"	9'0"	10'0"	9'0"	10'5"	12.5°	12.5°	(1)
C-133A	"	81'10"	11'10"	11'2"	(4)	12'0"	15'9"	9°(2)	9°	(1)
U-1A	"	12'8"	4'4"	4'11"	3'10-1/2"	3'9"	10'6"	15°	15°	(1)
YAC-1	"	28'9"	6'1-1/2"	6'2"	6'1-1/2"	6'2"	(1)	(1)	(1)	(1)
H-21	Helicopter	19'9"	4'1"	5'2"	3'9"	4'11"	(1)	(1)	(1)	5000
H-34	"	13'4"	4'11"	5'10"	4'5-1/2"	4'0"	(1)	(1)	(1)	5000
H-37	"	30'4"	7'3"	6'6"	7'3-1/2" (3)	5'2"	10'6"	13°	13°	10,000
HU-1A	"	3'9-1/2"	7'0"	4'8"	3'9-1/2"	4'0"				2500

(1) Not applicable.
(2) Ramp toe incline 15°.
(3) Straight in loading.
(4) Tapers from 9'4" at top to 12'1" at bottom.
(5) Tapers from 8'11" at top to 11'4" at bottom.

TABLE 30
CONTAINER SIZE LIMITS FOR C-54

DOUGLAS C-54

WIDTH OR HEIGHT (IN INCHES)

HEIGHT OR WIDTH (IN INCHES)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54
2	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
4		550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
6			550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
8				550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	540
10					550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	544	541
12						550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	538	533	530	521	517
14							550	550	550	550	550	550	550	550	550	550	550	550	550	550	544	533	521	514	503	493	486
16								550	550	550	550	550	542	539	536	533	531	525	523	520	508	498	487	480	471	462	456
18									550	550	550	537	528	518	510	505	500	491	483	480	470	463	453	447	439	429	420
20										550	536	521	509	498	489	482	476	467	461	455	445	434	432	417	408	396	389
22											510	502	488	478	469	462	456	449	441	435	424	412	400	391	380	369	356
24												485	470	460	450	442	435	428	419	411	401	389	377	366	354	343	331
26													457	445	434	423	415	403	394	387	377	366	357	346	334	321	310
28														427	413	400	389	375	365	358	349	342	332	322	311	301	294
30															392	383	370	357	346	335	328	321	312	303	294	286	278
32																367	355	344	333	320	311	303	294	287	279	272	266
34																	342	330	317	306	296	287	280	273	266	258	254
36																		316	305	292	283	275	268	262	256	249	244
38																			293	280	272	265	258	252	245	238	232
40																				270	263	255	248	242	235	228	221
42																					255	247	239	232	226	219	211
44																						239	230	223	216	209	202
46																							222	214	207	200	194
48																								206	199	190	184
50																									191	183	176
52																										176	169
54																											163
56																											
58																											
60																											
62																											
64																											
66																											

HEIGHT OR WIDTH (IN INCHES)	WIDTH OR HEIGHT (IN INCHES)						WIDTH ONLY (IN INCHES)																				
	56	58	60	62	64	66	68	70	72	74	76	78	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
2	550	550	550	550	550	550	407	276	249	233	230	200	190	192	186	182	178	173	168	163	160	155	150	146	141	137	133
4	550	550	550	550	550	550	368	247	225	211	200	190	181	177	173	169	165	162	158	154	150	147	143	140	137	133	130
6	548	547	547	546	543	540	395	234	212	198	188	179	171	167	164	161	157	154	151	148	145	142	139	136	133	130	127
8	543	540	538	530	522	516	348	222	201	188	176	170	162	159	157	154	151	148	145	143	140	137	135	132	129	127	124
10	533	527	521	508	495	488	335	218	198	178	168	160	154	151	148	145	143	140	138	136	133	131	129	127	125	123	121
12	505	499	492	478	464	454	318	202	184	172	163	156	150	148	145	143	141	139	136	134	132	130	128	126	124	122	120
14	476	470	462	448	431	421	290	195	178	167	160	153	147	145	142	140	137	135	133	132	130	128	126	124	122	120	119
16	445	438	431	416	391	383	264	186	171	164	155	148	144	141	139	137	135	133	131	129	128	126	124	123	121	119	118
18	413	405	387	378	358	348	244	180	164	157	151	146	141	139	137	136	133	131	129	128	126	125	123	121	120	118	117
20	378	368	357	332	303	295	233	169	157	151	147	142	138	136	135	133	131	129	128	126	125	123	122	120	119	117	116
22	348	330	315	302	278	265	215	162	154	146	141	137	134	132	130	129	127	126	125	123	122	121	120	118	117	116	115
24	327	304	290	275	261	254	200	156	147	141	137	133	130	128	127	126	124	123	122	121	120	119	118	117	116	115	114
26	299	286	273	260	248	238	190	150	143	138	134	130	127	126	125	123	122	121	120	119	118	117	116	115	114	113	112
28	283	271	261	247	237	225	181	147	141	136	132	128	126	124	123	122	121	120	119	118	117	116	115	114	113	112	111
30	269	259	250	243	227	215	176	144	140	135	131	127	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110
32	257	247	238	227	218	208	172	144	138	133	129	126	123	122	120	119	118	117	116	115	115	114	113	112	111	110	109
34	246	237	228	218	209	199	167	143	136	131	127	124	121	119	118	117	116	115	114	113	113	112	111	110	110	109	108
36	236	226	217	209	200	191	160	141	135	130	126	122	119	118	117	116	115	114	113	112	111	111	110	109	108	108	107
38	225	216	208	201	192	183	156	139	133	128	124	121	118	117	115	114	113	112	111	111	110	109	108	107	107	106	105
40	213	207	199	192	184	175	153	138	134	127	123	120	117	116	114	113	112	111	110	110	109	108	107	106	106	105	104
42	205	198	191	184	176	168	150	137	134	128	124	119	116	115	113	112	111	110	109	108	108	107	106	105	104	103	102
44	195	189	183	176	168	160	146	136	130	125	121	118	115	114	112	111	110	109	108	107	106	105	104	103	102	101	100
46	186	180	175	168	162	156	142	134	128	124	121	117	114	113	112	110	109	108	106	105	104	103	102	101	101	100	99
48	177	172	167	161	156	150	138	132	127	123	119	116	112	111	110	109	108	106	105	104	103	102	101	101	100	99	98
50	170	164	159	153	151	145	136	131	126	122	118	115	112	111	110	108	107	106	105	104	103	102	101	100	100	99	98
52	163	158	153	147	143	137	134	127	123	120	116	113	111	110	108	107	106	105	104	103	102	101	101	100	99		
54	158	152	147	141	138	133	130	125	121	118	116	114	108	108	107	106	105	104	103	103	102	101	100				
56	152	147	142	138	134	131	126	122	119	115	114	110	108	107	106	105	104	103	102	102	101	100					
58		148	138	134	129	127	122	119	116	113	110	108	106	106	105	104	103	103	102	101	100						
60			136	130	125	123	119	116	113	111	109	107	106	104	103	102	101	100	99	99							
62				126	121	119	115	112	109	107	105	103	104	100	99	98	97	96	98								
64					117	116	110	107	105	102	100	98	96	95	94	93											
66						111	108	105	103	100	98	96	94	93													

FIND LENGTH (IN INCHES) AT INTERSECTION OF HEIGHT AND WIDTH

(Courtesy: Air Corps)

TABLE 31
CONTAINER SIZE LIMITS FOR DC-6A AND DC-7BF

DOUGLAS DC-6A (ALL CARGO)
DOUGLAS DC-7B F (ALL CARGO)

Height or Width (in inches)

Width or Height (in inches)	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
3	623	623	623	623	623	623	623	623	620	612	590	570	547	521	499	473	446	430	412
6	623	623	623	623	623	623	623	620	605	593	581	562	521	501	476	449	431	410	393
9	623	623	623	623	623	623	623	610	595	579	556	523	494	477	453	430	417	394	382
12	602	641	600	575	560	545	530	511	504	496	472	458	432	417	404	387	372	363	354
15	550	536	519	506	490	489	475	460	445	430	440	403	392	380	369	356	349	341	330
18	484	477	463	452	444	436	424	414	406	390	384	373	361	349	341	330	321	312	302
21	430	421	414	409	401	395	385	376	367	358	350	339	328	321	313	304	290	289	282
24	398	390	385	379	368	363	359	348	339	330	326	322	319	308	299	291	284	279	271
27	365	358	350	347	341	336	324	322	315	307	298	287	281	278	272	269	266	263	259
30	336	330	328	324	319	311	304	300	294	286	279	271	264	260	257	254	251	247	245
33	310	311	307	301	298	292	287	282	278	271	263	255	248	244	239	235	231	227	224
36	290	286	284	282	280	276	272	267	263	256	249	243	235	231	228	224	219	216	213
39	274	271	269	267	264	260	256	251	248	242	237	230	224	219	215	211	205	201	198
42	259	256	254	252	250	247	243	238	235	230	225	219	214	210	206	199	196	193	189
45	247	244	242	240	238	235	231	226	223	218	213	208	204	201	197	193	189	185	181
48	236	232	230	228	226	223	218	214	211	208	204	199	196	192	188	185	181	177	175
51	222	220	218	216	214	210	207	203	200	195	191	188	184	180	177	174	172	170	168
54	210	208	206	205	202	198	195	193	191	188	185	181	179	173	171	168	165	163	162
57	198	196	194	192	190	187	185	183	182	178	175	173	171	167	164	162	159	157	155
60	189	186	184	182	180	178	176	174	173	171	170	169	168	163	160	158	155	153	149
63	181	179	177	175	173	175	168	166	165	163	160	158	156	154	151	149	146	144	142
66	174	171	169	167	165	164	162	160	159	156	154	152	151	148	146	144	142	140	138
69	169	166	163	161	160	159	156	154	152	150	148	147	146	144	141	139	137	136	136
72	163	161	158	156	153	151	150	148	146	145	143	142	141	139	137	136	134	132	130
75	157	155	152	150	147	145	144	142	140	139	138	137	135	134	132	130	128	126	
78	151	149	146	144	141	139	138	136	134	133	132	131	130	128	126	123	121	118	
81	146	143	140	138	135	133	131	130	129	128	127	126	125	122	120	116	115		
84	141	138	135	132	129	128	127	126	125	124	123	122	120	118	115				
Width only (in inches) 87	136	133	130	127	124	122	121	119	118	117	115	116	113						
90	132	128	125	122	121	120	118	117	116	115	112								
93	127	124	122	119	116	115	114	113	112	111									
96	124	121	119	116	114	113	112												
99	120	118	116	114	112														
102	117	115																	
103	115																		

Find Length (in inches) At intersection of Height and Width

(Courtesy: Air Cargo)

TABLE 32
CONTAINER SIZE LIMITS FOR DC-8

Height Inches	Width in Inches											
	3	6	9	12	15	18	21	24	27	30	33	36
	Maximum Length - Inches											
6	130	130	130	130	130	130	122	113	106	100	96	93
9	130	130	130	130	130	125	115	106	104	96	91	88
12	130	130	130	130	130	117	109	100	96	90	86	82
15	130	130	130	130	128	112	103	96	90	86	81	78
18	130	130	130	130	125	110	102	93	88	83	79	75
21	130	130	130	130	122	109	98	91	86	76	73	70
24	130	130	130	126	117	106	97	90	82	76	71	67
27	130	130	126	123	114	100	94	88	79	58	58	58
30	130	130	130	120	100	96	86	76	72	66	66	56
33	130	130	115	111	96	88	77	67	67	58	58	58
36	130	130	110	90	75	66	66	56	54	67	63	

(Courtesy: Air Cargo)

TABLE 33
CONTAINER SIZE LIMITS FOR SUPER CONSTELLATION

LOCKHEED SUPER CONSTELLATION

(All Cargo)

Height (in inches)

Width (in inches)	54	60	66	72	
3	A792	792	696	492	
	840	840	696	480	414
6	A792	792	624	456	
	840	792	624	462	372
9	A792	696	540	396	
	840	702	534	402	306
12	A756	624	492	360	
	762	624	495	366	297
18	A576	492	396	300	
	576	490	396	293	264
24	A480	396	312	240	
	480	402	318	246	228
30	A384	324	264	216	
	390	327	270	216	190
36	A324	276	228	180	
	324	276	231	189	162
48	A240	204	168	144	
	240	210	176	144	132
60	A180	156	132	108	
	186	165	138	110	108
72	A132	120	100		
	141	131	110		
84	117				

Find length (in inches) at intersection of height and width.

A - Applicable only to EA.

LOCKHEED CONSTELLATION SPEEDPAK

First dimension (in inches)

Second dimension (in inches)	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	50
6	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
8	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
10	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
12	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
14	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
16	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
18	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
20	300	300	300	300	300	300	300	290	290	290	290	290	290	290	290	290	290	290	290
22	300	300	300	300	300	300	[illegible]	290	260	260	260	260	260	260	260	260	260	260	260
24	300	300	300	300	300	300	270	290	260	196	196	196	196	196	196	196	196	196	196
26	300	300	300	300	300	300	[illegible]	290	260	167	167	167	167	167	167	167	167	167	167
28	300	300	300	300	300	300	270	290	260	196	167	166	166	166	166	166	166	166	166
30	300	300	300	300	300	300	280	290	260	196	167	166	133	133	133	133	133	133	133

Find third dimension (in inches) at intersection of first and second dimensions.

(Courtesy: Air Cargo)

TABLE 34
CONTAINER SIZE LIMITS FOR 707

BOEING 707

First Dimension (in inches)

Second Dimension (in inches)		4	8	12	16	20	24	28	32	36	40	44	48
69	C	81											
68	A	108											
	A	126											
67	C	87											
65	C	94	81										
64	A	140	106										
63	C	102	89										
62	A	152	125										
61	C	110	97	81									
60	A	162	139	101									
59	C	120	106	90									
58	A	171	150	118									
56	A	181	160	130									
	C	133	118	104									
54	A	190	170	141	98								
53	C	146	131	118	95								
52	A	199	180	151	118								
50	A	200	188	160	130								
	D	175	152	138	135	118	97	88	82	54			
	C	159	144	132	117								
48	D	180	161	140	138	128	110	100	91	78	68	52	
47	A	221	201	174	147	121	106	94	84	63	53	---	---
	B	127	120	114	103	95	87	78	70	63	53	---	---
	C	171	156	144	132	118	107	100	70	62	52	---	---
44	A	232	214	186	161	137	123	113	105	96	85	65	---
	B	133	126	118	118	102	95	88	85	82	80	65	---
	C	182	167	156	144	130	119	110	82	80	80	64	---
	D	187	175	156	144	135	130	120	108	96	86	73	52
41	C	193	177	165	153	141	130	118	105	98	81	---	---
40	A	243	229	202	178	156	140	126	114	106	95	85	---
	B	149	141	134	133	130	124	116	109	102	95	85	---
	D	197	185	170	156	144	140	132	120	106	97	86	68
38	C	203	186	173	161	150	138	126	114	107	100	91	55
36	A	250	241	218	195	173	156	138	125	113	106	96	74
	B	169	160	162	153	145	136	128	120	113	106	96	74
	C	209	191	178	165	155	143	131	119	112	105	96	73
	D	209	192	182	166	155	146	141	131	117	106	96	78
33	C	218	200	185	171	160	148	137	126	120	112	103	84
32	A	255	250	233	210	187	168	149	135	125	114	105	87
	B	190	194	182	170	160	148	139	130	122	114	105	87
	D	221	202	192	172	162	150	148	140	131	120	108	91
30	C	226	207	191	177	165	153	142	132	126	118	109	92
28	A	259	257	243	225	200	179	159	149	138	124	113	96
	B	222	215	200	186	174	160	149	139	130	122	113	96
	D	232	211	198	188	167	155	150	148	141	132	120	108
27	C	234	214	197	182	169	157	146	137	131	123	114	98
24	A	263	261	254	238	212	189	179	164	156	140	123	103
	B	242	236	219	202	187	172	158	147	137	128	119	103
	C	241	220	202	187	173	160	149	141	135	128	119	103
	D	241	220	202	187	173	160	155	150	146	140	130	110
21	C	248	225	207	191	176	163	153	143	138	131	123	105
20	A	266	263	261	249	222	212	200	187	173	156	137	109
	B	261	257	238	218	200	183	167	153	143	133	125	109
	D	250	228	208	192	177	173	167	162	155	144	139	129
18	C	253	231	211	196	179	166	155	147	141	135	126	115
16	A	271	268	266	258	249	238	225	210	195	178	161	142
	B	269	268	256	233	213	193	175	159	148	138	129	116
	D	259	235	219	197	192	187	188	173	166	156	144	138
15	C	259	236	215	198	182	169	158	149	143	137	129	115
12	A	273	271	269	266	261	254	243	233	218	202	186	169
	B	272	270	269	248	224	202	181	164	152	141	132	118
	C	264	241	219	182	185	174	160	151	145	139	131	18
	D	264	241	219	214	208	202	198	192	182	178	156	148
9	C	260	246	223	205	188	176	163	153	147	140	132	120
8	A	274	272	271	268	265	261	257	250	241	229	214	197
	B	274	272	271	263	233	209	187	169	155	144	134	121
	D	270	267	241	235	228	220	211	202	192	185	172	161
6	C	272	250	227	208	191	177	165	155	148	141	133	122
4	A	276	274	273	271	266	261	256	255	250	243	232	216
	B	275	274	272	270	260	216	190	172	150	146	135	123
	D	274	270	264	259	250	241	232	221	205	197	187	180
3	C	275	254	238	211	194	178	167	157	149	142	134	123

A, B - TWA, PAA

C - AAL

D - CAL, BNF, WAL

A- Use when package weighs less than 50 kilos and may be turned on side for loading.

B - Use when package weighs 50 kilos or more or when it cannot be turned on side for loading.

Find Third Dimension (in inches) At Intersection Of First and Second Dimensions.

Courtesy: Air Cargo

graphs for Air Force aircraft are illustrated in Figures 200 and 201, along with Table 35 of Army aircraft payloads.

TABLE 35

PAYLOAD (*) DATA FOR SOME TYPES OF ARMY AIRCRAFT
(Extracted from AR 705-35)

Airplane	Type	100 Nautical Mile Range Mission (lbs.)	100 Nautical Mile Radius Mission (lbs.)	350 Nautical Mile Range Mission(lbs.)
U-1A	Fixed Wing	2580	2450	2250
YAC-1	Fixed Wing	6100	5300	5200
H-21	Helicopter	3000	2450	
H-34	Helicopter	3100	2500	
H-37	Helicopter	5600	4000	
HU-1A	Helicopter	800	650	

(*) Loads are internal cargo loads

These figures, along with dimensional and ramp loading criteria, are guides in the development of missile containers. Where additional information is required, then the appropriate Air Force technical order or Army technical manual of the aircraft in question should be consulted.

When external transport by helicopter is proposed, the container suspension provisions must be such as to allow the sling web to be inclined at an angle 45° from the vertical toward the center of gravity of the suspended container without damaging the container when a force equal to its own weight is exerted on any or all of the sling webs.

Table 36 gives the restraint criteria for air transportation for Army and Air Force aircraft. These restraint factors are ultimate values and the minimum acceptable factors for crew and passenger safety.

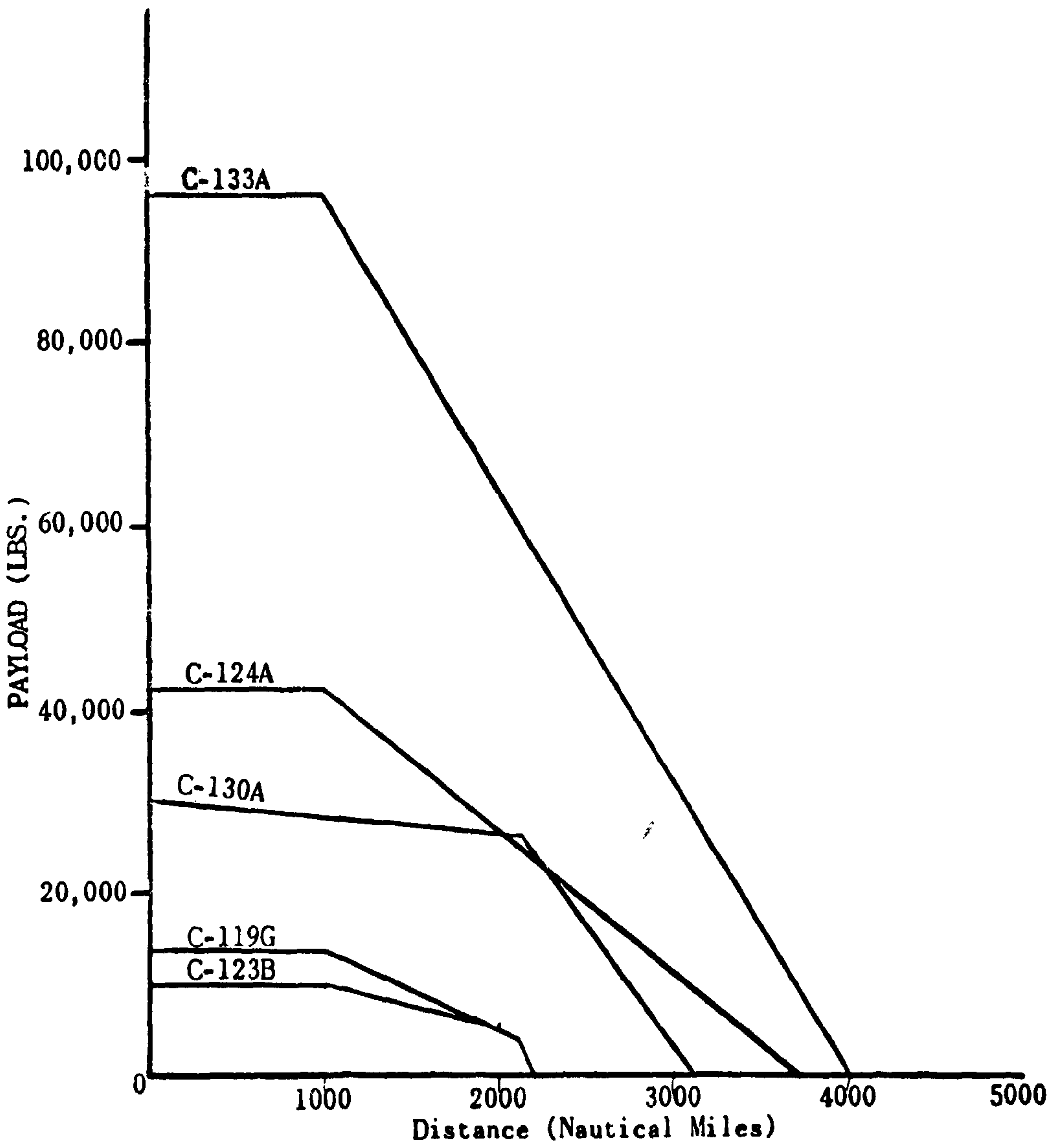


FIGURE 200. NORMAL STRATEGIC AIRLIFT MISSIONS. REFUELING AVAILABLE AT DESTINATION (AR 705-35)

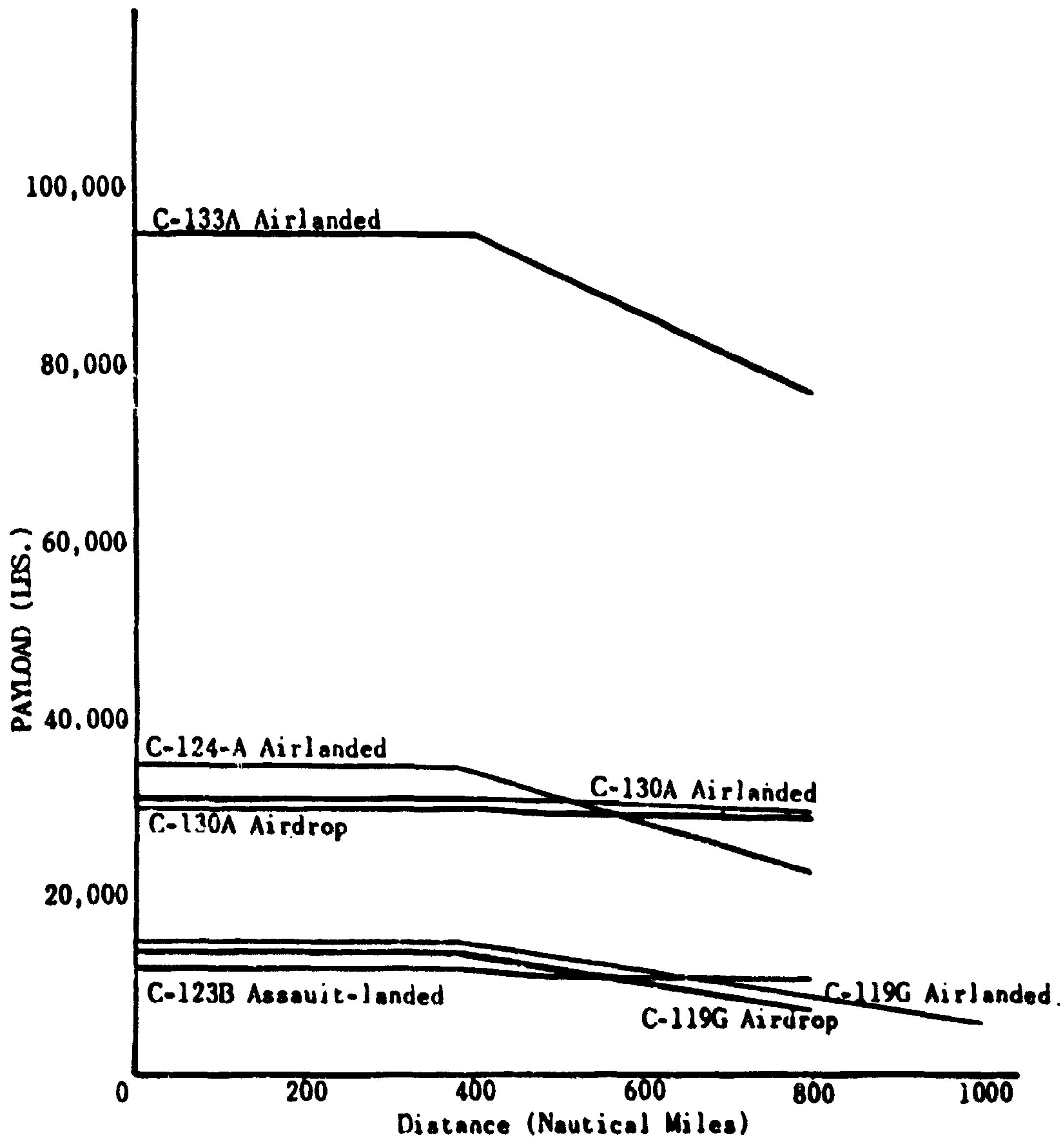


FIGURE 201. NORMAL TACTICAL RADII MISSIONS - CARGO AIRDROPPED OR LANDED. NO AIRHEAD REFUELING (AR 705-35)

TABLE 36

RESTRAINT CRITERIA

(Extracted from AR 705-35)

Type of Aircraft	U-IA & YAC-I	Helicopters	Airforce (1)	Aircraft (2)
Forward	4.5 G's	4.0 G's	8.0 G's	3.0 G's
Aft	1.5 G's	2.0 G's	1.5 G's	1.5 G's
Vertical (up)	3.0 G's	2.0 G's	2.0 G's	2.0 G's
Side	1.5 G's	1.5 G's	1.5 G's	1.5 G's

(1) This figure is used for airplanes or cargo compartments that are arranged or located such that the crew or passengers present in crew quarters or the cargo compartment will not be endangered by forward movement of the cargo.

(2) This figure is used for airplanes or cargo compartments that are arranged or located such that crew or passengers will not be endangered by forward movement of the cargo.

Air Drop

Containers intended for air delivery must be designed to meet the limitations imposed by the air delivery systems as well as the aircraft employed.

The standard air delivery system consists of wheeled conveyors installed on the cargo floor of the aircraft with buffer boards secured to the sides of the aircraft. In order to facilitate rigging procedures of the container, to be air dropped, a number of air delivery platforms of various sizes have been developed. These platforms consist of three sizes of unstressed platforms - 11, 15, and 22 feet in length and one stressed platform 12 feet in length. Containers utilizing the unstressed platforms must be provided with a minimum of four suspension fittings for parachute delivery. Each fitting should be designed to withstand a parachute opening force of not less than 2.25 G's ultimate applied in any direction above the horizontal plane. Where hoisting is a requirement for other types of transportation, these fittings must also be compatible with hoisting equipment. A single fitting should also be provided on each end of the container as close to the vertical and lateral location of the center of gravity as possible, for attachment of the parachute extraction line. The minimum strength of this fitting should be sufficient to support an ultimate force of three times the filled container weight. Containers using the stressed platform will not require suspension fittings for parachute delivery as these are an integral part of the platform.

Deceleration and shock absorbing devices are usually placed between the platform and the container to aid in the cushioning of the container when it lands. These devices should be designed for a maximum descent rate of 25 feet per second.

Containers rigged on air delivery platforms must allow a 5-inch lateral clearance and a 6-inch vertical clearance with the aircraft during loading and extraction. The container, when in contact with the platform, must be no wider than the distance between the outer tie-down rings on the platform. For critical characteristics of standard platforms, see Table 37. To air drop a 3,500 pound load, it will require approximately 700 pounds of air delivery equipment; a 7,000 pound load requires 900 pounds of equipment; and a 16,000 pound load requires 3,000 pounds of equipment.

TABLE 37

CRITICAL CHARACTERISTICS OF STANDARD PLATFORMS

(Extracted from AR 705-35)

Size	Width		Load Capacity			Tie-downs		
	Overall	Usable	Minimum	Design	Overload	Each side	Each end	Total
12 foot stressed	80"	70"	2,500	6,000	10,000	5	3	16
11 foot unstressed	80"	70"	**	*	**	1	4	10
15 foot unstressed	80"	70"	**	*	**	4	4	16
22 foot unstressed	100"	90"	**	**	**	6	4	20

* Strength rating of tie-down fittings is 5,000 pounds.

** Not applicable because materiel is item suspended. Governing factors are the overall length and width of the item with a maximum weight of approximately 16,000 pounds for the 22 foot platform.

Containers to be air dropped and containers utilizing the air delivery system must be secured to the floor of the aircraft in accordance with the restraint criteria of Table 38, until just prior to air drop.

TABLE 38

RESTRAINT CRITERIA FOR AIR DROPPED AND AIR DELIVERED CONTAINERS

(Extracted from AR 705-35)

Forward	4 G's
Sideward	1.5 G's
Vertical (up)	2.0 G's
Aft	1.5 G's

If specific air delivery problems should arise, or if parachute drops are required on developmental containers prior to release for user test, then the Mobility Equipment Command should be contacted.

Combination of Carriers

To promote maximum efficiency of distribution, a combination of the different modes of transportation will usually be required. In order for the container to be compatible with each mode selected, the most restrictive limitations of the combination of modes should be considered in the container design. One of the latest methods of solving the problem of efficient distribution is the use of the Roll-on/Roll-off System, by which military supplies are carried in semitrailers from depots to an ocean terminal, rolled onto a specially designed vessel, transported to another ocean terminal, rolled off and on to their destination. Since semitrailers of American industry were too large to easily maneuver in these ships, the U.S. Army semitrailer is used. The critical dimensions of the U.S. Army semitrailers used in the Roll-on/Roll-off technique are given in Table 39.

With new developments, Trailer-On-Flat Car (TOFC) has now become a safe and efficient means of transportation for missile systems. The TOFC mechanical type rail cars used for this type of transportation are available nationwide and are readily obtainable. Presently, TOFC equipment can handle trailer lading weights up to 40,000 pounds and can carry one or more trailers depending on the length of the flat car and trailers used. However, the highway limitations and minimum railroad clearances shown in Table 26 and Figure 198, should still be adhered to in order to permit efficient movement.

TABLE 39

EQUIPMENT DIMENSIONS OF THE U.S. ARMY SEMITRAILERS USED IN THE ROLL-ON/ROLL-OFF TECHNIQUE (EXTRACTED FROM THE U.S. ARMY TRANSPORTATION TRAILER SERVICE AGENCY)

Item	Van Model 220 KAK (l x h x w)	Van Model SKD 3809 (l x h x w)	Stake and Platform Model M127A1 and C1 (l x h x w)
Outside Dimensions	27' x 11' x 8'	26'5" x 11'6" x 8'	28'8" x 9' x 8'
Inside Dimensions	26' x 6'5" x 7'5"	25'10" x 6'8" x 7'6"	27'11" x 4' x 7'5"
Over-all Height (Top of rack)	11'	11'6"	9' (may be loaded higher)
Gross Cubic	2376 cubic feet 59.4 MTON	2430 cubic feet 60.8 MTON	2087 cubic feet 51.6 MTON
Capacity Weight STON	18	12	18
Capacity Cube MTON	31.1	32.3	20.7
6" above top			23.3
Tare Weight	10,500 pounds	8700 pounds	14,200 pounds

STON - Short ton; one short ton equals 2000 pounds.

MTON - Measured ton; one measured ton equals 40 cubic feet.

CHAPTER XV

CORROSION AND DETERIORATION

Corrosion abatement is one of the most important considerations of a new design. Corrosion is closely related to environment, particularly temperature, humidity, and the presence of chemicals. The destructive effects of moisture, chemical action, electrochemical action, and low temperatures and their prevention should be thoroughly investigated.

DETERIORATION OF METAL

Moisture

Moisture, in the form of water or water vapor, accounts for the majority of corroded equipment. This type of corrosion can be classified into three categories: 1. Catch basins or sump areas, 2. Condensation, and 3. Desiccant pumps.

1. Sump Areas

These are areas that are normally exposed to the weather and are designed in such a manner as to allow the accumulation of moisture. This condition is found mainly around the container bases and supports. These conditions may be relieved by avoiding angles, channels, pockets, etc., where moisture can accumulate (see Figures 202 and 203). When this is unavoidable, drain holes should be provided.

In cases where inclosed containers do not lend themselves to drilled holes, the use of desiccants should be employed.

2. Condensation

Moisture will appear inside of any closed container that experiences temperature changes in relation to the air surrounding it. As was previously mentioned, the amount of moisture may be minimized through the use of desiccants, dehumidification, venting, or drain holes. Drain holes should be located at the lowest possible point.

3. Desiccant Pumps

A desiccant pump is desiccant material that has become saturated with moisture to a point where it can no longer remove moisture from the air. On a day of low relative humidity, the desiccant material is actually a source of moisture. Desiccants should therefore be periodically checked and rejuvenated or replaced if necessary.

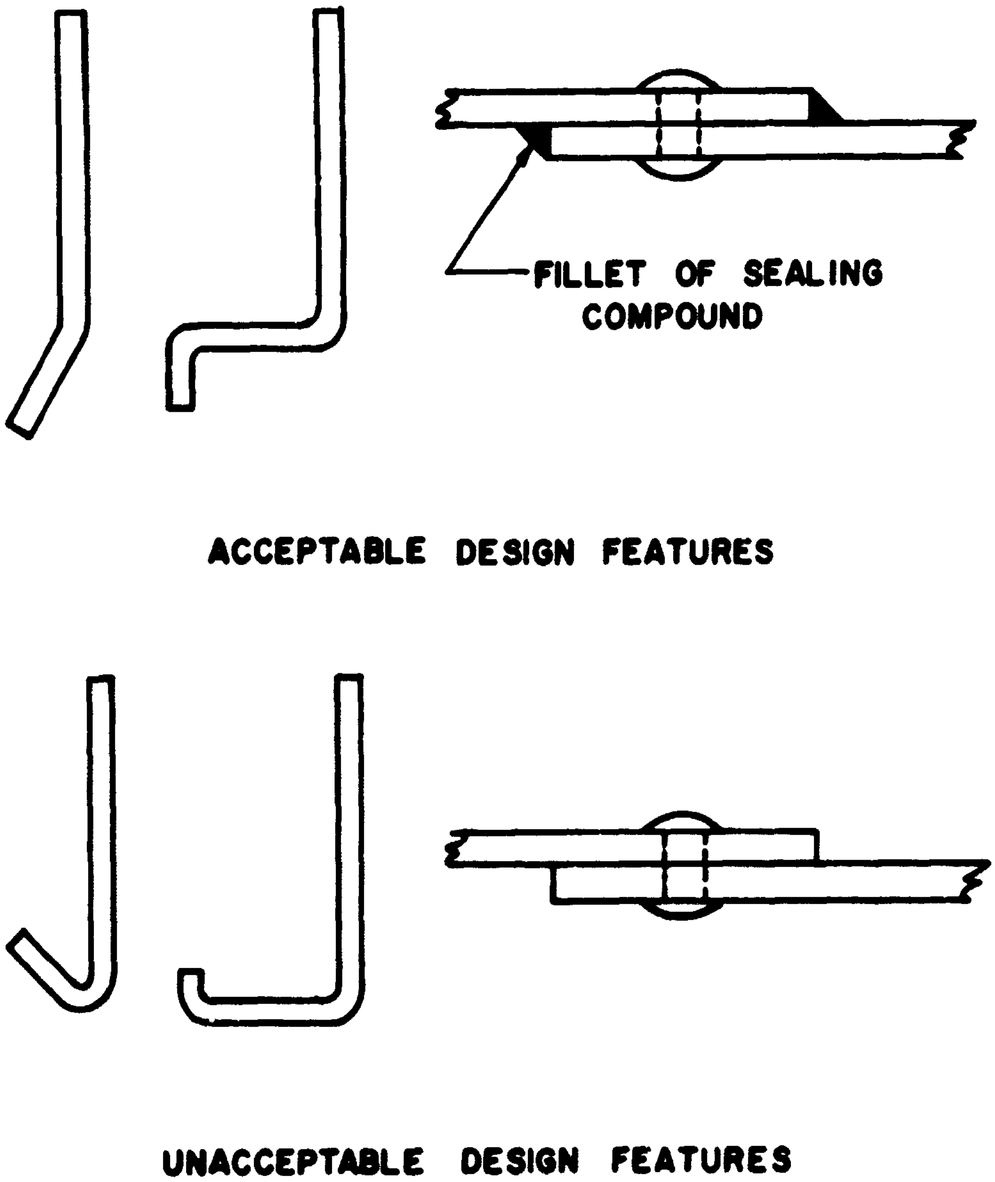


FIGURE 202. DESIGN FEATURES FOR CORROSION PREVENTION

FIGURE 203. WATER POCKETS DUE TO INADEQUATE DRAINAGE PROVISIONS

Galvanic Corrosion

With the increasing availability of new materials and alloys, it is most important that designers consider the problems of galvanic (or electrochemical) corrosion in selecting materials.

Galvanic corrosion is defined as an electrochemical action between two dissimilar metals, in the presence of an electrolyte, which results in the flow of current. The rate of current flow depends on the potential difference which, in turn, is dependent on the relative dissimilarity of the metals. Table 40 lists the electrochemical series along with the relative electromotive potential of the various metals.

Galvanic action results in the progressive corrosion of the more positive of the two metals, with the action continuing as long as an electrolyte is present.

In order to minimize corrosion due to electrochemical action, dissimilar metals should not be used together. When this is impracticable, the following rules should be followed:

a. Design the anodic member as large as possible.

b. Plate both anodic and cathodic members with identical material.

c. Cadmium plate threaded fasteners and other hardware.

d. Seal threaded inserts with zinc-chromate primer prior to insertion in castings.

e. Do not use dry-film lubricants which are not certified to be graphite-free.

f. When possible, avoid the use of lock washers over plated or anodized surfaces.

TABLE 40

ELECTROMOTIVE FORCE SERIES

Metal	Potential Volts
	Anodic (Positive) End
Lithium	-2.959
Rubidium	-2.925
Potassium	-2.924
Calcium	-2.76
Sodium	-2.714
Magnesium	-1.8
Aluminum	-1.337
Zinc	-0.761
Chromium	-0.557
Iron (ferrous)	-0.44
Cadmium	-0.401
Cobalt	-0.23
Nickel	-0.20
Tin	-0.136
Lead -	-0.122
Hydrogen -	-0.00
Copper +	+0.344
Silver	+0.797
Platinum	+0.86
Graphite	- - -
Gold	+1.36
	Cathodic (Negative) End

Chemicals

Corrosion of metals by reaction with chemical substances in the environment occurs under a variety of circumstances. Most chemical attacks depend on moisture to be effective.

Salt is particularly high in corrosive chemicals. Free acids and alkalies are encountered in airborne contaminants and in large concentrations in soil and natural waters.

Salts that are in the soil and water are the most widely distributed and troublesome of the corrosive chemicals. The natural salts causing the most trouble are the chlorides, nitrates, sulfates, phosphates, and carbonates.

When salts are in solution or in a moist environment, they hydrolize, forming acids and bases. What effect salts will have upon a metal depends on the chemical and electrochemical relationship between them. Iron and steels are primarily affected by sodium chloride salt spray. Aluminum is relatively immune to sodium chloride spray, but is readily attacked by the salts of strong bases and weak acids such as sodium, potassium and amonium salts of acetic, oxalic, and tartaric acids.

Acids and alkalies are rarely encountered in natural environments with the exception of the high acid concentration found in airborne contaminants. The worst offenders of this category are found in industrial gases in the form of sulfurous acid and carbonic acid. These acids are formed from sulfur dioxide and carbon dioxide in the presence of water.

Carbonic acid is classified as a fairly weak acid, resulting in minimal deterioration. Sulfurous acid, on the other hand, is a very strong acid which may be oxidized under suitable conditions to form the more powerful sulfuric acid.

Both of these acids are extremely corrosive towards iron, steel, copper and zinc compounds and, to some extent, aluminum. Hydrogen sulfide is another sulfur compound frequently found in industrial gases and, in the presence of moisture, presents a corrosive effect. This effect, however, is limited primarily to steel.

Temperature

It is a well known fact that as the temperature decreases, metals become more brittle. This change in the property of metals makes them more susceptible to failure in areas of high stress concentration. Some of these transition temperatures occur at relatively high temperatures, i.e., steels that are not thoroughly deoxidized will have their transition temperature at around 32 degrees F.

Although this phenomenon cannot be prevented, the designer should be aware of this property of metals and design accordingly. Some methods of overcoming this may be to add a sufficient safety factor or recommend that certain metals or certain manufacturing processes not be utilized for cold temperature use.

Filiform Corrosion

Filiform corrosion is a galvanic corrosion occurring under painted surfaces. Its form is a radial "worm-like" corrosion path emanating from central core of corrosion.

It occurs under paint, plating, or gaskets, due to the permiability of these coatings to moisture. The humidity level determines the degree of corrosion, and the temperature determines the rate and path of corrosion. Filiform corrosion will only occur between 78% and 85% relative humidity.

Lacquers and " quick-dry " paint are most susceptible to damage. A heavy, phosphate (Parkerized) coating eliminates filiform corrosion. Epoxy coatings with excellent adhesion and low water transmission are also good.

Hydrogen Embrittlement

Plated, high-carbon materials absorb hydrogen in grain boundaries, causing embrittlement of the part. The higher the stress in a part, the more susceptible it is to embrittlement failure.

It is recommended that the part be stress-relieved (25° to 50° below the draw temperature) prior to plating.

Hydrogen embrittlement occurs in welded assemblies, and in springs where it is recommended that they be stress-relieved right after coiling operation. A 450°F oven is recommended.

Finishes

The life of metals can be increased through the use of corrosion-resistant coatings of metal, paint, and plastic, and by surface treatment of the metal with semipermanent corrosion preventive materials.

1. Metal Coatings

Steel is usually protected against corrosion by a corrosion-resistant metal coating. Cadmium, zinc, nickel, chromium, tin, and lead are the metals most frequently used for this purpose. All of these metals can be electroplated onto steel while zinc, tin, and lead can also be applied by hot-dip.

Aluminum uses two major finishes, namely: a. electrochemical conversion (MIL-A-8625), and b. chemical conversion (MIL-C-5541), oxide coatings.

a. Electrochemical Conversion

The electrochemical conversion finishes can be classified into three different processes: (1) sulfuric acid anodize, (2) chromic acid anodize, and (3) aluminum oxide hardcoats.

(1). Sulfuric Acid Anodize.

This is the most economical process in anodizing aluminum. The coating varies from a clear, transparent film to one that is opaque or translucent. All welding and fabrication should be accomplished prior to anodizing, and caution should be exercised to insure that all the sulfuric acid electrolyte is bled from the pores, joints, and recesses. Where trapped electrolyte could be a problem, chromic acid anodizing is recommended. Dimensional changes are in the order of .0002 inches. The main advantages of sulfuric acid anodize are:

a. Provides good corrosion resistance and paint base qualities.

b. Good abrasion resistance.

c. Excellent heat resistance.

d. Good dielectric strength.

e. Better absorption qualities than other processes.

f. Lower voltages required than in other processes.

The disadvantages of this process are:

a. Should not be used where electrolyte may become entrapped in pores, joints, or recesses.

b. Welds become conspicuous.

(2). Chromic Acid Anodize:

The coatings produced from this process are opaque and grey in color. This process should be used on porous castings and aluminum assemblies with joints or recesses where the electrolyte may become entrapped. The advantages of this process are:

a. Good corrosion resistance properties.

b. Excellent heat resistance.

c. Good dielectric strength. This can be improved by saturating the coating with oil, grease, wax or other appropriate materials.

The main disadvantage of chromic acid anodize is:

Cannot be used on aluminum alloys of more than 5% copper or a total alloy of more than 7.5%.

(3). Aluminum Oxide Hardcoat Processes

This process forms an oxide coating of various shades of grey or black. Coating thicknesses range from .002 inches to .005 inches of which approximately one-half of the thickness is build-up, the remainder being penetration. Corners must maintain a generous radius or an easily damaged corner will be formed as shown in Figure 204a. The major advantages of this process are:

a. Excellent wear and abrasive resistance.

b. Excellent insulating properties.

c. Can be used to eliminate dissimilar metal inserts in aluminum where a hard wearing surface is required.

The disadvantages of aluminum oxide hardcoat processes are:

a. Dimensional build is heavy and must be considered during design.

b. Coatings are too hard to be machined and must be ground when close tolerances are required.

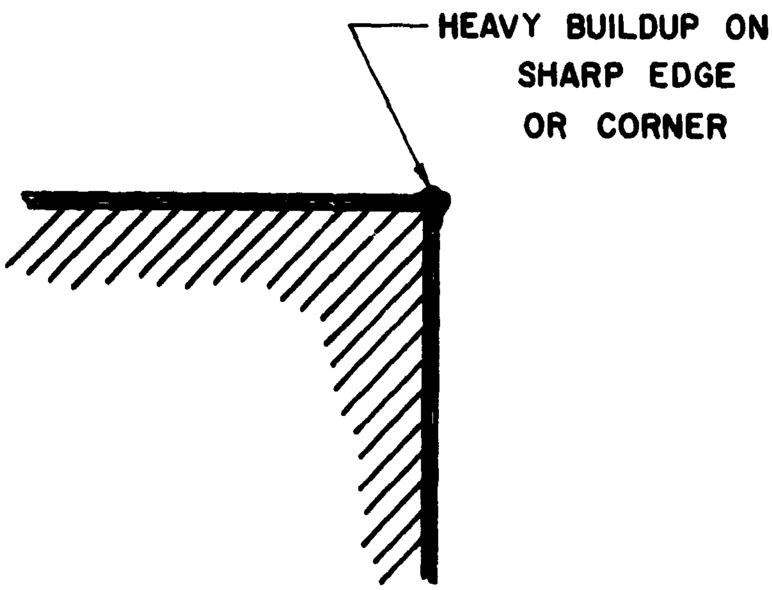
c. This process cannot be applied when aluminum alloys contain more than 5% copper or 7% silicon.

d. The fatigue strength of some alloys is lowered considerably.

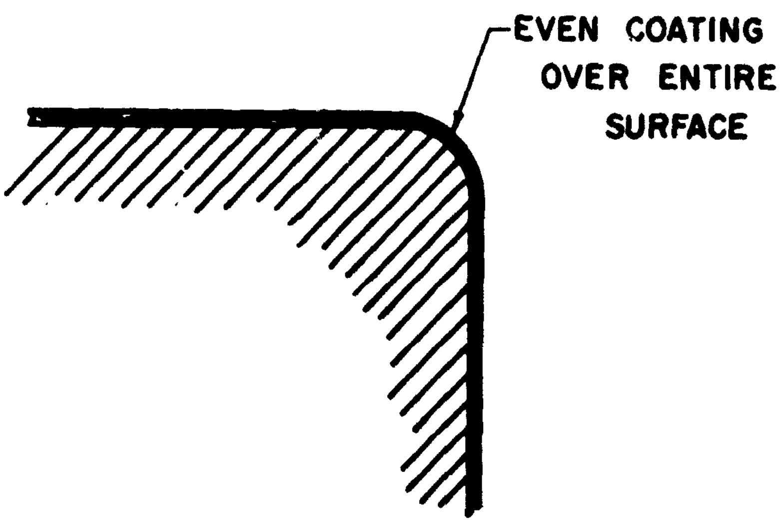
e. Coatings will not form around sharp corners.

b. Chemical Conversion

The chemical conversion group of oxide coatings form an oxide film on the material which is thinner, softer and more porous than those formed by anodizing. This process may be used as a paint base under most conditions, but exhibits low abrasion resistance and little corrosion resistance when exposed directly to the atmosphere. Chemical conversion coatings have low bond strength to the base material and, therefore, cannot be used for adhesive bonding with epoxy paints. Chemical conversion coatings are nonconductive.



(a) Plated Part with Sharp Edge



(b) Plated Part with Rounded Edge

FIGURE 204. DESIGN FOR PREVENTING DAMAGED CORNERS

2. Paint

Paint prevents corrosion by protecting a metal surface from moisture. There are also corrosion-inhibiting primers which can be applied to a metal surface prior to painting. These primers are primarily intended for metals used where more severe environmental conditions, such as salt spray and other chemical-laden fluids are present. These primers usually consist of a liquid vehicle or binder and a corrosion-inhibiting pigment such as red lead or zinc yellow. The lighter zinc pigments should be used where weight is a factor.

3. Plastic Coatings

Protective plastic coatings consist of solutions or dispersions of film-forming plastics in organic solvents. These coatings are satisfactory for continuous contact with mild corrosives such as fresh and salt water, some solvents, and some alkalies. Plastic materials, employed as protective coatings, are of two basic types. These are thermoplastic and thermosetting coatings.

The thermoplastic coatings most widely used are polyethylene, styrene copolymers, vinyl resins and saran. Several of the thermosetting types of plastics, being used for corrosion-resistant coatings, are polyesters blended with styrenes, urea-melamine, phenolic, and epoxy.

VCI (Vapor Corrosion Inhibiter)

VCI is a vaporizing type of chemical inhibitor used for corrosion control in closed areas. The inhibitor (dicyclohexylamine nitrite) is available both as a treated paper, MIL-P-3420B, or as two viscosity oils, SAE 10 and 30 (Spec. MIL-L-46002). SAE 10 oil is for rapid, short-lived protection, and SAE 30 oil is for slower but longer-lived protection. Their application in a sealed volume is necessary in order for the vapors to be effective as a preservative.

VCI is intended primarily for corrosion protection of steel; however, it is usable with cadmium, magnesium or zinc, if the proper grade is used for these materials. When the oil is used, it is so prepared that it has no harmful effects on cadmium, zinc, magnesium, or aluminum.

The compound VCI is unstable at temperatures higher than 150°F, or in atmospheres of high humidity. For details on the use of VCI, consult TM 38-230 "Preservation, Packaging, and Packing of Military Supplies and Equipment."

DETERIORATION OF WOOD

Wood is susceptible to deterioration from the effects of climate, physical forces, chemical agents, microorganisms, and insects.

Microorganisms

The growth of most microorganisms occurs most rapidly during warm, humid weather. Wood, in contact with the ground, is especially susceptible to fungi and molds. Most of these organisms cause decay with a resulting decrease in strength, while others attack plywood glues. Protection against microorganisms in wood can be obtained by the use of wood preservatives. Some of the preservatives are poisonous to the attacking organisms and some act only as repellants. Others form a physical barrier that prevents the organisms from entering the wood.

Wood preservatives may have either an oil base or a water base. Oil-based preservatives will not be washed away or leached out by water, and they make the wood moisture-repellant. Water-based preservatives are cheaper than oil-based preservatives, which is their primary advantage.

Items being shipped to areas where optimal conditions for decay are prevalent should use decay-resistant woods or some type of decay-treated woods. Table 41 lists the decay resistance of some woods.

Insects

Wood is subject to attack by insects even when it is supported above the ground and kept dry. Damage to wood in contact with the ground is primarily due to termites and powder-post beetles, while damage to wood supported above the ground is due primarily to powder-post beetles and dry wood termites.

The wood preservatives used to protect against microorganisms are also effective in combating insect infestation. The surface of the wood should be coated with a thin film to prevent the depositing of eggs in the wood pores.

Physical Agents

Wood is also susceptible to deterioration from such physical agents as abrasion, weathering, and high temperatures. Abrasion usually occurs during shipment and handling, and a hard, abrasion-resistant wood should be used for this purpose. Reinforcing in the areas where excessive wear occurs should also be used if possible.

Unfinished wood exposed to alternate periods of rainfall and hot, dry weather produces cracks, splits and general erosion of wood and, eventually a severe loss of strength. High temperatures also cause loss of strength with the rate of loss increasing with temperature.

Figure 205 shows the effect of weathering on two different types of plywood. The type on the left is an exterior plywood and shows no effect from weathering. The plywood on the right is an interior type of plywood and, as can be seen, the laminations have started to warp and separate.

TABLE 41

HEARTWOOD DECAY RESISTANCE OF SOME WOODS COMMON IN THE UNITED STATES

Good	Fair	Poor
Baldcypress	Douglas fir	Ashes[2]
Catalpas	Honey-locust[2]	Aspens
Cedars	Larch, western	Basswood
Chestnut	Oak, chestnut	Beech[2]
Junipers	Oak, white	Birches[2]
Locust, black	Pine, eastern white	Cottonwood
Mesquite	Pine, southern yellow	Firs (true)
Mulberry, red	Sassafras	Hemlocks[2]
Osage-orange		Maple, sugar[2]
Redwood		Oak, northern red[2]
Walnut, black		Spruces[2]
Yew, Pacific		Willows

(1) The species in each group are listed alphabetically, it being impractical to list them in order of relative decay resistance.

(2) These species may rate nearly as high in decay resistance as some of those in the next better group.

FIGURE 205. EFFECT OF WEATHERING ON PLYWOOD (EXTERIOR TYPE ON LEFT. INTERIOR TYPE ON RIGHT)

Chemicals

Chemicals can readily destroy or weaken wood and wood products. Some woods are resistant to certain chemicals and should therefore be used where contact with these chemicals is contemplated.

DETERIORATION OF PAPER.

Paper products usually consist of wood derivatives and, therefore, are subject to many of the deteriorating agents affecting wood.

Microorganisms

Microorganisms are also a serious threat to paper, paperboard, and fiberboard. Mildew, bacteria, and fungi are the chief offenders. Treatment of these products with fungicides and mold-inhibiting solutions is the accepted preventive measure.

Moisture

One of the ways moisture can cause deterioration of paper is by dissolving or softening the gelatinous binder used to hold the fiber together. This causes the paper to lose its structural strength and eventually fall to shreds. Where moisture is expected to be a problem, wet-strength papers should be specified.

Moisture also makes paper inhabitable for the growth of microorganisms which cause decay.

Insects

Some insects use paper as a food, thereby causing structural damage. Termites consume paper for its prime structural component, cellulose, whereas silverfish destroy paper by eating the starchy material, such as glue and sizing. Cockroaches feed on many materials, eating bindings and paper. Termites and cockroaches will attack sheet paper, pasteboard, composition board, fiberboard, labels, paper boxes, insulating paper and tar paper. The time required for insects to penetrate various paper products is given in Table 42.

An effective means of controlling insects is to incorporate insecticides in the material and to spray around storage areas. Tables 43 and 44 give some insecticides used for this purpose.

Rodents

Rodents damage paper products in their gnawing for food. Since these paper particles are not swallowed, toxic agents are useless. The only really effective preventive is to set out poisoned bait. The most effective poisons are warfarin and sodium fluoracetate. Other poisons such as thallium sulfate, red squill, ANTU and zinc phosphide have been used but are not as effective.

TABLE 42

TIME REQUIRED BY CERTAIN INSECTS TO PENETRATE VARIOUS PAPERS AND OTHER BAG MATERIALS

Material	Common Dampwood Termites	Nevada Dampwood Termites
Toweling	3-1/2 hours	3 hours
Asphalt bagging	7 days	8 days
Cellophane No. 300	4 days	5 days
50-lb kraft paper	1 day	1 day
50-lb kraft paper plus 50% sodium silicate solution	5 days	6 days
3/0 flint sandpaper	more than 35 days	more than 35 days
3/0 flint sandpaper, smooth side up	14 days	14 days
Cellophane No. 300 on 0.0006-in. lead foil	more than 35 days	more than 35 days
No. 30 sulfite paper on 0.00035-in. lead foil	10 days	10 days
0.00035-in. lead foil on No. 30 sulfite paper	more than 35 days	more than 35 days

Note:
Thickness, 0.00088 inches.

TABLE 43
INSECTICIDES

Compound	Effective Against
Pyrethrum	All
Rotenone	All
DDT	Roaches, silverfish
Chlordane	All
Methoxychlor	All
Pentachlorophenol	Roaches, termites, firebrats
Tar derivatives	Drywood termites
Kerosene oil	Silverfish
Benzene hexachloride	Drywood termites

TABLE 44
REPELLENTS

Compound	Effective Against
Thiocoumarin	Termites
Hexachlorocyclohexane	"
DDT	"
3, 5-dinitro-o-cresol	"
Phenothiazine-3, 5-dinitro-o-cresylate	"
Phenothiazine	"
3, 5-dinitro-o-crysalate	"
Lindane	"

Chemicals

Deterioration of paper from chemicals is another area that must be considered when using paper products. In industrial atmospheres, the greatest hazard is from the sulfur dioxide gas present. This gas forms acids that attack the gel-like portion of the fibers and, to a certain extent, the cellulose content.

Temperature

High temperature can weaken paper by altering its chemical structure. Heat also provides an ideal atmosphere for decay caused by microorganisms and moisture.

Sunlight

Continued exposure to sunlight causes deterioration of the main structural component of paper, cellulose. The rate and severity of deterioration is dependent upon the kind of cellulose used in the paper, and the impurities present in the cellulose.

DETERIORATION OF RUBBER

Rubber is subject to deterioration by a variety of chemical, biological, and physical agents, working individually or in combinations. The degrading effects of some of these agents are listed in Table 45.

Microorganisms

Certain rubber compounds are susceptible to microbiological deterioration. Deterioration is fairly slow and requires a warm, moist environment. Table 46 gives the resistance of several rubbers against attack by microorganisms.

Chemicals

The most serious cause of deterioration in rubber is caused by the ozone present in the atmosphere. Ozone causes rubber to become brittle and may produce fissures over its surface. The severity of attack varies greatly according to the type of rubber. Oxygen has similar effects but they are subordinate in importance to those caused by ozone. Neoprene, butyl, Thiokol, silicone, Hypalon, and polyaervlate rubbers are more resistant to ozone than polymers based on butadiene or isoprene, such as GR-S, nitrile rubber, or natural rubbers.

Natural rubbers swell when in contact with liquid hydrocarbons, such as oil, gasoline, and benzene. Disintegration and aging occur from prolonged contact. Several synthetic rubbers have been developed which are oil-resistant; these products are substituted for natural rubbers when contact with oil or

TABLE 45

PHYSICAL PROPERTIES OF SYNTHETIC AND NATURAL RUBBERS

Material	Effect of Heat	Abrasion Resistance	Effect of Sunlight (under tension)	Effect of Aging
Chemigum, oil-resistant	Stiffens	Excellent	Equal to rubber	Stiffens
Chemigum, tire	Stiffens	Good	None	Better than rubber
GR-I (Butyl)	Stiffens slightly	Excellent	None	Highly resistant
GR-M (Neoprene)	Stiffens slightly	Excellent	None	Highly resistant
GR-N (Perbunan)	Stiffens	Excellent	Slight	Highly resistant
GR-P (Thiokol FA)	Hardens slightly	Fairly good	None	None
GR-P (Thiokol ST)	Hardens slightly	Good	None	None
GR-S (Buna S), hard	--	--	--	Highly resistant
GR-S (Buna S), soft	Stiffens	Excellent	Deteriorates	Highly resistant
Hycar OR-15, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-25, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-15, hard	--	--	--	Highly resistant
Hycar OR-10, soft	Stiffens	Excellent	Deteriorates	Highly resistant
Koroseal, soft	Softens	Good	None	Highly resistant
Koroseal, hard	Softens	Excellent	None	Highly resistant
Pliolite, No. 40	Softens	--	None	None
Resistoflex	Softens	Good	None	None
Tygon T	Softens	Good	None	--
Vistanex, medium	--	--	None	Better than rubber
Vistanex, high	--	--	None	Better than rubber
Natural rubber, hard	--	--	--	Highly resistant
Natural rubber, soft	Softens	Excellent	Deteriorates	Moderately resistant

TABLE 46
RESISTANCE OF NATURAL AND SYNTHETIC RUBBERS TO MICROORGANISMS

Material	Resistance
Natural rubber	
Pure natural rubber—caoutchouc	Attacked
Highly purified natural rubber, 99%+, not vulcanized	Attacked
Natural rubber vulcanizate	Attacked Resistant
Hevea latex	Attacked
Guayule latex	Attacked
Crude sheet	Attacked
Crepe rubber	Attacked
Pale crepe, not compounded	Attacked
Pale crepe, compounded	Resistant Attacked
Plantation crepe	Attacked
Smoked sheet, not compounded	Attacked
Smoked sheet, compounded	Resistant Attacked
Reclaimed rubber	Attacked
Gutta-percha	Some attack but less than natural rubber
Chlorinated rubber	Resistant
Synthetic rubbers	
Neoprene-polychloroprene, not compounded	Resistant Attacked
Neoprene, compounded(1)	Resistant Attacked
GR-S, butadiene-styrene, not compounded	Resistant Attacked
GR-S, butadiene-styrene, compounded(2)	Resistant Attacked
GR-S, butadiene-styrene, compounded, acetone extracted	Resistant
Buna-S, butadiene-styrene, uncured	Attacked
"Hycar OR," butadiene-acrylonitrile, not compounded	Attacked
"Hycar OR," butadiene-acrylonitrile, compounded	Resistant Attacked
Buna N, butadiene-acrylonitrile, compounded	Attacked
GR-I (butyl), isobutylene-isoprene, uncured	Resistant Attacked
GR-I (butyl), isobutylene-isoprene, compounded	Resistant Attacked
"Thiokol," organic polysulfide, uncured	Attacked
"Thiokol," organic polysulfide, vulcanized	Resistant
"Thiokol," organic polysulfide, sheets for gasoline tank linings	Attacked
Silicon rubber	Resistant
Experimental elastomers from:	
Butadiene	Attacked
Isoprene	Attacked
Isobutylene	Attacked
Acrylonitrile	Attacked
Styrene	Attacked

(1) Neoprene containing nutrients may be attacked, but the hydrocarbon itself is not attacked.

(2) This sample produced by improved processing to give fungal resistance.

chemicals is expected. Neoprene, Thiokol, butadiene-acrylonitrile vulcanizates, some polyacrylic ester compounds, and chlorinated rubber are often used for these purposes.

Temperature

A number of changes take place in rubbers, particularly carbon-based types, under the influence of low temperatures. All of these changes are reversible, however, and the material recovers its original properties as temperatures return to normal. As the temperature is decreased, the rubber becomes more difficult to bend or stretch. Below a certain subzero temperature, this stiffness increases to a maximum, at which the rubber becomes brittle and will shatter under suddenly applied loads. Long time exposure is sometimes accompanied by crystallization and the plasticizer-time effect. Crystallization results in an increase in stiffness but not necessarily in brittleness. The plasticizer is thrown out of solution, which may result in a loss of flexibility above the brittle temperature and also causes the temperature at which brittlement takes place to rise. The various commercial rubbers differ appreciably as to the temperature ranges in which they pass through these various stages.

At high temperatures, both natural and synthetic rubbers become gummy, take on a permanent set, and decrease in tensile strength. The temperatures at which various types of rubber become unusable are shown in Table 47. The more general effects of heating are included in Table 45.

Sunlight

Decomposition of rubber by sunlight is due mainly to the blue and ultraviolet wavelengths. These rays cause the rubber to liberate gases as the rubber decomposes. The surface of rubber, undergoing solar deterioration, exhibits resinification of the surface and an irregular pattern of very fine cracks. The effects of sunlight on various rubbers are included in Table 45.

Preventive measures include coloring the rubber to decrease the effect of the damaging wavelengths, although storage in darkness is the most effective measure.

DETERIORATION OF PLASTICS

With the wide variety of plastics available today, it is possible to choose a plastic that is not affected by the particular environmental conditions through which it travels. The resistance of plastics to corrosion, heat, light, acids, alkalies, organic solvents, etc., can be found in various materials handbooks and manufacturers' brochures. It might be said that, in general, plastics have a good resistance to corrosion and chemical action.

TABLE 47

DEGRADATION OF RUBBER BY HIGH TEMPERATURES

Type of Rubber	Highest Usable Temperature °F (°C)
Silicone	500 (260)
Polyacrylic	350 (177)
Buna-N	340 (171)
Neoprene	315 (157)
Butyl	300 (149)
Buna-S	280 (138)
Natural	260 (127)
Thiokol	250 (121)

Microorganisms

Only a few plastics are attacked by microorganisms and, in these plastics, deterioration rarely proceeds further than the surface. Table 48 lists the relative resistance to microorganisms of several plastics.

Chemicals

Chemical deterioration of plastics results in loss of strength, erosion warpage, cracking, and loss of transparency. Most physical changes are caused by loss of plasticizer.

Temperature

As the temperature drops, plastics tend to lose their flexibility and turn brittle. The temperature at which this happens varies with each different plastic. Polyethylene, one of the more durable plastics, begins to stiffen slightly at -30°F and becomes brittle at -94°F.

At the higher temperatures, plastics become very flexible and begin to lose their strength.

TABLE 48
RESISTANCE OF PLASTICS TO ATTACK BY MICROORGANISMS

Material	Resistance
Acrylics	
Polymethylmethacrylate	Good
Polyacrylonitrile ("Orlon")	Good
Acrylonitrile-vinyl chloride copolymer ("Dynel")	Good
Cellulose derivatives	
Cellulose acetate(1)	Good, poor
Cellulose acetate-butyrate	Good
Cellulose acetate-propionate	Good
Cellulose nitrate	Poor
Ethyl cellulose	Good
Rayons	
Acetate rayon ("Estron")	Good
Saponified acetate rayon	Slightly more resistant than cotton
Cuprammonium rayon	Poor
Viscose rayon	Poor
Phenol-formaldehydes	
Phenol-formaldehyde(2)	Good
Phenol-aniline-formaldehyde	Poor
Resorcinol-formaldehyde	Good
Melamine-formaldehydes	
Melamine-formaldehyde(3)	Good, poor
Urea-formaldehydes	
Urea-formaldehyde(3)	Good
Protein-formaldehydes	
Zein-formaldehyde ("Vicara")	Good
Casein-formaldehyde	Poor
Polyamides	
Nylon(4)	Good
Polyesters	
Ethylene glycol terephthalate ("Terylene") ("Fiber V")	Good
Polyethylenes	
Polyethylene(5)	Good Questionable(6), Good
Polytetrafluoroethylene ("Teflon")	Good
Polymonochlorotrifluoroethylene	Good
Polyisobutylene	Good
Styrenes	
Polystyrene	Good
Polydichlorostyrene	Good
Vinyls and vinylidenes	
Polyvinyl chloride	Good Questionable(6)
Polyvinyl acetate	Poor
Polyvinyl chloride-acetate	Good

TABLE 48

RESISTANCE OF PLASTICS TO ATTACK BY MICROORGANISMS (cont)

Material	Resistance
Polyvinylidene chloride	Good
Polyvinyl butyral	Good
Glyptal resins (Alkyd resins)	Poor, moderate
Silicone resins	Good

(1) Fully acetylated cotton is resistant, but there are acetylated cottons in which the percentage of acetate is not high enough to impart complete resistance.

(2) Some cases are on record in which phenol-formaldehydes have been listed as poor. This difference in opinion probably arises from testing samples containing susceptible fillers, since the resin itself is considered as having rather good fungus resistance.

(3) White and Siu, in tests on cotton fabrics impregnated with urea-formaldehyde and melamine-formaldehyde resins, found that a high degree of fungal resistance was imparted to the cotton by the resins. It was not conclusively shown, however, whether the resistance was due to the resins as such or to the possible presence of free formaldehyde.

(4) Some tests have indicated nylon to be attacked in soil burial, but most evidence shows it to be immune.

(5) Klemme and Watkins in 1950 reported that the susceptibility of polyethylene and polyisobutylene resins to fungus growth decreases as the average molecular weight increases. Ethylene materials of molecular weights above 10,000, and a butylene sample of 100,000 mw, were found to be fairly resistant. Polytrifluorochloroethylene ("Kel-F") shows a nutritive inertness comparable to the high-molecular-weight polyethylene.

(6) Based on electrical measurements.

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TM 38-250, "Packaging and Handling of Dangerous Materials for Transportation by Military Aircraft."

TM 38-750, "Army Equipment Record Procedures."

PPP-T-60, " Tape; Pressure Sensitive Adhesive, Waterproof" for Packaging and Sealing.

PPP-T-76b, "Tape; Pressure - Sensitive Adhesive Paper."

PPP-T-97c, "Tape; Pressure - Sensitive Adhesive, Filament Reinforced."

MIL-P-116D, "Methods of Preservation."

MIL-B-121, "Barrier Material, Greaseproofed, Waterproofed, Flexible."

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MIL-C-5541, "Chemicals, Films, and Chemical Film Materials for Aluminum and Aluminum Alloys."

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GLOSSARY

ADP	- adapter	HE	- high explosive
approx.	- approximately	hr	- hour
APRV	- automatic pressure relief valve	hyd	- hydraulic
		in.	- inch(es)
AR	- army regulation	in/in.	- inch per inch
assy	- assembly	in/lb	- inch - pounds
Brg	- bearing	in/sec	- inches per second
brk	- bracket	kc	- kilocycles
BTU	- British Thermal Unit	kmc	- one thousand megacycles
BTU/pound	- British Thermal Unit per pound	lat.	- lateral
		lb.	- pound
°C	- degree Centigrade	lb/cu ft	- pounds per cubic foot
℄	- center line	lb/ft	- pounds per foot
comp.	- compression	lb/in	- pounds per inch
cont	- container	lb/in/sec	- pounds per inch per second
CONUS	- continental United States	lbs/sq in	- pounds per square inch
cps	- cycles per second	long.	- longitudinal
cu ft	- cubic feet	max.	- maximum
cycles/sec	- cycles per second	mc	- megacycles
cyl	- cylindrical	MIL	- military
DA	- Department of the Army	MIL-STD	- military standard
D&PS	- U.S. Army Development and Proof Services of Aberdeen Proving Ground	miles/sec	- miles per second
		millisec	- millisecond
		min.	- minimum
dia	- diameter	mph	- miles per hour
DOD	- Department of Defense	MPRV	- manual pressure relief valve
°F	- degrees Fahrenheit		
Fed Spec	- Federal specification	msc.	- milliseconds
FED-STD	- Federal standard	N.A.	- not available
FM	- from	OA	- overall
fpm	- feet per minute	ORD	- ordnance
fps	- feet per second	P.C.F.	- pounds per cubic foot
ft	- feet	psi	- pounds per square inch
ft/min	- feet per minute	psia	- pounds per square inch absolute
ft/sec	- feet per second		
fwd	- forward	psig	- pounds per square inch gage
G	- a dimensionless ratio of the acceleration on object to the acceleration due to gravity	pts	- points
		rad/sec	- radians per second
		rect	- rectangular
G&C	- guidance and control	RF	- radio frequency
G_m	- a dimensionless ratio of the maximum acceleration an object can safely withstand to the acceleration due to gravity	RH	- relative humidity
		S.A.E.	- Society of Automotive Engineers
		store.	- storage
		struct.	- structure
		temp.	- temperature

GLOSSARY (cont)

TM	- technical manual
vert	- vertical
w/	- with
w/h	- with head
w/o	- without
water-lb	- water per pound
wt	- weight
yr	- year(s)

INDEX

It is the intent to review this publication periodically to ensure accuracy and completeness. Those making use of this guide are encouraged to report any errors discovered and any recommendations for changes or expansion of content to the Commanding General, ATTN: AMSMI-IHC, U. S. Army Missile Command, Redstone Arsenal, Alabama. DA Form 1598, Record of Comments on Publications, as referenced in AR 310-6, may be used.