NAVWEPS REPORT
7870
VOLUME II

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STANDARDIZATION POTENTIALS IN DOCUMENTATION AND DESIGN OF GUIDED MISSILE CONTAINERS

A STUDY IN THREE VOLUMES

VOLUME II
DESIGN AND TEST CRITERIA

PREPARED FOR

BUREAU OF NAVAL WEAPONS
WASHINGTON 25, D. C.

IN SUPPORT OF
DEPARTMENT OF DEFENSE
STANDARDIZATION PROJECT NUMBER
MISC - 0015

Contract NOrd 18378

RR1544

Reed Research Inc.
WASHINGTON 7, D. C.

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INTRODUCTION TO VOLUME II

This volume will discuss possibilities for standardizing design and test criteria for missile containers. Our study has shown wide differences in what is specified, and even where the same thing may be specified, differences in specification reference and the like. Both types of difference cause great difficulty to the designer.

Reed Research, Inc. has examined practically every requirement of good container design as such requirements are being applied to guided missiles. We have found that there are substantial differences of approach as well as what might be termed "administrative differences" stemming from the existence of different specification numbers. In each specific area, we have found that standardization is not only possible, but desirable. Since such standardization is possible for each individual element, it is possible for the whole. Subject, therefore, to recognition of the differences imposed by certain different logistic patterns for guided missiles, we believe it is possible, and Appendix I comments certainly emphasize the desirability of so doing, to prepare a single document covering design criteria for guided missile shipping containers and means of measuring the degree to which such criteria have been satisfied.

It should be particularly noted that containers have no "knowledge" concerning their contents. In this report, we have really examined design criteria for containers. These criteria exist for any container although it is rare that they are, or should be, explicitly described. There appears, therefore, no particular reason why the document mentioned in the previous paragraph should be limited to guided missiles. It could serve for torpedoes, bombs (conventional and special), engines and any other very high value item in which the logistic pattern can be reasonably well predicted and whose nature is such as to require detailed design and test of the containers before permitting production. We suggest that the working title of the standard document to be developed be "Design Criteria for Special Shipping Containers and Devices".

Invariably, the three services have, on specific containers for specific missiles, wound up with detailed specifications applicable to the specific design concerned. MIL-P-21927 (NOrd) requires such preparation as does MIL-P-9024. The basic documents then, gradually , become converted to a series of instructions on how to design a container and how to test the resulting design. One of the problems immediately apparant is that the specification outline of form, aimed as it is at accurate description of a specific commodity, forces a rather turgid prose style and, by separating the requirement from the test, tends to lose a designer in a maze of cross references. This is fine for promoting debate, but not for communication. The first step in developing a container system for a weapon system is the procurement of an idea or a series of ideas. At this stage, therefore, the most the government can hope for is a reasonably standard approach to the problem together with an internal agreement concerning how it will approach specific situations as they arise.

Since what is desired is a standardized approach with detailed specifications and drawings to be prepared somewhat later, and inasmuch as the existing general documents do not buy hardware but only the designs of hardware, Reed Research recommends that the standardization document be prepared in the form of a Military standard. The authors of the standard can concentrate on stating the fundamental requirement and then discuss various acceptable means of stating the requirements and determining that the requirements are met.

Specifications rarely state basic design goals explicitly. In order to compare the various services' specification requirements on a uniform basis, we have derived and stated these design goals in qualitative terms. Further, specification requirements are supposed to be drawn in such a fashion that each requirement may be objectively inspected by some means such as:

a. Laboratory test
b. Visual Inspection
c. Certification or other documentation that specification materials, processes and components have been used.

In effect, each of the above constitutes a test and is so considered in the discussion given here.

The general plan of presentation is to state the basic design goal, to develop how compliance is required and how it is measured, and then to proceed to a discussion of specific tests and their standardization potential. In discussing standardization, we have taken the attitude that a recommendation that a specific test be abandoned is as much a step towards standardization as any other step might be.

Reed Research has felt for some time that the various design criteria and their tests needed considerable rationalization. In order to broaden the base, a questionnaire was sent to a number of other industrial firms known to be engaged in missile container design. The results of this questionnaire are reproduced in Appendix I, and reflect the effects on industry of current lack of standardization.

A. GENERAL ENVIRONMENTAL CRITERIA

Missile containers, while not often explicitly defined as such, are a part of the ground support equipment of the weapon system. The general specification for guided missiles (MIL-M-8555, dated 31 December 1952) contains environmental criteria in paragraphs 3.1.13 through 3.1.13.4, 3.1.19, 3.1.20, 3.1.22, Shock and vibration criteria are stated in general terms in 3.1.19 and certain handling characteristics are stipulated in paragraph 3.1.25.

Insofar as general environmental criteria are concerned, MIL-STD-210 is a later document and states ground equipment needs more explicitly. MIL-M-8555 should be amended to reference MIL-STD-210.*

Even if MIL-STD-210 were referenced, however, the basic standardization problem would not be solved. Our study shows wide variation between the services in determining how satisfaction of the environmental criteria is to be determined. It is in this area that standardization potentials are to be found and the discussion proceeds along these lines.

A-1. CORROSION PROTECTION

A container must protect the contents against the effects of a corrosive environment. In addition, the container itself must resist such an environment sufficiently to provide, on the average, adequate service life.

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*This statement assumes, possibly naively, that there is some useful purpose to be served by approaching MIL-M-8555 at all. It has been our experience that specifications which are <u>used</u> are amended frequently. Lack of change in MIL-M-8555 since 1952 implies non-use. Follow-up here, however, is outside the scope of this study.

The corrosive environment consists of air with varying amounts of water vapor and contaminants which markedly influence the rate of corrosion.* The contaminant usually considered as having the most devastating effect is sodium chloride, found (most commonly) in marine and coastal atmospheres. Industrial gases also play a major role, particularly in the corrosion of steel.

Protection against the environment is controlled:

a. For the contents directly by stipulating the method of preservation and compounds to be used and, indirectly, by prescribing the degree of sealing required (to be discussed under leakage testing) and by checks of the interior of a container after performance of the various environmental tests discussed below.

b. For the container by specifying exposure to tests simulating a both marine and highly humid atmospheres, by design criteria such as free drainage, and by specifying in greater or lesser detail, the surface treatments, platings and paint coatings to be used.

For analysis purposes, the various topics will be discussed in the order

Salt spray tests
Humid environment tests
Other requirements

---

* For a preliminary discussion of these points see Greathouse and Wessel, "Deterioration of Materials - Causes and Preventive Techniques", Reinhold, 1954, and the more recent papers by Larrabee, by Aziz and Godard and by Yocom, Corrosion, 15 526 et. seq., 1959.

A-1a. Salt Spray or Fog Tests

Objective

1. Container must be able to withstand the effects of corrosive salt atmosphere.

2. Container must be able to protect its contents from contact with salt atmosphere.

Requirements

Explicit statements of capability to pass a salt spray test are contained in MIL-W-21927 (NOrd), MIL-E-5272, (ARGMA, Brookley), MIL-E-4970 (Picatinny, WADC). BuAer does not explicitly require.

All methods stated use 20% concentration but, in view of known wide variations in reproducibility, any variations in angle of exposure, temperature, time and droplet size (which are not necessarily controlled above) can have drastic effects on results.

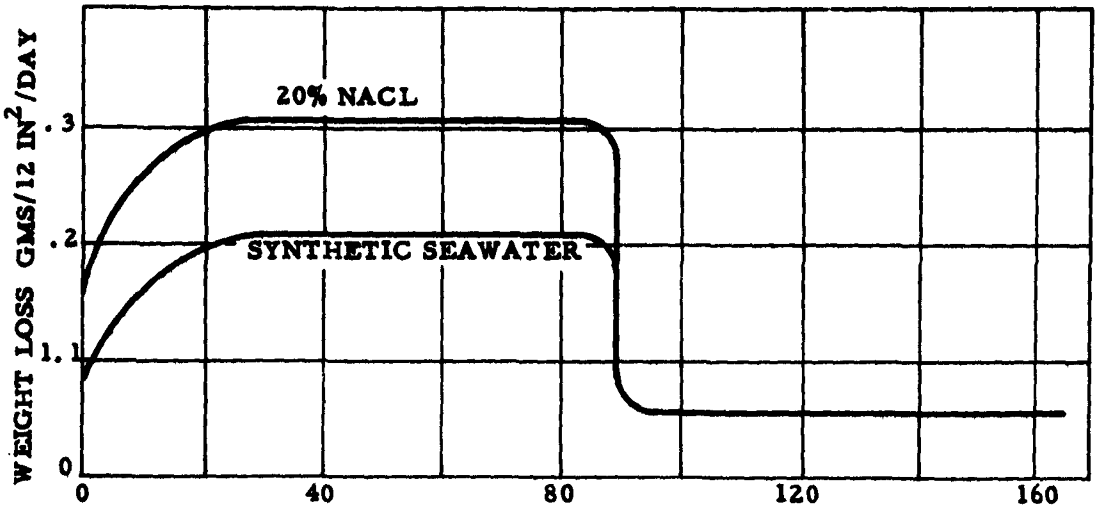
Other Standard Salt Spray Tests

ASTM Designation:

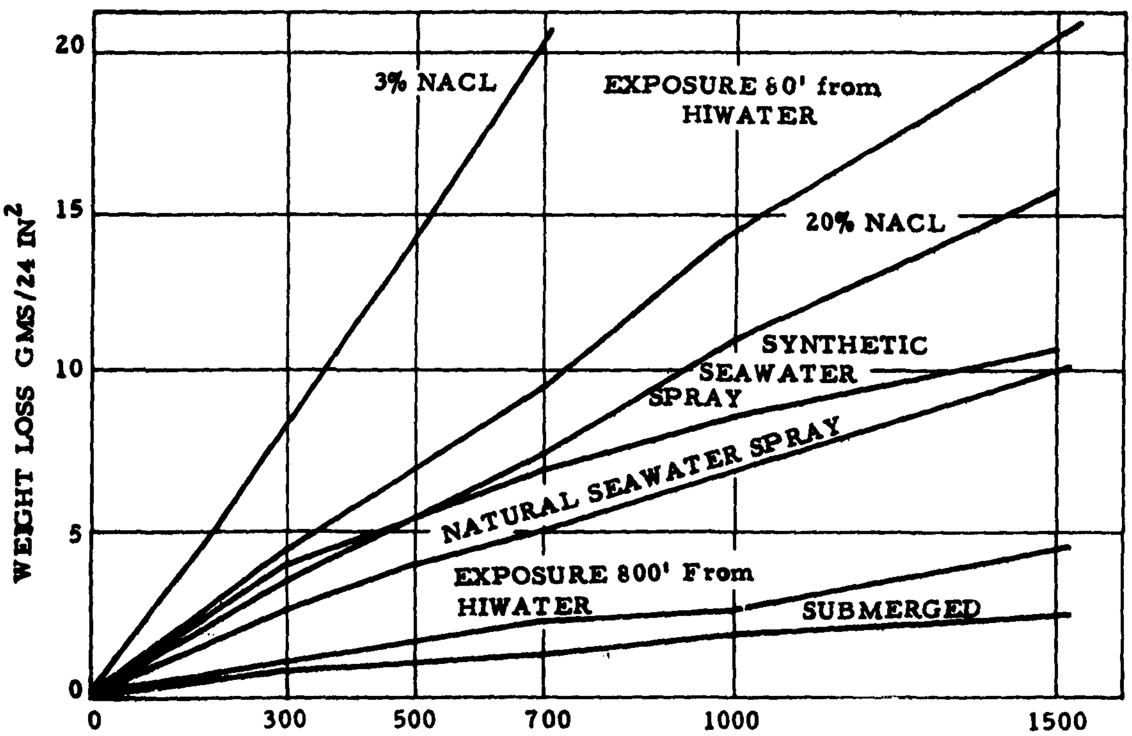
B-117-54T Salt Spray (Fog) Testing test method specifies everything except type and number of test specimens and period of test.

Remarks

1. MIL-E-4970 and MIL-E-5272 are essentially the same



ANGLE OF PANEL WITH HORIZONTAL
CORROSION RATE VERSUS SPECIMEN ANGLE FOR COLD ROLLED STEEL (LaQue)
Figure A-1



HOURS
COMPARATIVE SPRAY TEST ON COLD ROLLED STEEL (ALEXANDER AND MAY)
Figure A-2

and, although their time durations differ slightly, they follow ASTM B 117-54T very closely.

2. We are unable to find any technical justification for use of the salt spray test on complete containers even if it were feasible to conduct such tests at all. Only one responder in the industry survey admitted ever running such tests on complete containers, and that on small tear strip cans.

Experience of all who have worked with this test may be summarized as encountering extreme difficulty in obtaining reproducible results. Figures A-1 and A-2 illustrate some of the difficulties. Further, the test, even when run under rigidly standardized conditions does not reproduce field conditions. A prime example is the well known poor behavior of zinc in the salt fog test compared to its excellent record in marine atmosphere under service conditions. LaQue published a devastating critique in Materials and Methods several years ago. This paper and its written discussions are filled with phrases such as "does not predict failure in service nor does a good performance in a salt spray test guarantee satisfactory behavior in service" and "we can think of no particular instance in which the acceptability of any product can be ascertained by the simple expedient of exposing it to salt spray".

3. It is true that Air Force Specification MIL-P-9024 is a performance specification and the absence of the salt spray test here could, theoretically, lead to poor finishes on containers. This is, however, controllable through the detailed specifications written for special design containers. For standard containers (AN cans, transit cases, etc.,)

the finishes are controlled by their pertinent specifications.

4. It might be agreed that the salt spray test controls container accessory performance. Separately, in this report, we are recommending specifications be written to cover such areas not now covered. These specifications are the place to control this problem.

Recommendation

The salt spray test be abandoned as a means of measuring the corrosion resistance of complete containers.

A-1b. Humidity Test

Objective

The design objective is twofold.

1. To protect the contents of the container from damage by humid conditions.

2. To protect the container itself against the effects of high relative humidity.

How Required

Army Rocket-Guided Missile Agency and Brookley Air Force Base reference MIL-E-5272 while Norton and Picatinny reference MIL-E-4970. Very careful reading is required to determine that the tests are identical. Bureau of Aeronautics and Army Ballistic Missile Agency refrain from referencing any humidity test, but Bureau of Ordnance references MIL-STD-354, which is stated to be applicable in fuzes. This test is more severe in range (i.e. from -80 degrees F to +160 degrees F as compared to +70 degrees to +160 degrees F) and lasts two weeks in lieu of ten days.

Comments

The MIL-STD-354 requirement for testing to -80 degrees F appears incompatible with other requirements of MIL-W-21927 (NOrd) for performance at -40 degrees F.

Except for highly specialized designs, such as free breathing containers where the test could be performed on the breather unit, the hunidity test is a modified leak test for evaluating efficiency of seals. A most interesting recent article (see Harris, A.P. and Parrott, E.W., "What Designers Should Know About Humidity", Electronics, pp 50-55, October 30, 1959) contains an extensive review of the physical properties of water and its method of entering sealed structures. This article concludes, and we concur, that

> "(4) The penetration of water through imperfect seals is largely a function of the water vapor pressure present.
>
> "(5) The mechanism of vapor entry depends on whether the environment is one of low vapor pressure or high vapor pressure. Natural humid conditions, with vapor pressure as low as 4 mm Hg or as high as 28 mm Hg cause entry by low-pressure mechanisms.
>
> "(6) Humidity tests produce vapor pressures about 8 times as severe as natural conditions. Such tests should not be regarded as simulation of nature but as leak tests.

"(7) Because of the severity of humidity tests, the wide tolerances permitted, the temperature dependence of the electrical characteristics of water, the formation of fugitive water films and possible variation in leak sizes, correlation by sample testing is difficult, sometimes impossible;

"(9) If humidity testing is regarded as a means to predetermine potential causes of failure rather than simulation of the environment, there are more effective and less time consuming methods."

One industry responder did state that the temperature fluctuations inherent in the method produced "fatigue" that was not otherwise evident in pure leak tests as currently conducted. This can of course be simulated by other means such as simply changing ambient temperature, a cheaper process than changing temperature and relative humidity at the same time.

The argument could be advanced that the humidity test is a form of corrosion test for the container which will insure the use of adequate finishes on the exterior. It is only necessary to state that adequate specification finishes are available (see discussion below). Further, difficulties encountered in obtaining reproducible results on test panels in the highly standardized AN-H-31 humdity cabinet should be sufficient evidence that the humidity test, used alone, is an inadequate measure of the quality of finish used and a dubious check on the efficacy of its application.

In view of the comments above and the recommendations below, observations on varieties of humidity test references are academic.

Recommendation

1. The humidity test be abandoned for complete containers.

2. When used, the humidity test should be limited to tests of operating components. (Note: This conforms to the test selection chart of MIL-W-21927 (NOrd).

A-1c. Dissimilar Metal Contacts

Only MIL-W-21927 (NOrd) makes mention of avoiding dissimilar metal contacts, as defined in MS 33586, as a qualitative design criterion. Other general specifications, such as MIL-P-9024B, apparently rely on environmental tests to disclose bad situations.

There is no question that neither the salt spray test nor the humidity test is an adequate measure of the efficacy of dissimilar metal contact protection. In any case, should a general design document develop from this study, use of appropriate language limiting dissimilar metal contacts is indicated.

A-1d. Free Drainage

Free Drainage is not specifically spelled out in the general specifications. Same comment as for dissimilar metals.

A-1e. Finishes

The true key to whether container corrosion control is achieved is the finishing scheme used. The picture here is one of inordinate confusion engendered by the past practices of the activities concerned.

For example, MIL-W-21927 (NOrd) references OSTD-52 (Painting of Naval Ordnance Equipment). Army Ordnance activities may reference MIL-STD-171 (Ord). Individual specifications prepared by contractors may reference these or go to direct call outs of almost any of the some 250 paint specifications in existence.

When the designer beats his way through these second tier references, he may or may not find that he is required to use the same material. In the worst case, he may find that it is almost the same material, but his vendor is not in a position to help him for any number of reasons, most of which are involved in the complex administration of the Qualified Products Lists concerned and/or certification procedures. The comments in Appendix I on this subject are explicit (in personal interviews they have verged on the profane) and no reason exists why the confusion could not be eliminated. Technically, it makes no difference to the container whether it is painted with an alkyd enamel to an Army specification or with an alkyd enamel to a Navy specification.

Recommendation

1. A military or federal standard on painting and finishing containers be prepared.
2. Existing container specifications be amended to reference the standard.
3. Future general container design specifications reference the standard.

A-2. SAND AND DUST TESTS

Objective

1. The container must be capable of protecting the

contents from the abrasive and binding action of sand and dust.

2. The container's ability to function (damage to seals, malfunctioning of valves, etc.) must not be impaired by desert conditions.

How Required

ARGMA and Brookley reference MIL-E-5272 and Picatinny and WADC reference MIL-E-4970. The actual test procedures in these two specifications are identical. BuAer and Norton do not reference sand and dust tests as such. BuOrd lists sand and dust testing as a requirement applicable only to non-pressurized containers. The method specified is a partial paraphrase of MIL-E-4970 but with sand velocity increased from 100-500 fpm to 2,300 ± 500 fpm.

Comment

It is well known that sand will take the paint off surfaces and, from a practical standpoint, what harm is done the ultimate function of the container by such denuding?

Insofar as sealed containers are concerned, sand and dust testing can evaluate whether functional components, such as relief valves, will fail. A relief valve specification is the logical place to control this point in order to avoid undue testing duplication. This conforms to test selection criteria in specification MIL-W-21927 (NOrd).

On unsealed containers possibility exists of damaging the contents, the flexible barrier, if used, or the suspension system. Insofar as damage to contents is concerned, this is the equipment designer's problem and this test is one he has to pass anyhow.

If the design is based on a floating bag principle, the test simply evaluates the strength of the bag and the efficacy of its seals. There are simpler means of so doing..
With respect to suspension systems, no damage of "rubber" shock mounts is anticipated. Hydraulic mechanisms involving O - rings and pistons (sometimes used for damping and conceivably usable for primary shock isolation) can be damaged by accumulations of detritus. Similarly, on cushioned packs, foreign matter between the cushion and the contents could abrade finishes.

It should be noted that any open container, except an unsheathed crate, will provide shelter from sand blast and the major difficulty will be accumulation of foreign matter seeping through openings. Hence, 100-500 fpm velocity is more appropriate than 2,300 fpm.

Recommendation

Sand and dust tests only be used on unsealed containers with hydraulic mechanisms or cushioning materials which are outside primary water seal. When referenced, use MIL-E-4970 to avoid possible confusion.

A-3. FUNGUS TESTS

Evidence that fungus tests have been specified is lacking. Such tests have been a part of the general environmental tests (MIL-E-5272 and MIL-E-4970) and could have crept in from overzealous application of the requirements of these specifications. It is our opinion that they are not properly a requirement of a container specification (or component specification) where the materials and finishes are required to conform to government specifications. Certainly, it would only be silly to talk in terms of the fungus resistance test on metals.

In the event that a contractor proposes using a completely non-standard material for a container, then the government should exercise the option of discouraging its use either directly or by exercising the subtle, but highly effective, control of competitive pricing. Fungus testing makes sense when developing a new material, but only in this restricted area.

Recommendation

We recommend that fungus testing not be included in any joint documents which might be issued.

A-4. ALTITUDE TESTS

Changes in altitude result in changes of ambient pressure and temperature. Such changes become significant, even in surface transportation, when the height differential is approximately 2,500 feet i.e. pressure differential exceeds 1 psig. In general, increasing altitude reduces ambient temperature and pressure simultaneously. Thus, a container loaded or stabilized at one temperature will, when raised to an appropriate altitude, develop the equivalent of a large internal pressure increase. Because of the lag in temperature equalization, this pressure difference is temporarily larger than the difference in pressure-altitude alone. It is essential, therefore, that the rate of change of altitude be controlled in any test procedure directly simulating an altitude change. In connection with this point, most transport aircraft have a sea level rate of climb of around 1,500-1,700 fpm. Among U.S. made aircraft only the C-133 and the Electra climb faster (2,500 fpm). These published rates of climb figures have been, of course, arrived at arbitrarily. It is quite rare for a pilot with a loaded airplane to exceed these values significantly. Certainly, a rate of change of 2,500 fpm seems adequate for the forseeable future, particularly when considering that cabin pressurization will cause a lag in the true rate of change of pressure in the cargo compartment.

In connection with cabin pressurization, it should be noted that extensive use of cabin pressurization in all modern design aircraft also places a modest service ceiling on the expected pressure altitude to which any container may be subjected. In effect, a simulated altitude of 20,000' is possible for unpressurized aircraft (WWII Hump operations).

It should be noted that, if one accepts the foregoing limitations, the internal-external pressure differential at any instant can readily be computed. For breathing containers (either free or throttled through relief valves or controlled leaks) the mass of air flowing can also be computed easily. Hence, ability to withstand air transport conditions can be estimated without using an expensive, or perhaps unavailable, altitude chamber. Specifically, containers capable of being pressurized for test purposes could be subjected to a suitable pressure test and rate of leakage be determined.

In connection with rate of leakage, certain points should be clarified:

a. Sealed cans, with or without relief valves, should not leak at design pressures plus an adequate margin of safety for possible valve malfunction.

b. Margin of safety for containers with relief valves need not be so great as margin of safety for containers without relief valves now that reliable valves are available (which was not true when the aircraft engine container specifications were originally drafted).

c. Statement "a" above does not necessarily eliminate the AN can from consideration unless supplied with a relief valve. From such information as is available, it would appear that, wittingly or unwittingly, the entire closure and lid acts as the relief valve for internal pressure increase. Where improved closures are used, some consideration should be given to relief valves. In connection with AN cans in general, it is interesting to note that few of them have been reported as passing an internal pressure test after the handling tests specified in their own specification. This suggests the probability that, as several have claimed for a number of years, complete sealing and retention of sealing capability throughout service life is not a true criterion of ability to preserve. Hence, pressure testing for no leakage should only be considered as a means of determining a sort of relative quality of the design.

d. On free or restricted breathing containers, rate of flow through the orifice should be such as to insure against build up of unsatisfactory pressure levels during climb or descent. Such a requirement will more than take care of the flow needs of containers exposed outdoors on the ground.

e. When one moves to the free breathing container, one is immediately faced with the question of how tight the container needs to be. The only answer is: Tighter than the breather so that most of the air leaking in and out will go through the breather. It is interesting to note the tightness requirements for the long term storage hutments used for dynamic dehumidification (the fact that these large containers are not mobile is completely immaterial). The normal criterion for this tightness on structures designed for dynamic dehumidification (and active breathing through a desiccating tube is not far removed from this condition) is one complete air change every 24 hours under a pressure head of 1/8 inch water. Rock Island Arsenal (RIED 1731, 27 Dec., 1955) repeatedly encountered success when, under the same pressure differential, leakage rates as high as 1 1/2 air changes per 24 hours were encountered.

f. On flexible barrier containers, failure will occur when the internal pressure results in a tensile stress on the seams exceeding the seam's strength value. This is usually specified to be one pound per inch of width. Failure under internal pressure will, here, be a function of the specific design since seam placement is not directly controlled nor controllable.

Recommendations

Reed Research, Inc. considers it to be entirely possible to standardize altitude testing and pressure testing with the above background comments serving as a logical point of departure, and, therefore, recommends that these tests be combined and standardized.

A-5. TESTING AT TEMPERATURE EXTREMES

This section discusses the effects of temperature variation on the container and the specific methods used by the three services to measure and control these effects.

The generalized effects at the two temperature extremes are:

A. High Temperature

1. Increases the pressure in a closed container.* The weight of the entrapped air in a breathing container or a container with an actuated pressure relief valve is decreased, which tends in a small way to decrease the moisture content.**

2. Increases the rate of deterioration of organic materials.

3. Increases the corrosion rate.

4. Changes the elasticity characteristics of non-metallic materials, i.e., shock isolators, cushioning, etc.

5. Adversely affects the stability of certain rocket propellants.

---

* RD 219/3 Appendix 10.1, Pressure Changes in a Sealed Container.
**For discussion of the basic theory of water absorption: Modern Packaging, July 1949, Max Mueller.

B. Low Temperature

1. Decreases the pressure in a closed container creating a partial vacuum. In containers which can breathe, this partial vacuum leads to inhaling ambient air.

2. Eliminates, to a high degree, organic deterioration.

3. Decreases the rate of corrosion.

4. Stiffens or embrittles organic materials.

5. Adversely affects the stability of certain rocket propellants.

Of the generalized conditions tabulated above, only the effects of corrosion and changes in elastic characteristics are discussed here. The effects of increase or decrease in pressure are directly related to the thickness of the container shell (assuming a closed container) and the stresses developed are covered in any text on strength of materials.

The rate of deterioration of organics is a very controversial subject, but is generally conceded not to be measurable by highly accelerated tests except where the action is catastrophic. Thus, the subject of deterioration of organics is beyond the scope of this study. Adverse effects on stability of rocket propellants depend, of course, on the propellant itself and therefore do not fall into the standardization field under consideration here.

The effects of corrosion on containers and the tests applicable thereto are examined in the section on Corrosion Protection.

Now MIL-STD-210 defines the worldwide environment fairly well. The question is not one of definition, however, but, rather one of determining and specifying what practical compromises have to be made to live with (or in any case to accommodate to) this environment. It is here that the thoughtful viewer of various service documents finds that several points of view may have developed which apparently can be characterized as follows:

a. MIL-STD-210 is the party line of the faithful and everything must be made to work under any and all conceivable circumstances. Those who follow this literally do not count the cost, either through ignorance of the cost factor or (more charitably) from a conscious conclusion that reliability requirements for the particular device are so high that the extra cost is worth it. This latter approach is particularly attractive on large, reasonably low production, components because the total increase is fairly small compared to overall program cost.

b. MIL-STD-210 is a statement of goals but no great harm is done if practical answers are lacking now.

c. Cannot afford it, so will not comply. An individual with this point of view will often, when told he must comply with MIL-STD-210, change the severity of the performance tests so that the magic reference is mentioned but the intent of the document is not really followed. True, there are those who honestly feel that heights of drop or severity of vibrational mode are different at these temperature extremes, but the reader of the specification cannot discern true intent from the written words.

d. The particular device under consideration will not be exposed to these extreme conditions.

The truth of the matter is, whether or not the motives are correctly described, each of these points of view can be essentially correct for a specific missile. Troop issue missiles that are relatively small are going to be stored outdoors and are certainly going to be exposed to both high and low temperature extremes. Practically all missiles are exposed to surface transportation in some form of closed "containers" over the deserts where insolation is very severe for prolonged periods. Development of temperatures as high as 180 degrees F adjacent to the container is highly probable. If the contents can be damaged by such temperatures, it is probable that the services would be better off painting the containers aluminum in color and shipping them in open cars. Large birds to be fired from fixed installations, particularly in CONUS, will be exposed to local temperatures but not to minus 80 degrees F. Shipboard missiles (unless adopted for use by the Marine Corps) will rarely be exposed to temperatures below -40 degrees.

In other words, the low temperature extreme is, in actuality, determined by the planned flow pattern for the missile itself. Reed Research believes that such requirements can be used as the basis for standardization. Note that the same idea of dividing requirements in accordance with logistic pattern is suggested later. When approached on this basis, the matter of cost of achieving shock isolation ability at great temperature extremes can be evaluated in proper technical context.

B. HANDLING TESTS

Objective

The container should be capable of being handled in a manner consistent with the tactical and/or supply usage of the contained component. Tests used for evaluating compliance with this objective will be discussed in the following order:

a. Stacking

b. Forklifting

c. Hoisting

d. Assembly-Disassembly

e. Pushing and Towing

How Measured

Only MIL-W-21927 (NOrd) is completely explicit and the tests quoted are drawn from that source.

B-1. STACKING

The completed packs shall be loaded to simulate a height of fifteen feet minimum, allowed to stand overnight, removed, and examined for damage. Containers that are likely to be affected by humidity shall be conditioned at 90% relative humidity at temperature of 90 degrees ± 5 degrees for 24 hours.

By their nature, missiles will require premium storage. Hence, maximum stack height can be computed on the assumption that the units will be stored indoors.

While there is no absolute limit, the Joint Handbook on Storage and Materials Handling (TM 743-200, NavSandA Pub. 284, AFM67-3, Nav MC1101) intimates that 16-21 feet is a resonable stack height in warehouses. It is recommended, therefore, that all containers be capable of withstanding superimposed loads simulating the same container placed on the upper surface to a total height of 20 feet.

Flat top containers are subject to uniformly distributed loads from other types of cargo placed on top in ship holds plus loads inherent in outside storage such as snow, ice, etc. Now, since specification MIL-C-104 assumes a 50 psf loading for a distributed load, it is suggested that the services adopt this requirement for flat topped containers.

B-2. FORK LIFTING

"Loaded containers and completed packs which have skids and fork pockets and palletized unit loads shall be lifted clear of the ground and transported at least 50 feet and lowered. When palletized unit loads are tested, the test shall be conducted four times, i.e., forks entering the pallet from each of the four sides of the unit load."

Requirements here are rather mixed between design and performance criteria. Design is given as, for example, 30" spacing on centers, opening 3" x 10" minimum. Some specifications have, in the past, stipulated length of forks (inaccurately, by the way). According to specifications MIL-T-1544, MIL-T-15636, and MIL-T-15445, fork dimensions and spacing are as shown in Table B-1. It is also apparent that, on very long loads, there is some logical limit to what might be considered a container which would be handled consistently from the side on fork trucks. Thus, door widths might be taken as the standard limit.

A mixed requirement is still indicated. This contractor feels that spacing should be adjusted to take into account the capacities indicated by Table B-1 as design criteria. Then the test used by "BuOrd" should be considered the standard of evaluation provided this test procedure be modified to include the following:

1. Stipulating the capacity of the fork truck appropriate to the gross weight and to the width of the load.

2. Requiring the test only when the width is such that the load can be considered inherently unstable (this is best defined by illustration). Then run the test over a course that could cause trouble, e.g. over a railroad crossing or over an entrance with tracked doors such as an . .rplane hangar.

TABLE B-1
DIMENSIONS AND SPACINGS OF LIFT FORKS

Nominal Capacity* Lbs.	Fork** Thickness at heel	Fork Width	Fork Length Max.	Forks*** Together Max.	Forks*** Spread Min.
2,000	1-1/2	4	36	12	28
4,000	1-3/4	5	40	12	32
6,000	2	6	40	15	34
10,000	2-1/2	7	48	18	52
15,000	2-1/2	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 the fulcrum, i.e. the front axle.
**1/2 inch for all at the tip
***Outside to Outside

B-3. HOISTING

Only Bureau of Ordnance is explicit and some question exists concerning whether this explicit requirement is correctly aimed.

A safety factor of 5 on hoisting fittings, conforms with other practices to be found in the materials handling specifications and standards. It is conceivable, however, that a test requirement of loading a container to five times its indicated gross weight may cause difficulty, particularly if the design is such that the carry through structure from the shock isolation means to the skid is marginal for such overload.

This contractor feels that there is almost equal validity to a design concept inherent in the aircraft engine container specifications. Here the idea is clearly implied that the designer must consider the possibility of some "knucklehead" trying to pick up the entire container by one hoisting fitting. This not only multiplies the load by the number of hoisting fittings actually used, but also imposes an eccentric loading which could happen and is not controlled by the former requirement.

In the final analysis, it would appear that both forms of control are appropriate. It is suggested that consideration be given to stipulating that hoisting fittings have a design factor of safety of 5:1 (to be supported by calculations on demand) and that each also be capable of lifting the entire loaded container by itself, to be supported by test.

B-4. ASSEMBLY - DISASSEMBLY

"The contents (or reasonable facsimile thereof) shall be placed in the container and the container made ready for shipment. The container shall be opened and the contents extracted and the container reclosed. Time, manpower and functioning records shall be maintained of these operations for evaluation purposes. This test shall be repeated ten times for reusable containers."

We agree that some controls over assembly and disassembly are necessary, but we cannot quite bring ourselves to a feeling that a test of the type described performs any truly useful purpose. Predetermined elemental time standards such as Methods-Time-Measurement, Work Factor, Basic Motion Time Study or Motion Time Analysis will give as accurate a measure of the real time which would be required as an elaborately staged and thoroughly rehearsed single sample problem without allowances for fatigue. The requirement, as stated, is poor industrial engineering and should be dropped from the specification as a test. The requirement can be stated and the designer should be required to report anticipated times. The government should reserve the right, however, to require proof of operational feasibility.

B-5. PUSHING AND TOWING

"Loaded shipping containers, weighing more than 150 pounds, 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 non-skidded containers."

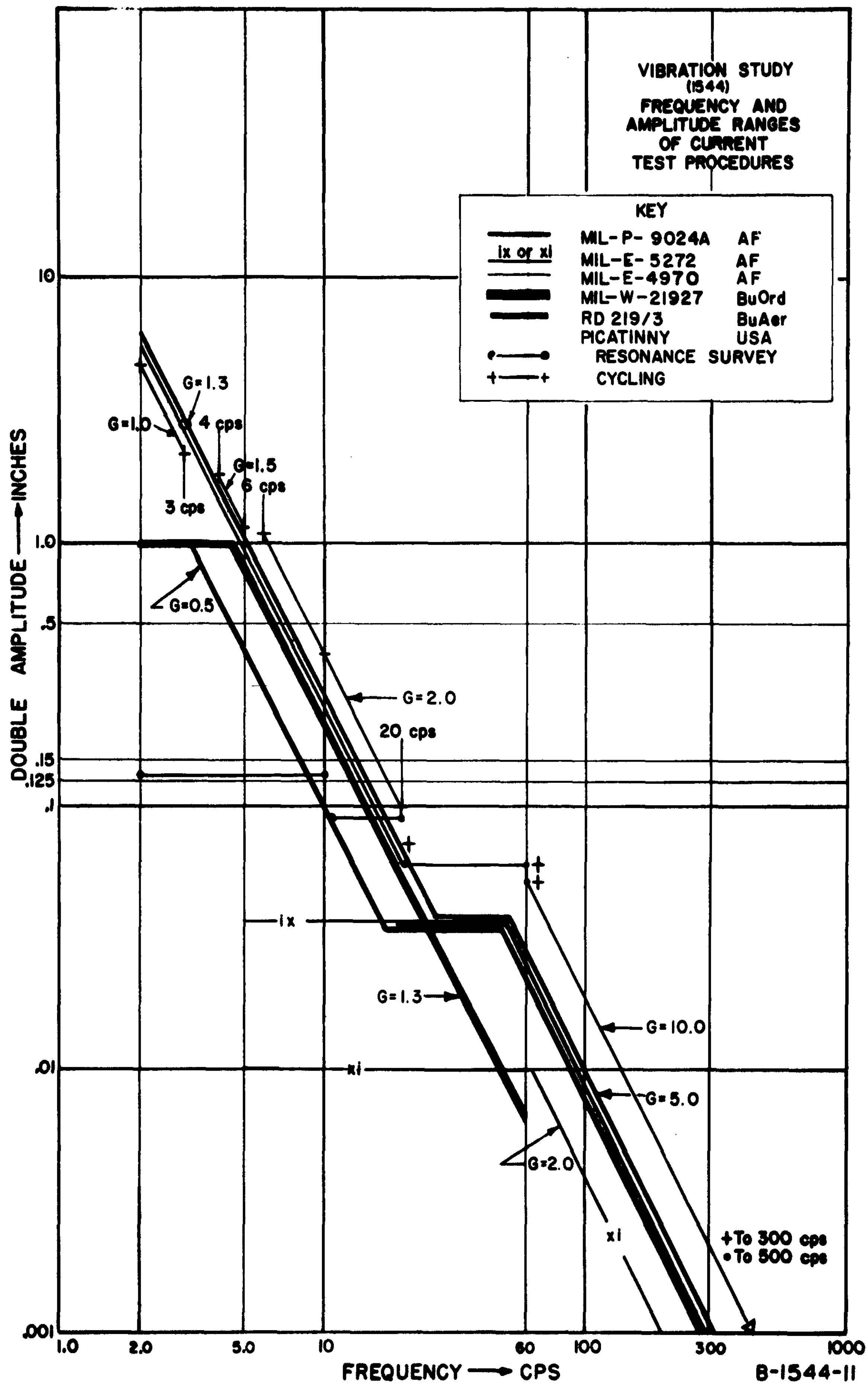
Aside from the fact that the phrase "rough concrete" needs further definition, this requirement does exist and is recommended for universal adoption. Data are not available however, concerning whether 5' is the best distance for this test. Presumably, the probability is that, should strength be inadequate, failure will occur sooner rather than later. This appears logical since static friction coefficients are normally larger than dynamic. In order to define rough concrete we could add the parenthetical phrase "(brush finish)".

C. VIBRATION

All progressive package designers agree that there is no way in which the service performance of a new design can be predicted in the laboratory without including some simulation of the vibrations encountered in shipment. This statement is as true of commercial packages as it is of military packages. In fact, it is standard practice to precede handling tests with a vibration test if only to measure the performance of the container in a more realistic configuration. When so used, the test can be considered as a part of the conditioning process.

Vibration isolation in missile shipping containers calls for maximum skill on the part of the container designer, particularly when one considers that a suspension system also must perform as a shock isolator. Designing to provide for satisfactory isolation of large, infrequently occurring, transients and smaller frequently occurring "steady state" phenomena demands a compromise between design goals which are essentially incompatible, except in special cases.

As of this writing, shipping vibration tests required by the government are all of the sinusoidal type. Study discloses, however, that there are almost as many tests as agencies capable of imposing the test. Figure B-1544-11 compares the seven more common tests. This figure does not include those previously required by various Bureau of Ordnance field activities prior to issuance of Specification MIL-W-21927 (NOrd). Nor does the figure include those tests which are primarily designed to test equipment (e.g. MIL-STD-167, MIL-T-18404, MIL-E-5400, MIL-T-945, MIL-STD-353). The procedures of MIL-E-5272 and MIL-E-4970 (also intended to be equipment tests) have, however, been included. They sneak in as shipping container tests in a manner often unsuspected by those responsible for package design and development.



VIBRATION STUDY
(1544)
FREQUENCY AND
AMPLITUDE RANGES
OF CURRENT
TEST PROCEDURES
KEY
MIL-P-9024A AF
ix or xi MIL-E-5272 AF
MIL-E-4970 AF
MIL-W-21927 BuOrd
RD 219/3 BuAer
PICATINNY USA
RESONANCE SURVEY
CYCLING
G=1.3
G=1.0
4 cps
G=1.5
6 cps
3 cps
G=0.5
G=2.0
20 cps
ix
G=1.3
G=10.0
xi
G=5.0
G=2.0
xi
+To 300 cps
•To 500 cps
DOUBLE AMPLITUDE → INCHES
10
1.0
.5
.15
.125
.1
.01
.001
1.0
2.0
5.0
10
60
100
300
1000
FREQUENCY → CPS

B-1544-11

As an example of this approach, we are aware that, in the ballistic missile program, the phrase "transit case" in MIL-E-4970 paragraph 4.6.8 has sometimes been interpreted by Space Technology Laboratories as meaning shipping container even though such is not sound packaging terminology and in spite of the fact that paragraph 4.6b specifically eliminates "equipment prepared for logistic or supply shipment and delivery."

The reader should also note that Air Force Specification MIL-P-9024A vibration test information is given in Figure B-1544-11. The latest version (MIL-P-9024B) has abandoned a laboratory vibration test but relies on a shipping test with a "suitable" vibration test as an alternate. Single sample shipment testing is time consuming and, because of the small sample, of exceedingly dubious validity.

Now any rational test could be the basis for a standard test. To determine standardization potential, one must answer two questions:

(a) Is standardization necessary or desirable?
(b) Is standardization possible?

The answer to (a) is emphatically yes. With minor exceptions all missile containers are being tested for exposure to essentially the same environments, i.e. vibrations, encountered when shipping via truck, rail, ship or air. There is, therefore, no defensible excuse for knowingly continuing a situation which seems to have produced as many test procedures as technicians. As shown in Appendix I, Reed Research received 11 replies concerning the desirability of vibration test standardization. Of these 11, 9 urged test standardization, 1 had minor reservations and 1 indicated no experience.

The answer to question (b) must be given in two parts:

(1) Standardization now is possible on an arbitrary basis if certain postulates are accepted.
(2) It appears possible to devise a standard form of test with quantitative confidence that it will predict service performance provided certain further investigations are undertaken.

Under a separate contract with the Bureau of Naval Weapons, the contractor has made a study in depth of a realistic approach to the shipping container vibration test problem. Because of the complexity of this problem, it was deemed expedient to withhold this standardization study report until such time as the results of the vibration test study were in hand. The report of the results obtained (some 80 pages with 19 figures and 33 references) has been issued as Reed Research Report 1175-36 dated 25 February, 1960 and is titled Theoretical and Practical Bases for Specifying a Transportation Vibration Test. Because the complete presentation is in the cited report, only a brief summary of the main line of reasoning will be given here.

The basic problem is to establish a theoretical basis for a transportation vibration test assuming that a valid statistical description of the environment exists and then examining what practical compromises are necessary to permit performance of any test now. Even to go this far we must proceed from two assumptions:

a. The <u>standard</u> shipping container vibration test can only be expected to evaluate shipping containers. In other words, one is testing performance of the isolator system, not performance of the missile. In effect, this assumption means that we will concentrate the container specification on the container leaving "trick" frequencies and amplitudes as a problem for the missile designer. If they exist, supplementary requirements may be written to permit one test to serve several functions, but are not properly a part of a general container design criterion. If we do not have a reliable suspension, then effects in the higher modes are academic.

b. Any test is a simulation not a duplication of the environment. In a laboratory test, the time scale is reduced and, most frequently, severity is increased to compensate. A significant aspect of the problem is to simulate realistically.

For a vibration test to have any validity whatsoever, it is essential that test response amplitudes exhibit a known relationship to field response amplitudes. First, therefore, it was necessary to determine what the field response amplitudes would be. After prolonged and difficult, although straightforward, mathematical analysis, it was found that

$$\sigma_r^2 = \frac{1}{8\omega_n^3 \zeta \left(1 + \frac{2\zeta}{B_1}\right)} S_{ia}(\omega_n)$$

where

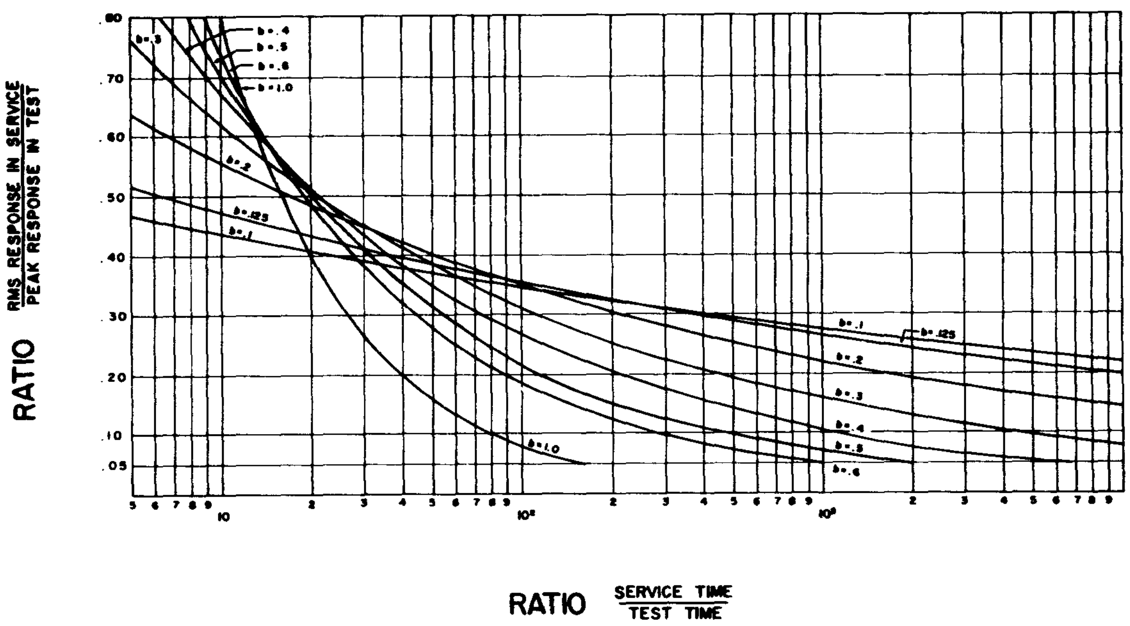
σ_r = root mean square relative motion of the object in its suspension system.

ω_n = natural frequency of the suspension.

ζ = ratio of damping to critical damping in the suspension system.

B_1 = bandwidth of input vibration near the natural frequency of the suspension.

$S_{ia}(\omega_n)$ = input acceleration spectral density corresponding to the suspension natural frequency.



EFFECT OF VARYING AMPLITUDES ON TEST TIME

The general field environment can be expected to persist for a long time. To permit accelerated testing, it is necessary to introduce from other fields of vibration analysis the concept of cumulative fatigue. When fatigue data are plotted on log-log paper (log-log S-N) curves, and the necessary mathematical operations are carried out, one arrives at the following complete expression of the ratio of test time to service life

$$\frac{t_T}{ct} = X_{rT}^{-\frac{1}{B}} \left(\sqrt{2}\, \sigma_r \right)^{\frac{1}{B}} \cdot \Gamma\left(1+\frac{1}{2B}\right) \left[1 - \frac{\gamma\left(1+\frac{1}{2B}, K\right)}{\Gamma\left(1+\frac{1}{2B}\right)} \right]$$

where

t_T = test time

t = service time

c = an empirical constant reflecting deviation of the suspension system from ideal linear damage accumulation hypotheses.

X_{rt} = response amplitude in test

B = slope of the S-N curve expressed in units of motion

K = an empirical parameter reflecting the endurance limit of the suspension system.

$\Gamma(n)$ = the complete gamma function

$\gamma\ (n,k)$ = the incomplete gamma function

Values for the complete and incomplete gamma functions are available in the literature and, therefore, solution of the equation is feasible for known input parameters.

It is interesting to compare the effects of varying test amplitudes on test times. For a specific package design, the extensive modifiers will remain constants.

$$\frac{t'_T}{t''_T} = \left(\frac{X''_{RT}}{X'_{RT}}\right)^{\frac{1}{B}} = \left(\frac{X''_{it}}{X'_{it}}\right)^{\frac{1}{B}}$$

in which

t'_T = test time at first amplitude
t''_T = test time at second amplitude
X'_{RT} = first response amplitude
X''_{RT} = second response amplitude
X'_{it} = first input amplitude
X''_{it} = second input amplitude

It is appropriate to review, at this point, what the theoretical approach does and does not tell us. The equations quoted indicate that:

a. For a specific package a quantitative relationship between sinusoidal test time and service life in a random environment can be computed if:

1. Suspension systems follow the cumulative damage hypotheses and provided, further that:

(i) The slope of and at least one point on the S-N curve for various materials can be found experimentally.
(ii) The level of the endurance limit, if it exists, can also be found.
(iii) Suitable values to use for Miner's cumulative fatigue constant can be found.

2. The response characteristics of the particular package in the field environment can be determined. Note that σ_r is a function of system damping and input characteristics.

3. Adequate descriptions of the environment are available. These descriptions must include acceleration spectral density, bandwidth and time. Unless we have these, we cannot compute σ_r nor can we compute K .

Since we do not now have the critical information shown above, it would appear at first glance that further progress towards standardization is impractical. But this is true only if we insist that we must have, now, a quantitative service life prediction. There are, however, certain other teachings implicit in the equations quoted. These are:

1. A sinusodial test can provide adequate simulation of a random environment.

2. The time of test can be varied provided there be a concomitant variation in test response amplitude. The minimum such amplitude should be such as to produce a stress greater than the endurance limit. The maximum is the one time failure stress. In practice, other considerations such as available clearance should probably govern.

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

These three major factors permit logical simplification of the confusion engendered by the conflicts inherent in Figure B-1544-11.

However it must be recognized that actual standardization is only possible if certain arbitrary postulates be accepted. We proceeded on the assumptions that the following are self-evident:

a. A test written as a specification requirement today must be capable of performance on equipment available today. If not capable of performance, it dies from non-use. Besides, how could it be a quasi-legal basis for acceptance or rejection under contract?

b. Since it is clear that some arbitrary decisions must be made, it is possible for all concerned to be arbitrary in the same way.

While existing data show that very high frequencies can be encountered in transportation, consideration of probable lowest natural frequencies to meet drop test criteria indicates that testing above 60 cps is essentially a waste of time. Low limit on frequency appears to be on the order of 2 cps.

Our theoretical study indicated that there is no input amplitude function (such as displacement-frequency or, acceleration-frequency) which would result in equal life expenditure for every suspension system. Thus, the specification writer's ideal of a simple test applicable to all suspensions is a will-o'-the-wisp. On the other hand, any reduction in the variety of tests currently prescribed is an obvious desideratum.

The equations given above show that input amplitude can be varied depending upon the response characteristics of the item on its suspension.

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*Sub-harmonics presumed not to occur.

These response characteristics (σ_r), are, in turn, functions of the acceleration spectral density, $S_{ia}(\omega_n)$. In the absence of statistical measures of $S_{ia}(\omega_n)$ we do not have a logical basis in theory for stipulating test time or response or input amplitude. While it should be possible eventually to obtain this information, and the results of such knowledge acquisition may be totally different amplitudes from those now specified, it is illogical to force vibration testing equipment development along a road, the direction and length of which cannot begin to be estimated at this time. That is to say, we have no right to ask for more capacity than is available until we know we need it.

In furtherance of this thought, therefore, we investigated the capacity of various commercially available vibration testers. One point that stands out above all others is that there is only one shaker which can cover all the amplitudes and frequencies shown in Figure B-1544-11 to be currently required between 2 - 60 cps.*
When amplitudes are restricted to those producing an acceleration of 1.3g on 5,000 lbs. gross weight, the Wyle W-1000 type can perform at all frequencies.** Maximum acceleration output, at 5000 lbs. gross for the MB HC-50 hydraulic types is 1g.

Obtaining more than 1 inch double amplitude below 5 cycles per second is a very expensive endeavor. As it now stands, the only location where this could be done today is at Norair Division, Northrop

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*This is the Northrop electro-hydraulic system of which the Wyle company is a licensee for the shaker components. Northrop has estimated that development costs for their system were around $700,000.00 and the cost of duplication of their facility would be about $300,000.00.

**An informal cost estimate from Wyle for a system of this nature is $48,000 and 6 months delivery.

Corp., Hawthorne, California* which would add considerably to the cost of testing a container designed and fabricated east of the Rockies. Let us, therefore, look a little more closely at the requirements of those specifications which ostensibly call for double amplitudes in excess of 1 inch. Such a procedure discloses the following:

a. MIL-P-9024A and MIL-E-4970A show the very high double amplitudes below 5 cps identified in Figure B-1544-11. Both MIL-P-9024A and MIL-E-4970 permit significant deviation as exemplified by the following from paragraph 4.6.8.1 of MIL-E-4970A: "...........at a suitable sweep frequency rate and with a vibratory double amplitude or a peak acceleration input of sufficient magnitude to establish significant resonant frequencies."

b. Picatinny Arsenal's procedure states "When the natural frequency lies in the 2 - 20 cps range input when cycling through resonance shall be reduced to those values listed in the resonance test for 2 cps below to 2 cps above the resonant frequency." Hence, for resonant testing in the low range, the double amplitude is really 0.13 inches.

c. Until quite recently, there were no commercially available equipments which could shake a container through an approximately 8 inch stroke. Hence, most previous tests have been run at 1 inch double amplitude obtainable from the standard package testers covered by ASTM D999-48T.

*Northrop has expressed willingness to make time available on their machine to others and has stated that, once accepted, outside tasks will have equal priority standing with in-house work.

In view of the foregoing, practically no vibration tests have been run at a double amplitude in excess of 1.0 inches and yet the vast number of tests which have been run at this amplitude gives an indirect measure of confidence that can be relied upon in a very large number of cases.* We have machines available to us which will vibrate at this amplitude between 2.5 and 5 cps, the L.A.B. and Gaynes package testers. With minor changes in pulleys, the machines can be modified to operate between 2 and 4.5 cps. As will be brought out later, 4.5 cps (1g at 1 inch double amplitude) is considered high enough. Aside from the fact that most tests have been run at this amplitude, this simple change makes it possible to substitute a machine costing around $5,000 max. for one costing almost 10 times as much. This, then, represents our recommendation for the 2 - 4.5 cps. range.

Over 4.5 cps one must choose between the 1.5 g stipulated by Picatinny up to 7 cps, the 1.3 g of MIL-P-21927 (NOrd, MIL-P-9024A and MIL-E-4970 and some of the lesser units. Here we take the view that the maximum practical number of machines

*There is no way one can avoid the implications of the National Safe Transit Committee program. One of the authors has personally conducted such vibration tests many times. Among other things that have been predicted successfully and cures found in the laboratory, are vibration damage to TV sets and electronic organs, fatigue failures of an overloaded shock mount system, fretting corrosion damage to empty aluminum foil dinner trays, improved design of hot water heaters, causes of shipment damage to large electron tubes, etc. The basic NSTC procedure is not as bad as some people think. When properly used, and interpreted, it can be and is a powerful tool.

should be usable. Looking briefly at the machines capable of 5,000 pounds force output we find an awkward gap between 4.5 cps and 5 cps at the 1.3g level (assuming that the L.A.B. machine has been modified to get down to 2 cps) where only one machine in existence can produce the necessary frequency and amplitudes. This same gap exists all the way down to 100 pound capacity machines.*

Over 5 cps, at 5,000 lbs. MB C70 and Ling 246 have the theoretical capacity. If we drop the input to 1g, however, we bring into the picture the MB HC50 family of hydraulic shakers plus Royal Jet's special and, above 5 cps, the whole family of MB electromechanical shakers. In other words, stipulating 1g above 4.5 or 5 cycles per second results in maximum machine availability for performing the necessary tests. Of particular importance, the MB line of machines is made usable. Regardless of any merits or demerits of these particular devices, the MB concern has sold more of their machines than any other company, partly because they were among the very first in the field. In the absence of a statistically sound description of the environment, we can see no compelling reason for eliminating the majority of available devices from consideration just because of a statistically questionable interpretation of that environment. We therefore recommend an equally arbitrary decision setting the amplitude at 1g between 4.5 and 60 cps. The complete frequency amplitude spectrum recommended as a possible standard is shown in Figure B-1544-4.

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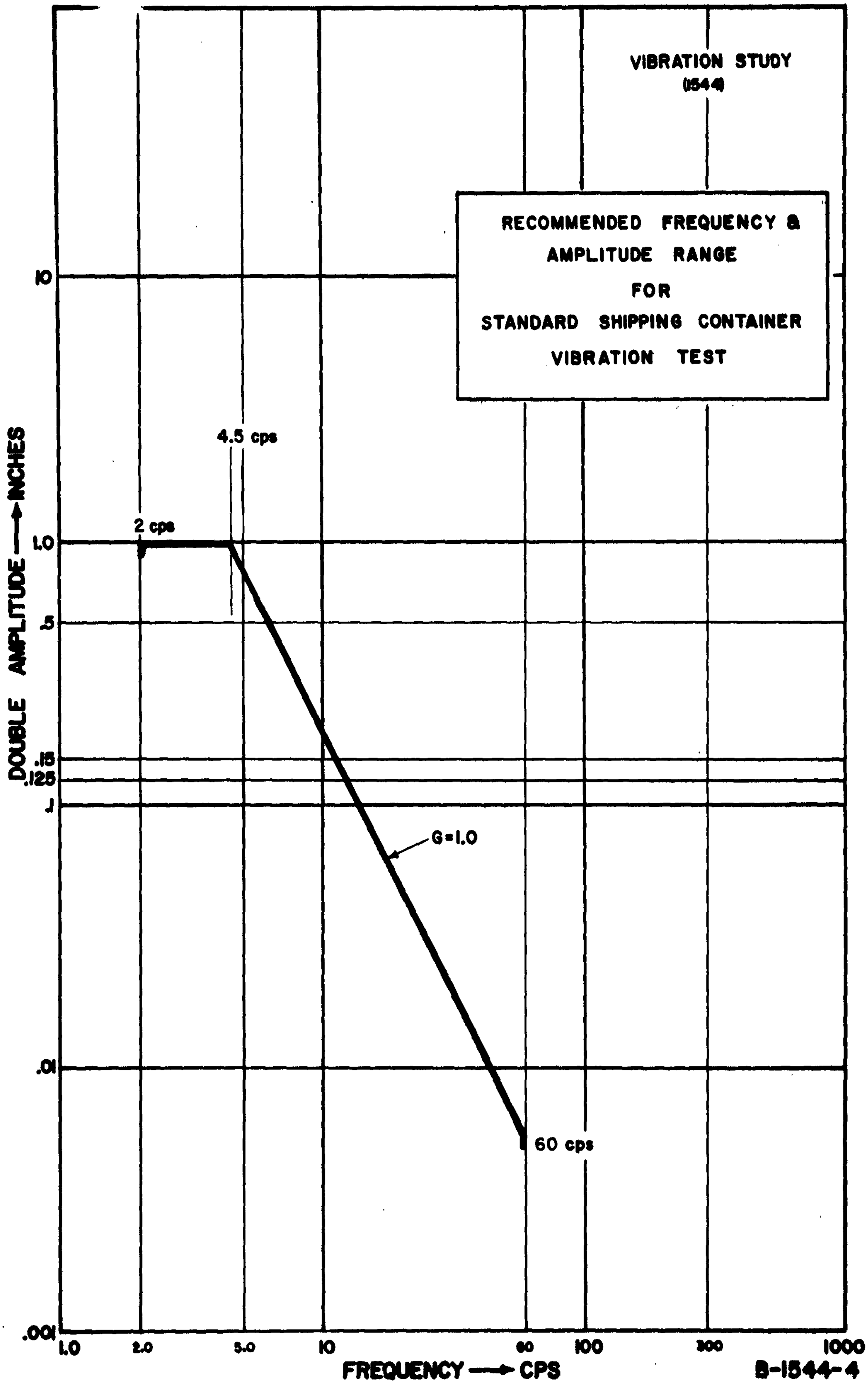
*This gap is not always present. Thus, it is possible to modify a "package tester" so that it will cover both 2 and 5 cps. Further, at 5,000 lbs. the Ling and MB machines might be run down that extra 1/2 cycle. If the load is considerably less than maximum capacity, one does have a chance of covering the gap with a machine of considerably greater capacity than would normally be rated for the job.



VIBRATION STUDY
(1544)
RECOMMENDED FREQUENCY & AMPLITUDE RANGE FOR STANDARD SHIPPING CONTAINER VIBRATION TEST
DOUBLE AMPLITUDE → INCHES
10
1.0
.5
.15
.125
.1
.01
.001
4.5 cps
2 cps
G=1.0
60 cps
1.0
2.0
5.0
10
60
100
300
1000
FREQUENCY → CPS

B-1544-4

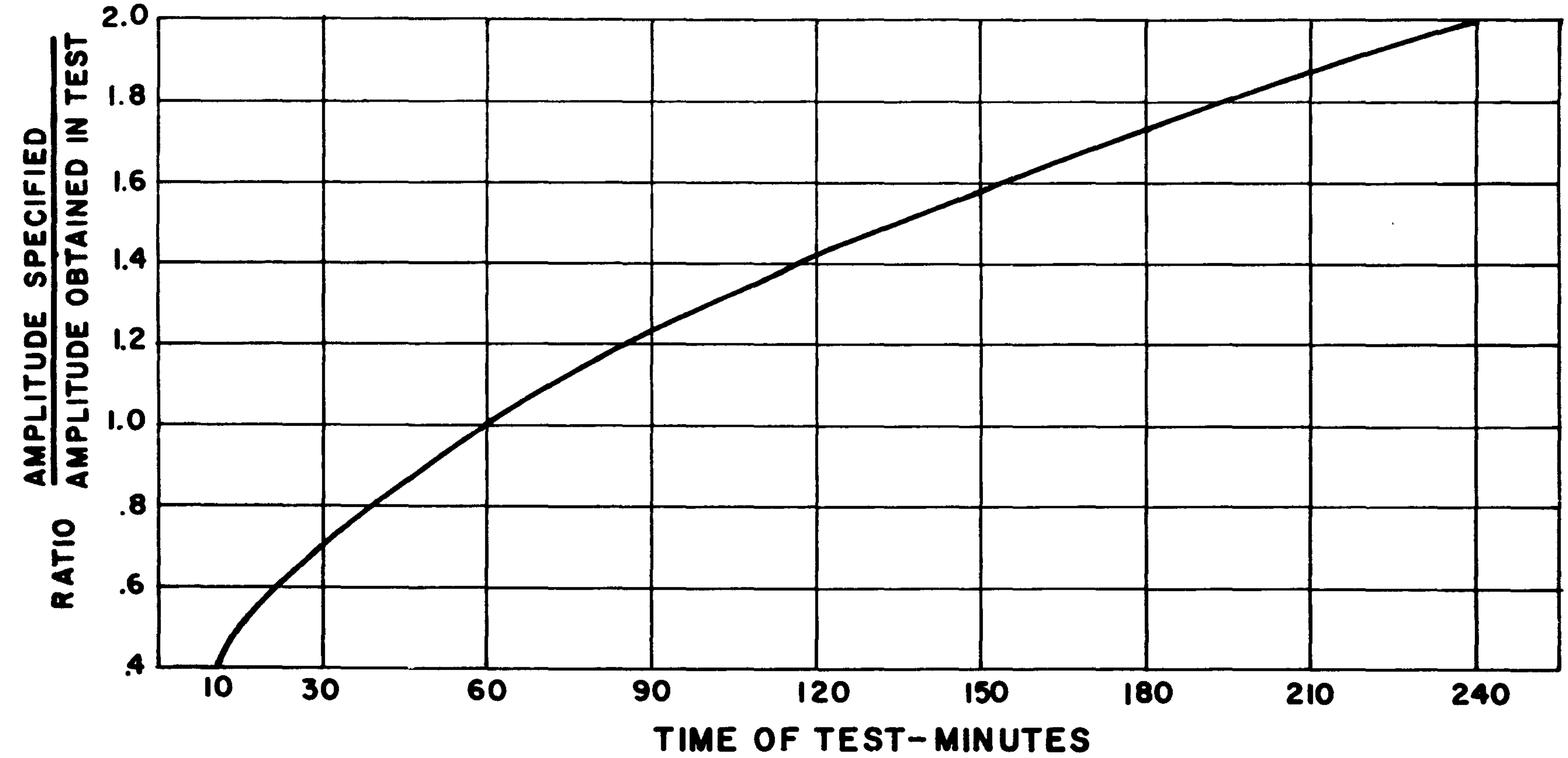
Time at resonance varies among the various procedures with 1/2 hour at the 1.3g level being fairly common. In view of the theoretical approach, we should specify a greater time for the lower amplitudes which are recommended here. In connection with this point, we cannot see why missile containers should be tested to a lesser severity than commercial containers. Inasmuch as the National Safe Transit Committee procedures call for 1 hour at or near resonance, we likewise recommend one hour when testing to the syllabus recommended.

Now the frequency-amplitude spectrum recommended is concerned with these values as measured adjacent to the mounts or cushion centroids. There are a number of practical reasons why it is not always possible to obtain these amplitudes in practice unless one restricts one's self to the very few testers which can move the entire container. One method of obtaining equivalence while still permitting flexibility on the testing floor is to equate total input work. Since work for a given sine wave cycle is conveniently measured by the mean square amplitude, we find that total work is the same when the ratio of test time is inversely proportional to the mean square amplitudes, or

$$\frac{t'_T}{t''_T} = \left(\frac{X''_{IT}}{X'_{IT}}\right)^2$$

This expression is the same as the theoretical ratio previously derived simply through setting $B = \frac{1}{2}$. By the cumulative damage hypotheses, this relation is valid in the range X_{it} = at least large enough to produce a stress exceeding the endurance limit to X_{1t} = the maximum one time stress the isolator can withstand. In practice, however, input amplitude need not be less than 1/2 that stipulated. While considerable excess amplitude can sometimes be obtained, a 10 minute period would appear to be a practical minimum.

SUGGESTED TIME OF TEST AT AMPLITUDES DIFFERING FROM THOSE GIVEN IN B-1544-4



A-1544-14

The curve of Figure A-1544-14 is the logical result of the foregoing considerations.

Recommended Language for A Standard Test

With the above reasoning in mind, it is possible to write a test procedure requirement which could be adopted as standard and which approaches our self imposed criteria. This proposed language follows:

Basic Test

The container, loaded with its contents or with a dummy of equal weight and equivalent principal moments of inertia, shall be vibrated in such a fashion as to discover the frequency producing the maximum transmissibility within the frequency range of 2 to 60 cycles per second. The container shall then be suitably fastened (maximum permissible motion freedom approximately 1/32nd of an inch) to the table of a vibration testing device producing an essentially sine wave motion and vibrated for one hour at the frequency producing maximum transmissibility and at the double amplitude shown in Figure B-1544-4. In the event that a specific natural frequency is not found in the range indicated, the container shall be vibrated at a frequency of 268 cycles per minute for a period of one hour.

The test shall be applied to each of the three principal orthogonal axes of the shipping container except that when containers are equipped with a definite base, defined by skids or equivalent, vibration inputs shall be applied only through such base. This test shall preferably be applied just before any required shock tests.

Permissible Alternates

a. When a device, such as one meeting ASTM specification D996, is used for frequencies less than 5 cycles per second, the horizontal motion inherent in such machines is acceptable. Wherever possible, however, machines shall be adjusted to produce "vertical-linear" motion.

b. When testing devices are not available to produce the required double amplitude over the entire container, alternate methods will be acceptable provided the motion at the locations of mounts (or the centroids of each cushion on either side of the item center of gravity) is the same as that specified. A test procedure which places one end of the container on a pivot while the other end is moved is also acceptable provided the position of the vibration generator is changed from one end of the container to the other as rapidly as possible halfway through the test.

c. Variations in stipulated double amplitudes are permitted provided that the time of test be adjusted in accordance with Figure A-1544-14. The minimum time at resonance shall be 10 minutes and the maximum time at resonance shall be 4 hours.

D. SHOCK

A complete container is supposed to provide shock protection for the contents and be capable of resisting shock effects on its own structure. Shock has been defined as a transient phenomenon associated with a sudden change in speed or direction of motion. Environmental shocks on containers (excluding the near miss by enemy action or earthquake motions) result from starting or stopping of the transport vehicle, hoisting and lowering and the accidental drops more correctly associated with the phrase rough handling.

In view of the nature of shock, as just defined, it is clear that environmental shock can be simulated in the laboratory by drop and impact tests which, ideally, should be set at a level of severity representative of the environment. This representation should not be of the average condition, but rather, of an extreme value which may reasonably be expected during some significant fraction of the possible journeys. This being so, there should be some agreement concerning the types of tests and their severity for missile containers which are to be exposed to essentially the same environments. Our study shows, however, that there is wide disparity in tests used and even where the tests are similar, little agreement on the severity of the test to be used. This section discusses these problems and suggests a direction in which greater standardization could be sought.

Appendix I contains numerous comments on shock testing offered by industry and will be referred to several times. It is appropriate to note that present lack of standardization produces considerable confusion. Our study shows several different specifications being used to control the vital shock parameter and wide variation in shock intensities prescribed for differing sizes and weights of containers.

D-1. SPECIFICATION COMPARISON

Shock tests are performed by various forms of drop and/or impact. The forms of test used are:

a. Free fall drop onto a flat face of a container
b. Free fall drop onto one or more corners of a container
c. Rotational drops with one end pivoted above the floor and the opposite end edge allowed to hit the floor
d. Same as c except impact is on a single corner at a time
e. Horizontal (with reference to the container) translational impact into a relatively rigid barrier (pendulum impact or incline plane)
f. Tip over test.

Each of the specifications referenced for controlling these inputs has been analyzed. In order to permit comparison, all tests (except f) were placed on the common basis of equivalent height of drop of the center of gravity, assuming the center of gravity to be in the geometrical center of the container. Thus, flat and cornerwise drops are made equivalent (insofar as energy is concerned). Rotational drops, pendulum, and incline impact tests were converted to equivalent drop heights by use of the following:

Rotational Drops: $h = \frac{X_1}{L} h_1 = .5 h_1 \; (X_1 = .5L)$

Pendulum Impact: $h = \frac{V^2}{2g}$

Incline Plane: $h = d \; \mathrm{SIN} \; 10° = .174 \; d$

where

h_1 = height of drop of one end (ins.)

X_1 = distance from pivot to projection of c.g. on base (ins.)

h = overall length (ins.)

V = velocity at impact (ins./sec.)

g = 386 ins./sec. 2

d = distance up incline, ins.

Results of these comparisons are shown in Table D-I for maximum drop height. Note that MIL-P-9024 is not referenced in this table since it refers, in turn, to MIL-P-7936. This table shows that differences between the various specifications are somewhat random in nature except that, with MIL-W-21927 (NOrd), the specified 12 ft.sec. impact speed becomes the dominant design criterion when the gross weight exceeds severity as gross weight increases. Differences are, however, found in the specifications concerning the container length maximum at which one should shift from a free fall form of test to a rotational test. MIL-W-21927 (NOrd) changes at 36", MIL-P-116 at 60", MIL-P-7936 at 48", 60" and 72" (depending on weight) and MIL-E-4970 differentiates only in weight.

Experience has shown that many containers fail progressively. Hence, in comparing requirement severity, the total impact energies must also be compared. This is accomplished in Table D-2 where the energy is summed in the form of total number of inches of drop. This table shows that, surprisingly, MIL-W-21927 (NOrd) is (under 60 inches long and under 200 lbs. gross) less severe cumulatively than all the specifications except MIL-E-4970, which is basically designed to evaluate ground equipment, not shipping containers.

In connection with the overall analysis, recommendations were sought from industry correspondents concerning recommended flat drop heights for containers. During the course of the study, the results of an Aerospace Industries Association survey on reusable containers (AIA PPC 59-10) were made available to Reed Research. The results of this survey as well as the results of a review of six different specifications in terms of flat drop are summarized in Figure D-1.

As will be developed more fully in the ensuing discussion, it is neither necessary nor desirable that all missile containers be tested in the same way. Such a procedure would wind up in the rather ridiculous idea that the Saturn engine should always be capable of transfer-at-sea.

Nevertheless, it is self evident that the existing plethora of requirements simply must be reduced in number. Further, there is no logical basis for different performance requirements so long as logistic patterns are essentially the same. In approaching the problem of achieving standardization in this area, this contractor feels that no useful purpose would be served by attempting to pick one of the existing specifications in preference to another. For example, no one is in a position to quarrel with the underlying thesis of MIL-W-21927 (NOrd) as being applicable to missiles to be transferred at sea. On the other hand, MIL-P-116 and MIL-P-7936 were written (at different times) to control general spares packaging and specialty containers for specialty items simply are inadequately covered (e.g. no vibration test).

We believe that standardization can be achieved by breaking with past tradition through preparing a set of test requirements applicable to

TABLE D-I

Maximum Drop Heights
From Specifications

Gross Weight Groups (pounds)		Maximum Dimension (inches)		Maximum Drop Heights (Inches)				
Equal to or more than	less than	More Than	Less Than	MIL-W-21927	MIL-P-116*	MIL-P-7936 Level A	MIL-P-7936 Level B	MIL-E-4970
0	20	0	36	36	30	30	22	42
0	20	36	48	18	30	21	16	42
0	20	48	60	18	30	18	14	42
0	20	60	72	18	15	18	13.5	42
0	20	72	114	18	15	12	9	42
21	50	0	36	36	30	30	22	36
21	50	36	48	18	30	21	16	36
21	50	48	60	18	30	18	14	36
21	50	60	72	18	15	18	13.5	36
21	50	72	114	18	15	12	9	36
51	100	0	36	30	30	21	16	30
51	100	36	48	15	30	21	16	30
51	100	48	60	15	30	18	14	30
51	100	60	72	15	15	18	13.5	30
51	100	72	114	15	15	12	9	30
101	150	0	36	30	30	18	14	30
101	150	36	60	15	30	18	14	30
101	150	60	72	15	15	18	13.5	30
101	150	72	114	15	15	12	9	30
151	200	0	36	27**	30	16	12	30
151	200	36	60	27**	30	16	12	30
151	200	60	72	27**	15	18	13.5	30
151	200	72	114	27**	15	12	9	30
201	250	0	36	27**	15	18	13.5	30
201	250	36	72	27**	15	12	9	30
201	250	72	114	27**	12	18	13.5	24
251	500	0	36	27**	12	12	9	24
251	500	36	72	27**	12	12	9	24
251	500	72	114	27**	12	12	9	24
501	600	0	72	27**	9	18	13.5	12
501	600	72	114	27**	9	12	9	12
601	1000	0	114	27**	9	12	9	12
1001	3000	0	114	27**	6	12	9	12
3001	4000	0	114	27**	6	9	9	12
4001	∞	0	114	27**	6	9	9	12

* Packs exceeding 100 pounds which are secured to the bases of the container are tested as indicated for packs exceeding 200 pounds.

** Height controlled by impact test requirements.

TABLE D-2

Cumulative Drop Heights
From Specifications

Gross Weight Groups (pounds)		Maximum Dimension (inches)		Cumulative Drop Heights (Inches)				
Equal to or more than	less than	More Than	Less Than	MIL-W-21927	MIL-P-116	MIL-P-7936 Level A	MIL-P-7936 Level B	MIL-E-4970
0	20	0	36	216	240	240	176	126
0	20	36	48	108	240	168	128	126
0	20	48	60	108	240	144	112	126
0	20	60	72	108	88	108	90	126
0	20	72	114	108	88	84	72	126
21	50	0	36	216	240	240	176	108
21	50	36	48	108	240	168	128	108
21	50	48	60	108	240	144	112	108
21	50	60	72	108	88	108	90	108
21	50	72	114	108	88	84	72	108
51	100	0	36	180	240	168	128	90
51	100	36	48	90	240	168	128	90
51	100	48	60	90	240	144	112	90
51	100	60	72	90	88	108	90	90
51	100	72	114	90	88	84	72	90
101	150	0	36	180	240	144	112	90
101	150	36	60	90	240	144	112	90
101	150	60	72	90	88	144	112	90
101	150	72	114	90	88	108	90	90
151	200	0	36	168	240	128	96	90
151	200	36	60	156	240	128	96	90
151	200	60	72	156	88	108	90	90
151	200	72	114	156	88	84	72	90
201	250	0	36	168	88	108	90	90
201	250	36	72	156	88	108	90	90
201	250	72	114	156	88	84	72	90
251	500	0	36	168	70	108	90	72
251	500	36	72	156	70	108	90	72
251	500	72	114	156	70	84	72	72
501	600	0	72	144	52	108	90	36
501	600	72	114	144	52	84	72	36
601	1000	0	114	144	52	84	72	36
1001	3000	0	114	144	34	84	72	36
3001	4000	0	114	144	34	60	54	36
4001	∞	0	114	132	34	60	54	36

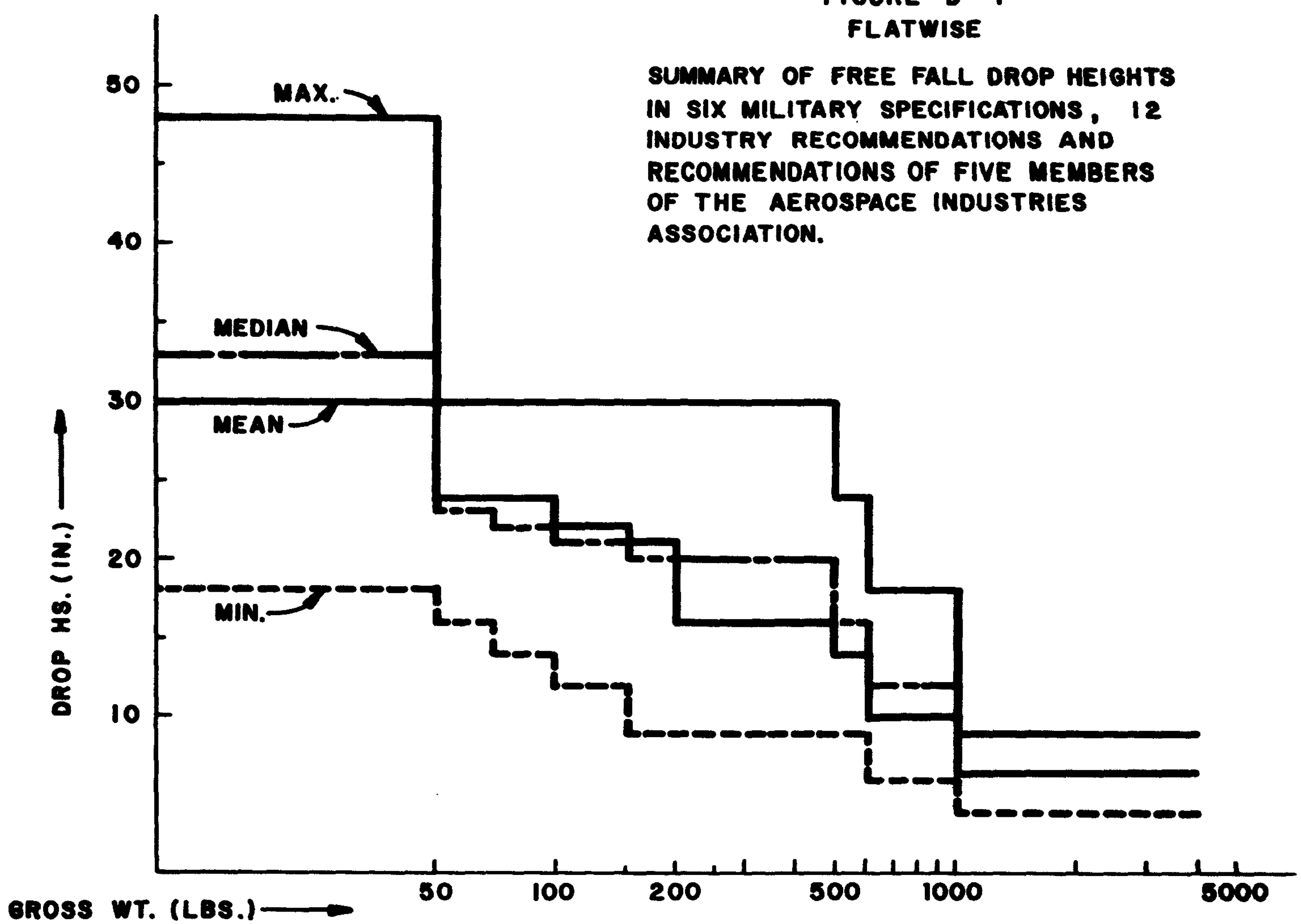


FIGURE D—1
FLATWISE

SUMMARY OF FREE FALL DROP HEIGHTS IN SIX MILITARY SPECIFICATIONS, 12 INDUSTRY RECOMMENDATIONS AND RECOMMENDATIONS OF FIVE MEMBERS OF THE AEROSPACE INDUSTRIES ASSOCIATION.

missiles and their components and never even mentioning the other general specifications. Since, in general, those charged with designing missile containers are not simultaneously designing spares containers, this would produce considerably less confusion than any other scheme.

Standardization will require certain agreements on common approaches to the problem. The sections which follow discuss areas in which such agreement appears logically possible.

D-2. LOGISTIC PATTERNS

First, since the container must be compatible with the distribution system applicable to the missile, it will be necessary for the various activities concerned to agree that there are categories of logistic patterns into which missiles can fall and that these categories have requirements sufficiently similar to permit standardization within the category. While almost any system will do, one method is to categorize by function and operating base. Such a possible categorization follows.

Case 1. Items will probably be shipped overseas in wartime and issued through the supply system to troops in the field in the immediate combat area. Multiple handling, including manual handling of smaller containers, is probable. Storage outdoors must be considered almost inevitable. Hence, true all weather capability is indicated.

Case 1A. Same as above, but contents hazardous to own personnel.

Case 2. Same as Case 1, except that the unit is unpackaged at a relatively well-developed rear area and transferred to a specialized launcher or transporter for delivery e.g., airplane, tank, etc., etc.

Case 2A. Same as Case 2, but contents hazardous to own personnel.

Case 3. Same as Case 2, except that transfer-at-sea intervenes. Overseas system involves reasonably good transfer and handling conditions.

Case 3A. Same as Case 3, but contents hazardous to own personnel.

Case 4. Shipment within the North American continent only, in containers.

Case 5. Shipment in specialized vehicles. Such specialized vehicles may include specially designed trailers or rail cars specifically modified to carry the load or specialized dollies or trailers used in air transport.

Attention is particularly invited to the parallelism that exists between Cases 1, 2, and 4 as defined above, and Class 1, 2, or 3 use, as defined in Specification PPP-B-585 for wirebound boxes, or the addition of Level D packing to Specification UU-S-48 for paper shipping sacks. Apparently the "classic" Level A, B, or C definitions have already broken down for some of the more prosaic commodities. Reed Research, Inc. can see, therefore, no logical objection to summarily abandoning the Level definition when considering the case of specialty containers for very high value items. This opinion is particularly buttressed by the usual interpretation of Level C as "standard commercial practice". Inasmuch as we are dealing, quite obviously, with a product for which there is no past shipment history, commercial or otherwise, the phrase "standard commercial practice" and any definition using such phraseology is essentially meaningless.

Having established five major cases it is now necessary to establish a grouping based on probable shock expectations. As a result of this analysis, we find:

a. Case 1 differs from Case 1A primarily in the margin of safety the designer should be willing to settle for. As soon as the gross weight exceeds authorized limits set forth in the Interstate Commerce Commission Regulations, the Bureau of Explosives tends to pass proof responsibility back to the Department of Defense and is willing to settle for reasonable proof of shipment capability under domestic conditions. Case 1, in general, therefore, calls for maximum performance capabilities in all weather. Specifically, the shock and vibration capability should be demonstrated not only under ambient conditions, but also under extremes of weather, such as high and low temperatures, high and low humidities, etc. Insofar as shock tests at room temperature are concerned, we consider that Cases 1 and 1A are the same unless the container itself is supposed to meet ICC specifications, which would then govern.

b. Similarly, we are unable to find justification for any substantive difference in the levels of shock test intensity at room temperature between Cases 1 and 2. Such differences as exist between these cases stem from the fact that exposure to extreme climatic conditions is simply not nearly so likely with Case 2 as it is with Case 1. For example, prolonged outdoor storage is not likely. Thus, exposure to 180 degrees F internal temperature is occasional, not regular. Similarly, performance under low temperature conditions does not have the same urgency as prevails in Case 1. Thus, the low limit for shock and vibration isolator performance could be set at -40 degrees F on a sound basis, provided exposure to say -65 degrees F does not result in brittle fracture. Reed Research, Inc. feels that most Navy and Air Force missiles will fall into this category. The trend is definitely toward more complex mobile launchers, whether on the ground, in the air, or under the surface of the water.

c. Case 3 becomes different from Case 2 because the rain, salt spray and water environment becomes emphatically more severe, approaching or exceeding Case 1. Nevertheless, low temperature environment for shock performance of shipboard missile containers and handling gear can be the same as for Case 2. The major difference between Case 2 and Case 3 is that, in the latter, units may slam against the relatively unyielding side of a ship.

Thus for room temperature shock tests, Cases 1 and 2 are, essentially, identical and specifications can be drawn accordingly. Case 3 is the same as Cases 1 and 2 with exception that, in addition to simulating rail humping hazards, one must also simulate possible bulkhead slamming.

d. Case 4 would appear to be similar to what has been called Level B in military policy, although the definition officially given to Level B defies objective analysis. There are, it is true, fairly well established commercial testing cycles but, for the most part, they are comparative tools, rather than absolutes. The one so-called "go-no-go" testing cycle, the National Safe Transit Committee test, is generally considered to produce unreliable results when used for complex mechanical gear. These tests were, after all, devised for use with porcelain enameled ware.

e. Case 5 is invariably a special study situation which need not concern us for the moment.

A tentative breakdown, based solely on information available in the public press such as Missiles and Rockets, is shown in Table D-3.

True, the above breakdown is substantially along service lines but, if agreement were reached, it would be a functional one rather than an administrative one and would emphatically facilitate cross-servicing.

D-3. CONTAINER CLASSIFICATION

The next question to be resolved is some form of hazard classification. In the absence of any better data, it would appear as logical now, as it was when the first specification requirements were written, to classify containers as falling in one of the following categories:

a. One-man throwing
b. One-man carrying
c. Two-man carrying
d. Mechanical handling only

The category into which a container must be classified is dictated by the weight and geometry of the container, not by any expected environmental hazard. There apparently is considerable divergence of opinion concerning the specific weights which should be considered critical for differentiating between categories. There has also, except for the recommendations of Committee PP-5 summarized in the above, been a tendency to lump one-man throwing and handling into a single category. In the final analysis, Reed Research, Inc. feels that such lumping is not quite warranted. Human beings will toss or handle packages which they can handle with one hand somewhat more severely than those which require both hands to pick up. Differentiation between one-man throwing and one-man carrying remains, however, an essentially subjective decision. Most specifications set the amount at 25 pounds maximum. In the absence of compelling data to the contrary, it is suggested that the Government could, if it wished, establish a limit at 25 pounds without causing significant differences of opinion.

Similarly, there are few really objective means of determining what constitutes one-man carry or two-man carry. Not too many years ago, the critical weight value was considered to be 100 pounds. This limit was particularly noticed in the 100 pound shipping sack.

Today, most fertilizer manufacturers and similarly oriented companies consider 80 pounds to be the desirable maximum. On the other hand, most military specifications have placed a limit of 70 pounds on fibreboard boxes based on the assumptions that this is a one-man carry type of package. MIL-W-21927 (NOrd) on the other hand, has one weight group limit at 50 pounds. Certainly, in today's technology, it is possible to agree that 100 pounds is entirely too much weight to expect, reasonably, one man to carry and handle safely. On the other hand, 50 pounds seems to be well within the capabilities of any reasonably healthy man who would be assigned to package handling. 70-80 pounds is beginning to ask him to work a little. On the grounds of commercial favoritism plus historical

TABLE D-3
A Tentative Logistic Breakdown of Missiles

(Based Only on Information in Public Print)

Missile	Service	Basic Case	Missile	Service	Basic Case
Alfa	Navy	3	Nike-A	Army	2
Asroc	Navy	3	Nike-H	Army	2
Astor	Navy	2	Nike-Z	Army	4
Atlas	A. F.	5	Pershing	Army	2
Bomarc	A. F.	4 or 5	Polaris	Navy	2 or 4
Bullpup	*A. F.	2	Quail	A. F.	4
Bullpup	Navy	3	Redeye	Army	1
Bullpup	Marines	1	Redstone	Army	2
Cobra	*Marines	1	Regulus	Navy	4
Corporal	Army	2	Sergeant	Army	2
Claymore	Army	1	Shillelagh	Army	2
Davy Crockett	Army	1	Sidewinder	Navy	3
Eagle	Navy	3	Sky Bolt	A. F.	4
Falcon	A. F.	2	Snark	A. F.	4 or 5
Genie	A. F.	2	Sparrow	Navy	3
Hawk	Army	2	Subroc	Navy	2
Honest John	Army	2	SS-10	Army	1
Hound Dog	A. F.	4	SS-11	Army	1
Jupiter	Army/A. F.	2	Talos	Navy	3
LaCrosse	Army	2	Tartar	Navy	3
Little John	Army	2	Terne	Navy	3
Lulu	Navy	3	Terrier	Navy	3
Mace	A. F.	2	Thor	**A. F.	5
Matador	A. F.	2	Titan	A. F.	5
Minuteman	A. F.	4 or 5	Typhon	Navy	3
M-55	Army	1	Zuni	Navy	3

* Note differences in containers for same missile to permit cross servicing

** Airlift to U.K. is an exception

background in military specification requirements, it is suggested that consideration be focused upon setting the limit of one-man carry package at 75 pounds.

If we accept 75 pounds as the limit of one-man carry, it is reasonable that one should state that 150 pounds is the limit of two-man carry. However, simple multiplication is not always the correct answer and a compelling argument could be advanced to the effect that, if it is as big as 150 pounds, it is possible to get four men to carry it and then perhaps 200-250 pounds could be considered a logical limit to manhandling possibilities. One way in which this problem could be resolved would be to consider the size of the objects. Thus, if we have a container around 6 ft. long, it is quite easy to arrange for its being carried by four men (assuming the four men to be available). It is equally easy, and probably considerably cheaper in the long run, to arrange for some form of skids on such a container, however, so as to permit one man with a fork truck or a pallet truck to handle the container by himself. All things considered, therefore, Reed Research, Inc. feels that 150 pounds is the limit which we should consider as the maximum suitable weight of specialty containers for manhandling.

We believe it appropriate to require skids or other fork lift access for containers heavier than the "magic number" finally established as the threshold for machine type handling.

D-4. TESTING LEVELS - GENERAL

After the services have agreed on the breakdown of weight categories establishing the groupings of missiles, at least within the broad limitations indicated above - and we see no logical reason why agreement cannot be reached - then testing levels applicable to the individual categories can be established.

The actual level of testing intensity required to control the performance expected should, ideally, be based upon:

a. A statistical evaluation of the hazard probabilities, more particularly the hazards involving sudden velocity changes due to starting and stopping of vehicles, coupling of rail cars, and such random phenomena as accidental drops, etc.

b. Degree of reliability desired.

In other words, "What are the true hazards and, knowing this, how many components can we afford to damage?"

In setting up tests designed to evaluate, in the laboratory, probability of survival of a given container, the engineer must remember that the test should evaluate not only the shock isolation mechanism used, but also the structural integrity of the container itself. Thus, it is quite possible that, because of the difficulty of testing certain configurations in one manner (such as by a free fall drop test), it might be necessary to apply a shock test in a different fashion such as by pendulum impact, etc., etc. All other things being equal, these particular variations should be so designed as to produce the same basic maximum shock intensity and also, because containers tend to fail progressively, alternative tests should be so programmed as to produce the same total intensity over the test syllabus. One method of accomplishing this latter goal is to make sure that the approximate total energy input is the same throughout alternate tests.

D-5. INCLINE IMPACT TESTS

In connection with statistical studies of environment, one of the more useful analyses is that by J. M. Roehm (ASME Paper 52-SA-41, June, 1952). Distribution of coupling impact velocities is shown in Figure D-2.

The question immediately arises as to whether one may take some impact velocity as representative of the normal population of the curve, say for example 10 miles per hour, and simulate this coupling impact velocity accurately by the tests which were originally designed to do so. The answer must be a qualified no since the rail car is equipped with couplers and draft gear and the dynamic problem is more complex than that represented by tests which involve slamming the container into an unyielding surface. The discussion which follows is designed to show why this is so. The mathematical treatment is admittedly incomplete. It will, however, yield some insight into the general problem and indicate possible directions for ultimate solution on logical grounds.

Rail cars come equipped with many forms of couplers and draft gears having differing dynamic characteristics. To illustrate extreme conditions we will restrict our analysis to the case which is probably the most severe, i.e., a car weighing 69,000 lbs. empty, equipped with friction draft gear capable of 2 5/8 inches travel before bottoming. We will impact this car with various loads at various speeds into a train of cars

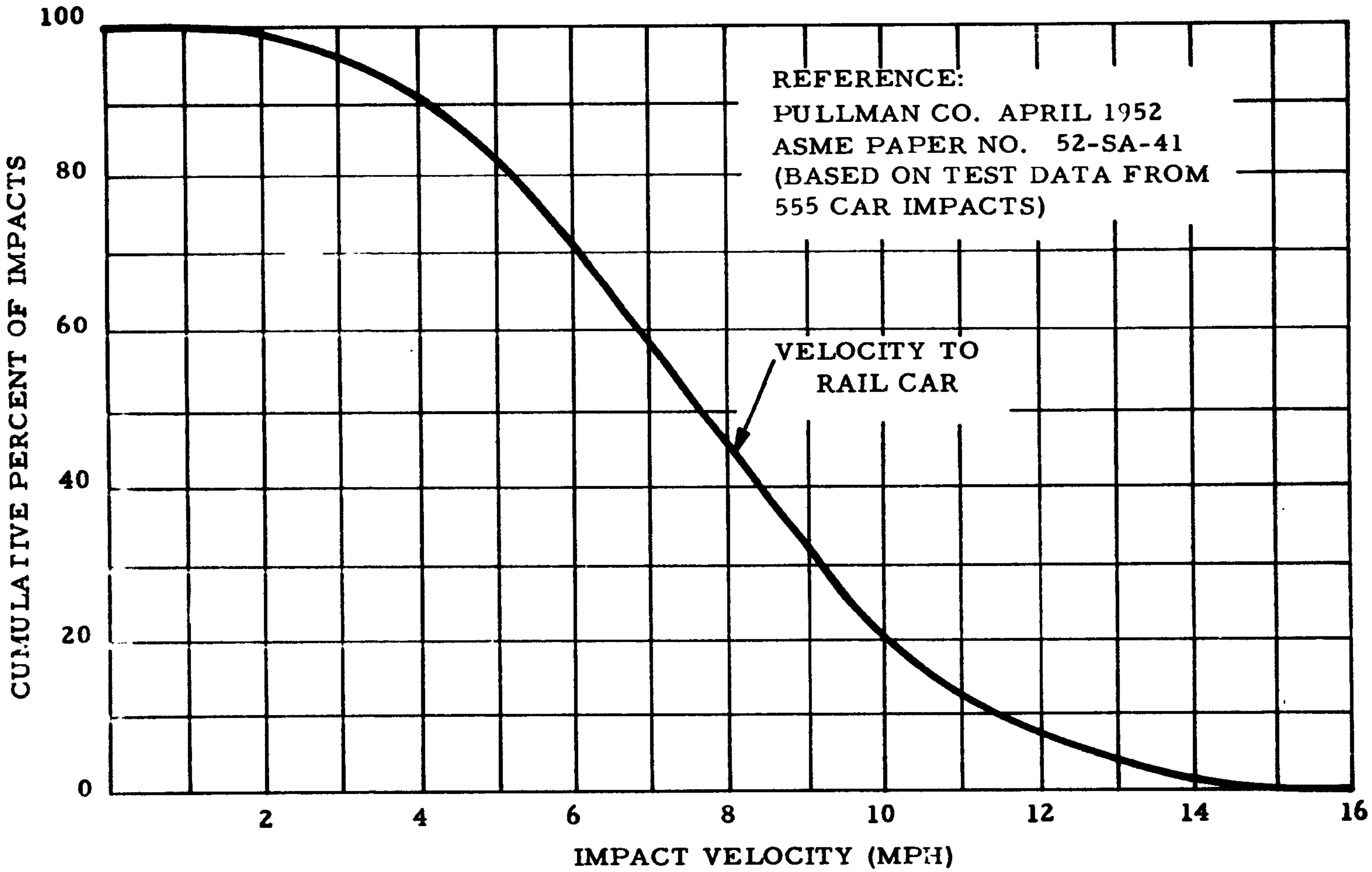


Figure D-2 RAILROAD ENVIRONMENT

similarly equipped and with the assumption that the struck car does not move after impact. T. T. Blickle (ASME Paper 59-A-221, Dec., 1959) shows that the two car couplers will bottom out (i.e., travel a total of 5 1/4 inches) at seven miles per hour coupling speed when the car weighs 169,000 pounds. Hence spring rate (K_2) is given by:

$$K_2 = \frac{WV_1^2}{d_s^2 g} = \frac{16.9 \times 10.3^2 \times 10^4}{.438^2 \times 32.2} = 2.89 \times 10^6 \text{ LBS/FT}$$

while natural frequency (f_2) is given by

$$f_2 = \frac{\omega_2}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{K_2 g}{W}} = \frac{1}{2\pi}\sqrt{\frac{2.89 \times 32.2 \times 10^6}{W}} =$$

$$= 1.54\, W^{-\frac{1}{2}} \times 10^3 \text{ cps}$$

where W = gross weight of car, lbs.

V_1 = coupling velocity, ft./sec.

d_2 = bottoming distance = 5 1/4'' = 0.438'

g = acceleration of gravity = 32.2 ft./sec./sec.

ω_2 = natural frequency, radians/sec.

π = 3.1416

The amount of deflection of (K_2) is obviously a function of a gross car weight and velocity. Mindlin (Bell System Technical Journal, July-October 1945) teaches that velocity at bottoming (V_2) is given by*

$$V_2^2 = V_1^2\left(1 - \frac{d_s^2}{d_0^2}\right) = V_1^2 - \frac{d_s^2 K_2 g}{W}$$

where d_0 = deflection which would have occurred without bottoming

*This assumes total weight of contents is small compared to car and container weights. Influence of content masses tends to make the closure velocity figure used here a trifle high.

Inasmuch as

$$V_2 \leq 0 \quad \text{WHEN} \quad \frac{d_s^2}{d_o^2} \geq 1.0$$

critical coupling velocity (V_c) bottoming to occur is given by

$$V_c = d_s \sqrt{\frac{K_2 g}{W}} = d_s \omega_2 = 2\pi d_s f_2$$

It is necessary to evaluate the effects of coupling shocks differently depending upon whether or not bottoming occurs during coupling for the car under consideration.

Figure D-3 represents design curves for isolators exposed to impact testing. The portion of the graph concerned with deflection vs. impact velocity is a plot of the familiar relation

$$d_I = \frac{2h}{G} = \frac{V_T^2}{Gg}$$

where d_I = isolator deflection

h = height of drop

V_T = test impact velocity

G = maximum acceleration in multiples of the acceleration of gravity

Below the velocity scale we have a plot of isolator natural frequency (f_I) resulting from the deflection and the velocity change. The basic equation plotted is

$$f_I = \frac{Gg}{2\pi V} = \frac{V_T}{2\pi d_I}$$

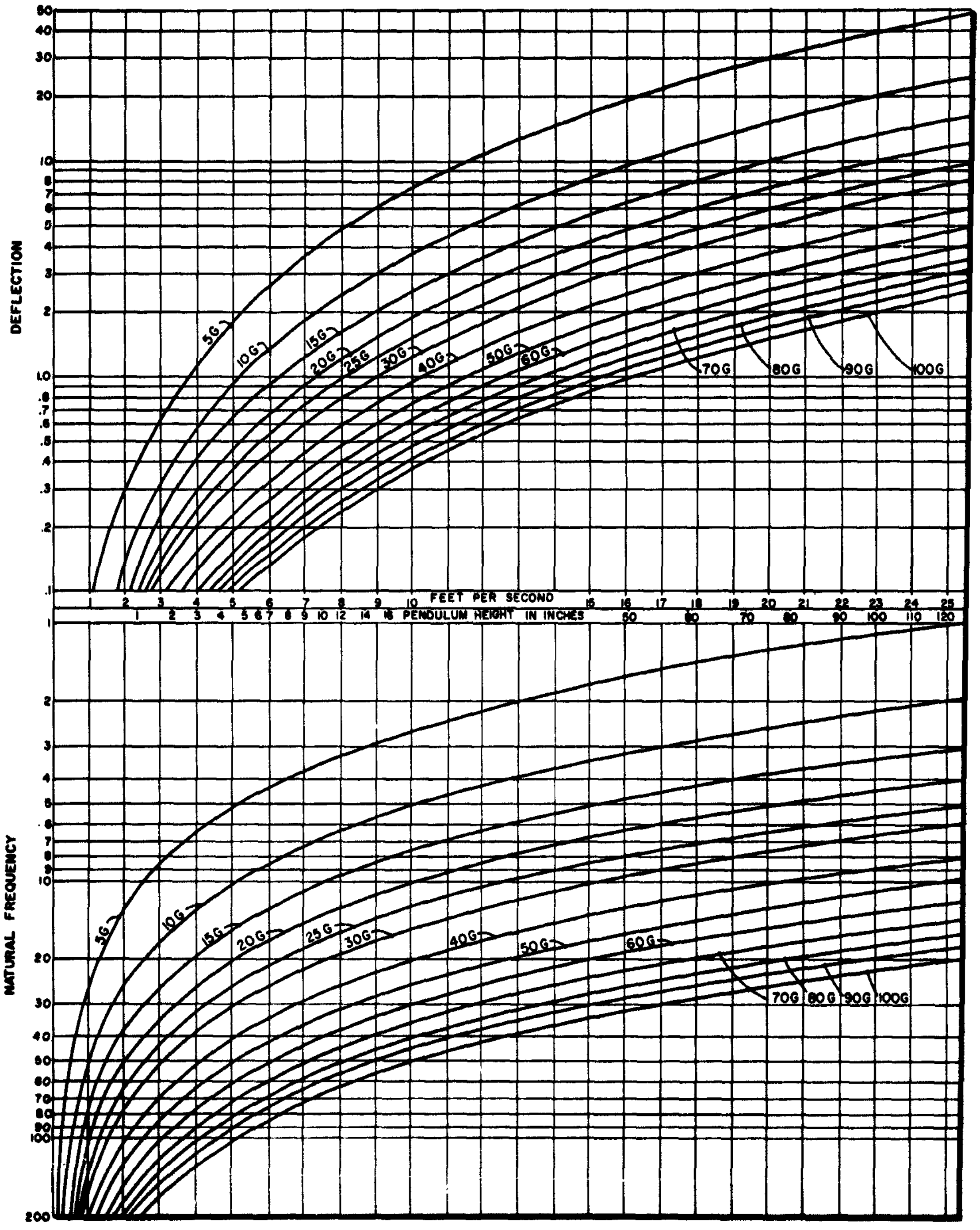


Figure D-3, ISOLATOR DESIGN FOR IMPACT

The plots given are of course independent of the weight of the object being isolated. To determine isolator spring rate, (K_1) solve the following classic equation

$$K_1 = \frac{4\pi^2 f_1^2 W}{g} = \frac{W V_T}{d_1^2 g}$$

Let it now be assumed that an item is supported in a container by an isolator with the foregoing characteristics and that the container is rigidly fastened to the floor of a car. The car is coupled to another car which is considered immovable. Mindlin teaches that, before bottoming, amplication factor (A) is given by

$$A = \frac{d_m}{d_1} = \frac{\frac{\omega_1}{\omega_2}}{\frac{\omega_1}{\omega_2}-1} \text{ SIN } \frac{2n\pi}{\frac{\omega_1}{\omega_2}+1}$$

where d_m = maximum item deflection relative to container wall

d_1 = previously defined

ω = $2\pi f$

n = that integer which maximizes the argument while keeping it less than π

Note that the value of A is dependent only on the frequency ratio of two springs, i.e., container spring and car coupler spring. The value of A is less than one when the ratio of container spring frequency is equal to or less than one half. A rises abruptly to 1.67 when f_1/f_2 = 1.6 from which it drops to about 1.1 at f_1/f_2 = 5.0. Above 5.0 it remains reasonably constant, never exceeding 1.2.

As an example of the significance of the foregoing equations, consider a container with an isolator natural frequency of 9.0 cps impacted against a solid wall at a velocity of ten feet per second. Indicated deflection required

$$d_1 = \frac{V_T}{2\pi f_1} = \frac{10 \times 12}{2 \times 9\pi} = 2.12 \text{ inches}$$

Now let this container be placed in a car loaded to 75,000 pounds gross weight which is then coupled at ten feet per second. Car frequency is, therefore,

$$f_2 = \frac{1.54 \times 10^3}{\sqrt{7.5 \times 10^4}} = 5.63 \text{ cps}$$

Amplification factor for $f/f_2 = 1.6$ is found to be 1.67. Maximum deflection of container content with respect to the container wall is given by

$$d_m = \frac{f_2 VA}{2\pi f_1^2} = \frac{5.63 \times 120 \times 1.76}{2\pi \times 81} = 2.38 \text{ inches}$$

Unless the designer just happened to provide the 12% indicated extra clearance, the contents hit the container wall. Should the coupling velocity be increased (up to critical bottoming velocity), the degree of overshoot will increase linearly.

Under the type of test being performed, equivalent deflections would be encountered in test as would be encountered in service, assuming undamped systems and no rebound, when

$$V_T = \frac{f_2}{f_1} AV_1 = \frac{V_1}{\frac{\omega_1}{\omega_2} - 1} \text{ SIN } \frac{2n\pi}{\frac{\omega_1}{\omega_2} + 1}$$

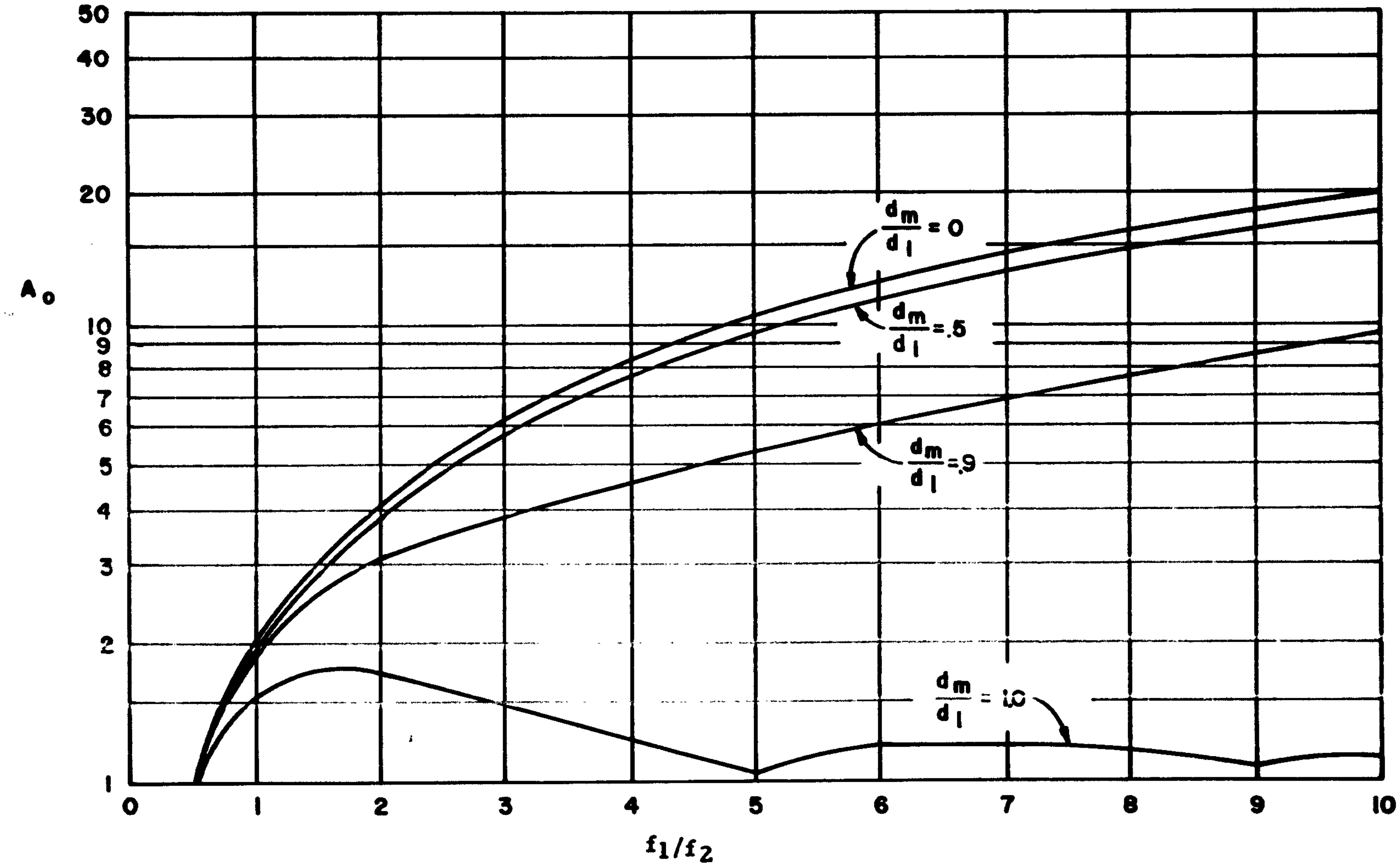


FIGURE D-4
AMPLIFICATION FOR ABRUPT BOTTOMING (MINDLIN)

In the instant case test velocity may, for design purposes, have been

$$V_T = \frac{5.63 \times 1.67 \times 10}{9.0} = 10.43 \text{ fps}$$

but it should be noted that V_1 could well be less than V_S for other combinations. $V_T = V_S$ only when the transcendental relation

$$\frac{f_2}{f_1} A = \text{SIN } \frac{2n\pi}{\frac{\omega_1}{\omega_2}+1}$$

It is clear, however, that a designer could estimate his probable carload with fair accuracy. From this he could arrive at a value of f_2 which he could then use to set a design velocity based upon V_1

0 fps could be representative of what the services consider proper handling. This approach assumes, of course, that the services wish to insist on capability of shipment by cars equipped with friction draft gear. Possible effects of changing car characteristics will be discussed later.

Where the coupler bottoms, amplification factors are as shown in Figure D-4. Here the reference deflection is d_1 i.e., the deflection that K_2 would have reached if it had not bottomed.

Let it be assumed that an object is rated at 50 g fore and aft allowable acceleration, that linear isolators are designed to provide 48 g's acceleration when the container rams into a solid wall at a velocity of

6.0 feet per second. Natural frequency of the container becomes 41.2 cycles per second and design deflection is 0.28''.

Now let this container be loaded into a car grossing 140,000 pounds, (i.e., natural frequency 4.12 cps) which is then coupled at 8.6 miles per hour (12.6 fps). with bottoming deflection held at 5.25''.

Critical bottoming velocity

$$V_C = 2.76 f_2 = 2.76 \times 4.12 = 11.4 \text{ fps}$$

Residual velocity is

$$V_2 = \sqrt{V_1^2 - V_C^2} = \sqrt{159 - 130} = 5.4 \text{ fps}$$

Relative deflection of the item is

$$d_1 = \frac{V_2}{2\pi f_1} = \frac{5.4 \times 1.2}{2\pi \times 41.2} = 0.25''$$

However, the reference deflection is found to be

$$d_0 = \frac{V_1}{2\pi f_2} = \frac{12.6 \times 12}{2\pi \times 4.12} = 5.83''$$

and the ratio of bottoming deflection to reference deflection is found to be 0.9 when $f_1/f_2 = 10.0$ and $d_s/d_0 = 0.9$ amplification of the reference acceleration is 9.4. This reference acceleration is found to be

$$G_o = \frac{V_i^2}{d_o g} = \frac{12.6^2 \times 12}{5.85 \times 32.2} = 10.1$$

from which the maximum acceleration is found to be

$$G_m = AG_o = 9.4 \times 10.1 = 95$$

which, if 50g maximum is realistic damage threshhold, will cause damage to the item.

When this form of difficulty impends the indicated solution is to reduce the natural frequency of the container mounting system so that the maximum acceleration is appropriately reduced. In the chosen example, a reduction in frequency ratio to 4 would reduce the amplification factor to 4.7 and thus produce a safe acceleration under coupling conditions. This results in a natural frequency of 16.4 cycles per second and a deflection at 6 feet per second impact of .75 inches. A test velocity which would have enforced such a clearance is 10 feet per second. In connection with this impact velocity for test purposes, attention is particularly invited to the fact that the test velocity is considerably below the coupling velocity assumed for the service velocity. This demonstrates once again the lack of one to one correspondence in most cases.

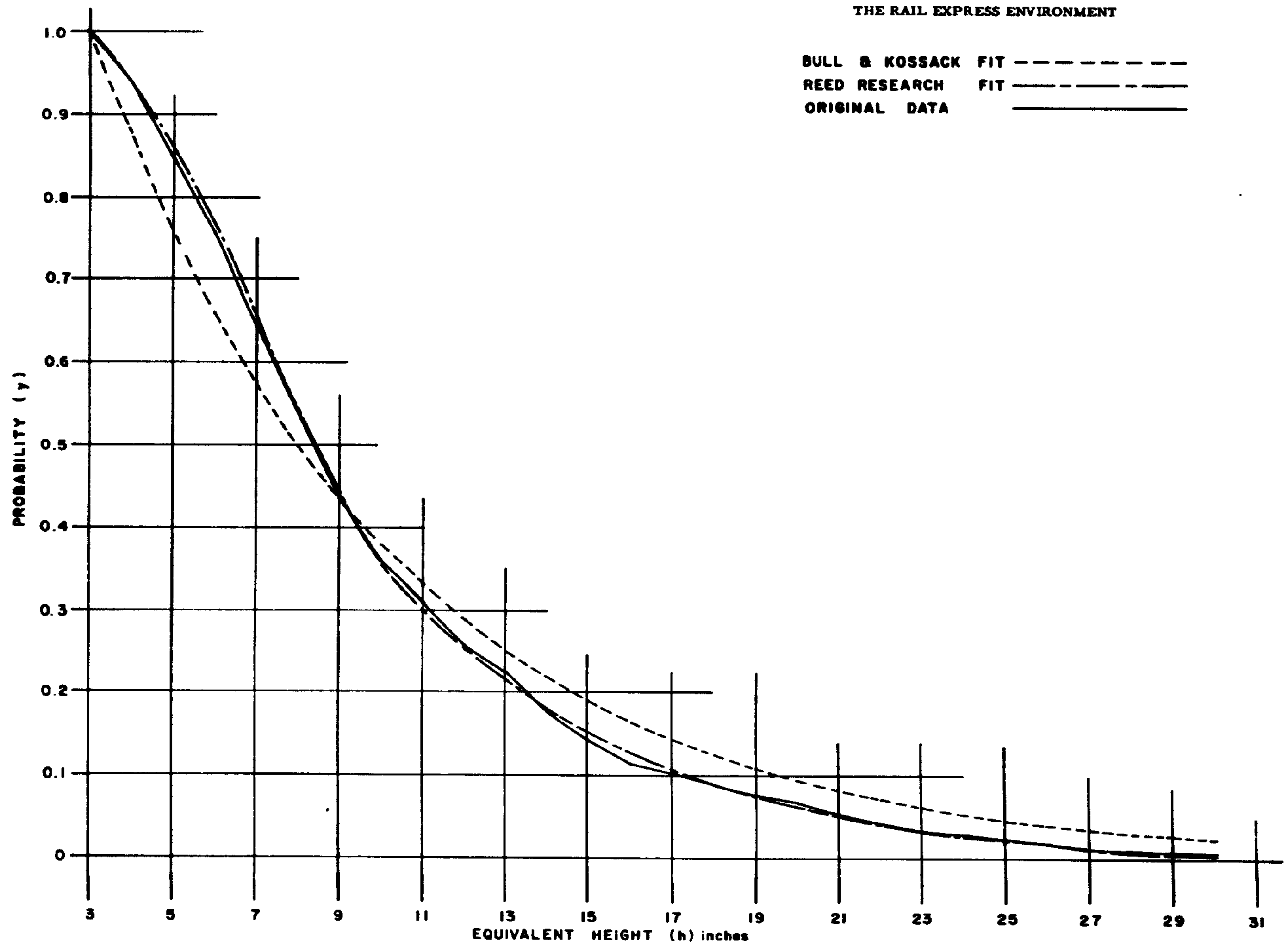
The foregoing discussion is predicated upon impacts being conducted in cars with friction draft gear. The Santa Fe Railroad has, on the other hand, at least 5000 cars of a special design and the Car

Builders Cyclopedia lists well over 100,000 of another type of cushion underframe car as having been placed in service through 1957. When talking in terms of a specific very high value item (particularly one that might be considered quite large) or even restricting the discussion to missile shipments, it should be possible for a traffic manager to insist upon and obtain cars with cushion underframes. Perusal of the data given by Blickle (ASME Paper 59-A-221, December 1959) concerning the Santa Fe car, indicates that the car coupler exhibits approximately cubic elasticity with an initial spring rate on the order of 1.7×10^4 pounds per inch when impacted into a car with conventional friction type gear. Reference natural frequency for this car becomes approximately 1.5 cycles per second for a 75,000 pound gross weight. Thus, using the first example, the ratio of container frequency to car frequency is 6 to 1 and amplification factor is on the order of unity, at most 120 percent of input to container. In effect, the container spring is so stiff that practically all required deflections are taken by the car springs and the acceleration to the container's contents is almost exactly the same as the acceleration felt by the car. Blickle's data on the Santa Fe car indicate accelerations to the car of 2g at 9 mph couplings, and a maximum of 4g with 10 inch travel at 12 mph. Above this speed, the coupler will bottom out and any springs on the inside of the container can reasonably be expected to take care of any additional shock isolation or energy absorption considered necessary.

Attention is particularly drawn to the assumption of rigid containers rigidly attached to the car in the foregoing analysis. Many loads do not so qualify, e.g. a tightly packed carload of goods in fibreboard containers. This condition has been treated by Peterson

FIGURE D-5

THE RAIL EXPRESS ENVIRONMENT



(ASME Paper 59-A-312, December, 1959). Here, the lading spring is essentially made up of the friction force of the cartons aginst the car floor and the sum of the flat crush resistences of the fibreboard used in making the shipping containers. Peterson has shown that, even on coupling impacts less than those which would break glassware, or damage goods directly, the containers at the end of the car opposite to the impact end will move a matter of some 18 inches. Couple the car in the other direction and there is a great tendency for individual containers in the load to tumble with resultant typical forms of damage which have proved such a burden to railroad claim agents.

In any case, however, we have shown that there is not one-to-one correspondence between the velocity change encountered in a Conbur test and the velocity change encountered in car coupling situations except when certain unlikely circumstances prevail. Pending completion of the further study which is so obviously indicated here, it is suggested, therefore, that the services consider establishing, based upon such statistical data as are available, a coupling speed which they will consider maximum for normal service. Obviously, this coupling should be substantially in excess of the four mph that the railroads now consider to be their standard coupling speed.

D-6. DROP TESTS

Analytical and practical approaches to designing to offset the effects of accidental drops are well-established in the literature. All such procedures, however, proceed from the assumption that the height of drop has been given to the designer as an immutable truth and that he has, at the same time, correct information concerning allowable acceleration. The well known brutal truth is allowable acceleration data are usually of extremely dubious validity, and this study demonstrates that there is little or no agreement concerning what the height of drop should be for various container categories.

Recently, Bull and Kossack (Wright Air Development Division Technical Report 60-4, Febr., 1960) published the results of a preliminary study of shocks encountered in transit. This study, working from a limited sample, concluded that data obtained could be fitted to an exponential curve of the form $y = \exp(.138\ (h-3))$ and that 90 percent of all impacts occurred from equivalent heights of 21 inches or less.

Several points concerning the Bull and Kossack report particularly deserve pointing out:

a. The authors assumed that they were faced with an exponential distribution and found a curve that matched such an assumption. Further, they have plotted a curve of fitted data and observed data with significant plotting errors in observed data. This results in substantial lower percentage prediction below 9 inch heights and higher percentages over 9 inches. The error becomes progressively larger to almost 250% at 30 inches. Application of the Chi-squared test indicates that the differences between the fitted curve and the actual data are not due to chance variation. Chi-squared is 218.3 whereas for the 25 degrees of freedom, it should not exceed 48.3.

b. A better fit is obtainable by a dual curve such that

$$Y = h(10.14175 - 9.69846 \, \text{Log } h) \quad 3 \leq h \leq 10$$

$$Y = \frac{47.47706}{(1.176659)^{h-10}} \qquad X > 10$$

Chi-squared for this composite curve is 6.036 whereas, for the 22 degrees of freedom, Chi-squared could be as high as 40.289 without questioning goodness of fit. Data and the two curves are plotted in Figure D-5. The new curve indicates that 94.8% of all drops fall below 21 inches under the conditions of test. Analysis of the probable sampling error indicates that the sample was ample, assuming satisfactory instrumentation.

c. The standard error for the instrument is reported to be 6.17 inches. Assuming error distribution to be Gaussian and homogeneous at all drop heights, one could claim 67% confidence that Reed derived curve is an accurate description of the population measured within ± .22", 95% confidence in ± .44", and better than 99% confidence in ± .66". The report itself indicates some bias in the data on the low side depending upon the past history of the box and permanent deformation of the styli springs. The degree of bias is not recorded. Nevertheless, it would certainly appear that the 95% occurrence point in the population measured is closer to 21 inches than it is to any other discrete value used in package testing such as 18" or 24".

d. It would appear, therefore, that the data reoriented as done herein, provide an adequate description of the environment measured. It is important to reiterate that this environment was predominatly rail express in domestic service. Thus, no humping shocks are recorded and the cars are equipped with high speed passenger type trucks rather than conventional freight trucks. Further, no dockside handling or stevedoring were involved.

All we can really conclude is that the environment described was a form of premium transportation called Rail Express. This may not, at least as yet, even be taken as descriptive of the domestic shipment environment. A commercial package testing firm* has found good empirical correlation at the 95% level by breaking the domestic environment into a number of sub-environments as follows:

Less Carload rail
Less Truckload
Full Carload
Full Truckload
Rail Express
Fourth Class Mail
Parcel Post

Nevertheless, the report does indicate that a substantial reduction in test severity for some forms of domestic shipment is possible.

It would appear, based on the foregoing, that there exists little or no objective basis for standardizing container shock tests. This statement is, however, only true to the extent that one might insist upon neat compilations of probability data. In the absence of such data, it is necessary to rely on the opinions of those working in the field. Figure D-1 represents such a consensus and is applicable to the overseas condition.

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*Container Laboratories, Inc.

Based upon such information as is available, and the generalized discussion presented in this section on shock, the contractor feels that it is possible for the services to agree upon a general testing schedule which would provide the same shock protection criteria for the same logistic pattern. Thus, there would be a series of drop and impact tests applicable to Case 1, possibly another series applicable to Case 1a, etc. In most practical cases, because the services develop missiles to meet their own particular needs, each service would probably tend to use one drop test syllabus in preference to another. For example, the shock test syllabus applicable to transfer-at-sea would be used largely by the Bureau of Naval Weapons.

The major advantage to be gained from placing these varying requirements in the same document is to enhance cross servicing ability. Further advantage is gained from frank recognition that different logistics pose different problems to the container designer and makes much easier the determination of the correct testing level for the logistics involved. Neccessary differences within a technical service would not result in contractor confusion which is known, in one case, to have let the contractor proceed to a point of no return on a design while wrangling was in process.

Figure D-1 may be taken as the definition of the overall problem but it is still felt that within the broad limits shown all services can relatively easily agree upon certain testing levels for the specific cases concerned. It should be noted in passing that, with the very minor exception of exterior color and service markings, the question of shock test severity represents practically the only area where complete standardization is not feasible at this time.

Standardization in the form suggested is, however, practical and recommended.

E. MISCELLANEOUS STANDARDIZATION TOPICS

During the course of this study, we have continually encountered areas where the same essential device is covered by one or more sets of drawings. In theory, it is possible to reference any government drawing number, in practice it has been difficult to do so. Attention is invited to the statements in Appendix I concerning the added cost of preparing drawings to Government Standards. It behooves the Government (granting for the nonce that the standards are necessary) to eliminate all unnecessary drawing preparation. Certain of the comments stem from this goal.

E-1. VISUAL HUMIDITY INDICATORS

Granted that specification MIL-I-8835 and MIL-I-26860 are supposed to cover this situation, we have the following numbers for card type indicators

MS 20003	Three Spot 65-40-30
MS 26507-1	One Spot 8%
BuOrd 1228236	Four Spot 50-40-30-20, for use in certain windows
Army Ord 8911667	6 spot, 60-50-40-30-20-10, circular in window
Sandia 826004 Redstone Arsenal 10349491	6 Spot 60-50-40-30-20-10, rectangular
Sandia 128621	4 Spot circular 50-40-30-20

The following drawings for plug type indicators, with or without cards are known to us:

BuOrd 1128232	Metal Insert Type
Convair 7-03307	Special type with electronic shielding but with 3 pie-shaped indicators on card 30-20-10
Sandia 827526	Plastic button with three dot card 40-30-20
Sandia 828596	Plastic button with six dots
Army Ordnance C8791666	Metal Insert Type

Obviously, here is an area of standardization which can and should be seized. In general, we believe that two types of plugs are required:

a. Metal for use in rigid barrier containers.

b. Plastic for use in flexible barriers.

As to spots, requirements do vary but consolidation will help stop creation of more numbers.

E-2. AN CANS

The military standards for AN cans have not been revised for quite a while. As far back as six years ago, it was apparent to some that the total number of containers was inadequate for diameters used. Further, absence of the 18-1/4" diameter (30 gal. drum diameter) has caused a number of difficulties. In addition, introduction of the prefabricated humidity indicator assembly has introduced non-standardization in mounting hole location. It is considered that the time has come when a new project should be undertaken to bring this important family of containers into line with current realities of need and of industry capability to produce.

In conducting this study, containers conforming to the following drawings should be given due consideration:

Army Ordnance	F8807378
BuOrd LD	497777
BuOrd LD	497862
BuOrd LD	479356
BuOrd LD	412102
BuOrd LD	412103
BuOrd LD	497775
BuOrd LD	252690
BuOrd LD	497762
BuOrd LD	268500

In addition, it is known that Air Force Supply Channels and the Aviation Supply Office have permitted contractor controlled drawings involving modified AN cans into their systems. These too should be carefully considered.

E-3. RECORD RECEPTACLES

Agreement on size of record receptacles does not exist. Specifications quite often stipulate a 4" ID x 14" receptacle. These requirements were taken directly from the aircraft engine container specification where relatively stiff backed books had to be rolled. The Arizona Gear unit (TA 375) has about 1-3/4 inches I.D. and is 9-1/2 inches long and appears suitable for most applications. BuOrd Dwg. 2103433 has been prepared as a specification control drawing. It is recommended that a MS envelope drawing be prepared.

E-4. RELIEF VALVES

Relief valves are a necessary ingredient of containers designed for light weight and to be flyable. Now that specification MIL-V-8712 (ASG) has been cancelled (the valves described are essentially unreliable), new valves and/or replacement valves must be bought on an essentially proprietary basis. It is recommended that a procurement specification and envelope MS drawing be prepared under high priority. The Glaeser valves (BuOrd Dwg 2109436) and the Arizona Gear TA-300, -500 and -750 valves should be among those considered.

APPENDIX I

REED RESEARCH QUESTIONNAIRE RESULTS

A. TESTING STANDARDIZATION)

1. Granting that missile containers must have a higher degree of reliability than containers for more conventional components, which general testing philosophy do you favor:

a. Increasing the hazard level to the extreme anticipated value while permitting container "failure" so long as contents are undamaged and you can get them out.
b. Holding the hazard to somewhat more representative of a weighted mean and permitting no damage to container.

ANSWER:

1. a. And container can be overhauled occasionally for reuse.
2. b.
3. a over b, because 1) of the greater value of the contents over the container. 2) of the much greater tactical value of the contents in wartime.
4. Hard question: favor a over b.
5. No experience in Testing Standardization
6. Loaded questions
7. a.
8. a.
9. a.
10. b.
11. Prefer something between these.
12. a.

2. Should a single sample container be tested against all hazards? For example, Picatinny follows the 1-a philosophy and, further, would not expect a single sample to pass all handling tests at all temperature extremes.

ANSWER:

1. Yes, done in the right order, you can prove your points. The other way costs too much.
2. Good idea although expensive. It is essentially our procedure.
3. No - for advanced containers or large production runs. Yes - for simple containers or possibly in small production runs (depends on cost, performance, etc.)
4. Yes
5. See answer to 1
6. No
7. Yes
8. No
9. No
10. Would be nice to know, but facilities and monies for this extensive testing are not always available.
11. No
12. Single sample should pass all tests.

3. Have you ever run any of the following tests on a complete container assembly larger than a 55 gallon drum?

-80 deg. F Soak	MIL-P-116 Cycle Exposure
-65 deg. F Drop	Altitude
-65 deg. F Vibration	Sand and Dust
+160 deg. F Drop	Rain
+160 deg. F Vibration	Salt Spray
Fungus	Humidity

JAN Cycle

ANSWER:

1. Yes. Humidity test
2. Yes. The -65 deg. F Drop and the +160 deg. F Drop Test
3. Yes. The -80 deg. F Drop, the -65 deg. F Drop (imperfectly)
4. No experience
5. No
6. No
7. Yes. The -65 deg. F Drop, -65 deg. F Vibration
8. No
9. No
10. Yes. Humidity test.
11. Yes, the -65 deg. F Drop, +160 F Drop, and the Humidity test.
12. No answer.

4. If so, did you learn anything you couldn't have predicted from component tests?

5. If so, what?

ANSWER:

1. No.
2. Yes. The actual missile shock. This could probably have been calculated from test results although the cost would not have been much cheaper, the results would have been much more questionable than an actual hi or lo temperature drop.
3. Yes, except in the Salt Spray Test.

Changed time for missile warm-up.

More shock protection at -65 deg. F than expected (50 percent confidence)

Altitude leakage

Rain leakage

Severe water accumulation in poorly sealed containers in storage under tarpaulins in a sunny, semi-marine atmos.

4. No experience
5. No experience
6. No
7. No
8. No
9. No
10. Yes. Work has to be done on full breather with a temperature-humidity cycle - this was somewhat a special case - otherwise on a standard type container we use a submersion test with container pressurized. For cushioning, we test the material separately - not as part of the container.
11. Yes. It is very doubtful that the structural and dynamic response of the entire container in the drop vibration tests could have been simulated without having the entire full-scale article.

12. Probably not. See answer to question 4.

6. With all the strictures that have been placed on it by such eminent experts as LaQue (non-reproducibility between cabinets, unusual behavior of zinc in test and in service, etc.), is anything useful ever learned from salt spray testing?

ANSWER:

1. Not that I know of.
2. No, don't do it.
3. Not much
4. We did on tests on small tear strip containers
5. No experience
6. No
7. Generally not
8. No
9. Yes
10. No
11. No opinion
12. Yes

7. If so, what?

ANSWER:

1. Nothing
2. Don't do it
3. We feel that it is primarily a test on the quality of finish process that is specified

4. See answer to 6
5. No experience
6. Nothing
7. Generally nothing
8. Nothing
9. Relative information re corrosion resistance
10. This test gives relative results and can't be used to predict number of months or years a finish or container will serve
11. No opinion
12. Design errors. New material qualification

8. What does a humidity test tell us in a container system specifically designed to resist high humidities?

ANSWER:

1. It will prove whether a breathing tube is safe or not. If humidity is a big factor on the contents of your container.
2. It says the seal leaks.
3. It will discover or force leaks that a normal seal test won't find. Reasons: Superior penetrability of moist air hardening of seals under cycling stresses, and occasionally because of corrosion.
4. Unfamiliar
5. No experience
6. Only that it will resist humidity, naturally
7. Questionable - generally
8. Serves to check workmanship

9. No experience

10. Other than quality assurance it tells little

11. Whether excessive moisture will enter the container

12. Design errors

9. There is wide variation in altitude performance requirements. For example, MIL-E-4970 stipulates 50,000 feet but without being definite about rate of change. MIL-P-9024 calls for climb rate of 3000'/min. MIL-W-21927 (NOrd) stipulates 30,000 feet at rate of climb of 1000'/min. and rate of descent approximately 4200'/min.

a. In your opinion is it proper to insist that a large shipping container go to a pressure altitude it will never see unless there is a failure in the carrying airplane?

ANSWER:

1. No

2. We've always used ± 1-1/2 psi valves with a flow rate that presumably takes care of all this since we have never heard any comment about rate of change of altitude

3. Yes, because of safety margins for statistically poor testing coverage

4. Unfamiliar

5. No experience

6. No

7. Yes

8. Have not looked into this area

9. Yes

10. Disagree with method of presenting. I feel that maximum conditions should be established and stated in terms of psi. Tests should then be handled similar to pressure results, i.e., Proof pressure test to force the maximum operating pressure. In the case of valved containers we make it a practice to proof pressure test to twice the pressure rating of the valve.
11. Depends upon the results of failure in airplane
12. No

9b. What, in your opinion, is the logical pressure altitude a container will normally see?

ANSWER:

1. 30,000 feet maximum
2. See answer to 9a
3. 25,000 feet
4. Unfamiliar
5. No experience
6. 30,000 feet
7. 35,000 feet
8. See answer to 9a
9. Maximum flight altitudes for cargo planes
10. See answer to 9 a
11. No opinion
12. See MATS or Logair

9c. Is not rate of change of altitude of equal importance as max. altitude achieved?

ANSWER:

1. Yes
2. See answer to 9a
3. No
4. Unfamiliar
5. No experience
6. Yes
7. Definitely
8. See answer to 9a
9. Yes
10. Definitely
11. Yes
12. Yes

9d. Since altitude changes are non-linear, a) should the rate of change be set at maximum anticipated? (e.g., a typical unpressurized airplane might be expected to climb at about 2400 feet/min. during the first minute).

ANSWER:

1. a) No, too tough to simulate. b) Yes
2. See answer to 9a
3. No comment
4. Unfamiliar
5. No experience
6. a) Yes b) No

7. a) No b) Yes
8. See answer to 9a
9. Set at maximum
10. a) No b) Yes. Comment that 2400 feet/min. is excessive except in an F-100
11. Yes. If feasible to test in manner established
12. See MATS OR Logair

9e. What, in your opinion, is a logical rate of descent?
ANSWER:

1. Should be figured on the safe rate for diving airplane involved.
2. See answer to 9a
3. No comment
4. Unfamiliar
5. No experience
6. No answer
7. 2,500 feet/min.
8. See answer to 9a
9. No opinion
10. 1,500 feet/min. maximum
11. No opinion
12. No answer

10. MIL-E-4970 says rain on each of the "four sides" of the equipment. Which four sides? (five are exposed).

ANSWER:

1. Maybe the top gets wet anyway you do it.
2. Which way is the wind blowing?
3. Presumably all but the ends.
Our missile containers can be turned upside down, so can many equipment containers.
It should be "all practicable sides".
4. Unfamiliar
5. No answer
6. Sorry, we still don't know the answer to this one.
But, I sure hope that your survey will enlighten us.
Please come to the aid of the "ignorant".
7. Good question
8. Good question. Should be posed to the custodian of the specification
9. No answer
10. The entire specification should be revised and clarified
11. Have not used this specification
12. Top is considered as being obvious

11. Have you ever had to rework a container design because of failure to pass the rain test?

ANSWER:

1. No
2. Rain test not required on our containers
3. Yes
4. Unfamiliar
5. No experience

6. No

7. No

8. No record that we have

9. No

10. No. Basic design considerations should never permit such a thing to happen

11. No

12. No

12. a) Can it not be agreed that all missile containers can be expected to be exposed to vibration environments characteristic of the following transportation media:

1. Truck
2. Rail
3. Ship
4. Air (in any case for most of them)

b) This being so, is there any reason why standardized test procedures should not be sought?

ANSWER:

1. a) Yes b) We could use them now

2. a) Yes b) Absolutely. This is the area that has given us the greatest trouble, expense, and argument with our sponsor

3. a) In most cases, it works out that way (as it did for some of ours), but in some situations the transportation environments can be limited, and money saved by using limited handling containers. b) No

4. a) No. Many missiles can be controlled for economic reasons of one type of shipment, such as truck. b) Containers for truck shipments, under proper control, may be much less expensive and rugged than for all modes.

5. No experience

6. a) Yes b) No

7. a) Yes b) No

8. a) Yes b) No

9. a) Yes b) No

10. a) Yes, with possible exception of shipboard
    b) Standardized tests - Yes

11. a) Yes b) No reason why not

12. a) b) No

13. Granting that the variations in procedures are the results of the best thinking of widely separated technologists (all considering the same, or essentially the same, data), which method do <u>you</u> consider the most applicable?

MIL-E-4970 Method
BuOrd Method
BuAer Method
Picatinny Method
Other (Pls. describe)

ANSWER:

1. MIL-E-4970

2. Can't compare, since not familiar with all methods. It looks as if they are not considering the same data.

3. MIL-E-4970 (Imperfect). I'm not acquainted with the other methods. Others: MIL-P-7936 and MIL-P-9024.
4. No experience in comparisons
5. No experience
6. No answer
7. MIL-P-116
8. No opinion
9. No answer
10. This would require more space and time than I am prepared for.
11. Not acquainted with all of these.
12. Insufficient knowledge to answer question.

14. Almost all methods involve a sweep through a frequency band and then vibration at "resonance" for various times. Do you think 1 hour at resonance long enough? (One instance of design failure is recalled where a container vibrated at 1/2 inch total extension for 1 hour successfully then failed in service.)

ANSWER:

1. Ten minutes is long enough. Natural frequency should be outside bands expected in transportation.
2. Yes. If container failed in service it was a freak.
3. Yes
4. Unfamiliar
5. No experience
6. We know, don't we? No comment on container failure.
7. One hour is adequate - perhaps less
8. No answer

9. Not necessarily

10. What is going to happen should happen in one hour.

11. Yes. Perhaps too long. An attempt to apply conditions more typical of the actual service would be desirable.

12. 1/2 hour should usually be enough.

15. One difficulty (perhaps) with current tests is that equipment is not always readily available. For instance, achieving 1.3 g at 2 cps is a neat trick. Most specifications, therefore, recognize this difficulty by permitting variation in the "optimum" amplitude (see, for example, next to last sentence of MIL-E-4970A USAF) but do not recognize on paper that decrease in amplitude reduces energy input. Do you consider that resonance testing could be more equalized by equating time and average energy input?

ANSWER:

1. No. During transportation resonance should not be sustained if container is properly designed.

2. Yes

3. Yes. It provides better testing of fatigue and deterioration-in-damping effects, but it doesn't properly test non-linear effects.

4. Unfamiliar. Anyway, I prefer rough road testing

5. No experience

6. Yes

7. Yes

8. No answer

9. Yes

10. No answer

11. Perhaps, but would be more costly.

12. Send your containers to our company. We can test them to complete spec. (96,000 lb. force vibration).

16. Recognizing all the shortcomings of resonance testing, can anything better be offered that can be used by the container industry? (After all, the simple test used in the NSTC test cycle is a form of resonance test and works fairly well when used in conjunction with other tests).

ANSWER:

1. Don't know of anything better.
2. Probably not.
3. I think that a combination of impact and vibration tests might have some value (like the Sig. Corps package tester, perhaps).
4. See answer to 15
5. No experience
6. No answer
7. Possibly a transportation test such as described in MIL-P-9024B section 3.2.11.
8. No answer
9. Yes. Define exact frequencies encountered in all types of carriers.
10. Actual shipping tests are ideal-proof is in the pocket then. See answer to 14.
11. Very probably.
12. No

17. Have you ever learned anything useful when vibrating a container at over 60 cps. If so, what?

ANSWER:

1. No
2. We've learned that very few military people and even many engineers don't recognize that it is practically impossible to get 60 cps into a container as a whole and about all you end up testing is the resonant frequency of the fixtures that are supposed to transmit the vibration from the table or head to the box.
3. Not a great deal. We've discovered a few secondary resonances. There was one case of poor attenuation in shock mounts in one direction, and very little damage observed in either contents or container.
4. Unfamiliar, but it seems necessary to test above that frequency.
5. No experience
6. No answer
7. No
8. No answer
9. No experience
10. No
11. No
12. For containers, nothing

18. Same question for range 25-60 cps?

ANSWER:

1. No
2. For about 6 foot sized containers, below 60 cps is reasonable since it is possible to test. It does tend to duplicate a field condition, and there are significant resonances here although the most important ones are in the 10-25 cps range. We feel strongly about greater than 60, certain that we should test in the 10-25, and sort of neutral about 25-60.
3. Yes. A few equipment containers had resonance. There has been some damage to equipments and containers both.
4. Unfamiliar, but seems unnecessary to test above that frequency.
5. No experience
6. No answer
7. At resonance is the only frequency that is critical
8. No answer
9. No experience
10. No
11. Yes. Amplification peaks corresponding to the container resonant frequency.
12. No

19. Same questions for 10-25 cps.

ANSWER:

1. Yes. Whether shock mounting system is effectively designed.

2. See answer to 17 and 18.
3. Yes. Most container resonances are in this range, and occasionally equipment resonances. Some container damage here. Our latest missile container has primary resonances in the 5 to 7 cps range.
4. Believe tests should be performed in this range.
5. No experience
6. No answer
7. See answer to 18
8. No answer
9. No experience
10. Yes. Absolute need for dampers in tension spring package. Would change limits from 2 - 25 cps.
11. Yes. Container suspension system resonant frequency.
12. No, but we expect to in future.

20. Considerable overlap exists in drop test heights. For purposes of this survey, the largest number of breakdowns in weight category has been selected, but see next question. What <u>flat drop</u> height do you consider most realistic for package in the following weight characteristics (circle 1 in each category)?

0-50	48	36	30	27	24	18	12	9	0
51-100	48	36	30	27	24	18	12	9	0
101-150	48	36	30	27	24	18	12	9	0
151-200	48	36	30	27	24	18	12	9	0
201-500		36	30	27	24	18	12	9	0
501-600		36	30	27	24	18	12	9	0
601-1000			24		18	12	9	6	0
1001-3000			24		18	12	9	6	0
3001-4000			18		12	9	6	3	0
4001-up			18		12	9	6	3	0

Note:

Answers given for question 20 and 21 are shown in Figures I-1, I-2, I-3 and I-4. Remarks only are given below.

1. No remarks
2. We cannot recommend a sensible lumping of this since we don't have a good feel for the field situation as it affects these conditions. However, we do feel that the basic 24 inch drop to which we have been designing does not truly reflect the real situation since we have made about 25,000 containers and there is not a single case on record of a missile ever being damaged.

Thus, we conclude that 24 inches is too high and that 25,000 cases have had more capability (and therefore more cost) than is really warranted.

In our case (with the benefit of 20-20 hindsight) it would have been better to have made containers with less capability at a lower cost and wrecked a few missiles since the cost savings times 25,000 would pay for the missile.

3. Number 3 gives two answers to this question. One that he calls "ideal", the other as "less ideal, but simpler". He has no experience in the weight range above 600 lbs.

4 to 9. Made no remarks.

10. We have finally adopted MIL-P-7936A Drop Tests completely - right or wrong.

11. No opinion

21. Please circle weight groups you think can be combined.
See Figures I-1, I-2, I-3 and I-4.

22. Where a flat drop requirement is combined with a rotational drop requirement, do you think flat drop should be an approximate percentage of the rotational drop height?

If so, which: 75 60 50 40 25

ANSWER:

1. Yes. 50 percent.
2. Yes. 50 percent.
3. Yes. 60 percent.
4. No experience
5. No experience
6. No answer
7. No
8. No answer
9. No
10. See remarks to question 20

11. Yes

12. Yes. 50 percent.

23. Do you not feel that, on containers over 250# (if other, state other) provided with skids, drop testing should be limited to the skidded face?

ANSWER:

1. Definitely
2. Yes, but pendulum impacts probably are a good simulation of railroad humping.
3. Yes, provided that there are supplementary pendulum impact tests as in question 26.
   Minimum weight 200 lbs.
4. Yes
5. No experience
6. Yes
7. Yes
8. Yes
9. Yes
10. Yes
11. Yes
12. Yes

24. What do you feel to be the practical maximum height of drop of one end in a rotational-drop test for the following weight groups:

	Inches						
201-500	36	30	27	24	18	12	9
501-600	36	30	27	24	18	12	9
601-1000	36	30	27	24	18	12	9
1001-3000	36	30	27	24	18	12	9
3001-4000	36	30	27	24	18	12	9
4001-up	36	30	27	24	18	12	9

ANSWER: To few answers received to tabulate.

25. Obviously, whatever the maximum height of drop might be, you design for it. Do you, therefore, learn anything from a test syllabus stipulating a gradually increasing height of drop?

ANSWER:

1. Container resistance to repeated drops
2. Only how well you designed
3. Not much, except in prototype tests when the degree of inadequacy of a failed container may be determined.
4. No experience
5. No experience
6. No
7. Yes, sometimes
8. No answer
9. Yes
10. This we do - it is similar to crawling before walking
11. Yes. The drop height capability for possible use in obtaining deviations.
12.

12. No

26. What do you feel is the correct height of drop for pendulum impact testing to simulate?

a. Railroad end impacts: 27 24 18 12 9)
b. Transfer at sea: 27 24 18 12 9) inches

ANSWER:

1. a. 12 b. 18
2. a. 12 - This is a guess only of a number that ought to be tested and standardized. b. No answer
3. a. Added "and side". Twenty-four inches if containers are nailed or rigidly attached to the car floor. If containers have freedom to slide, or similar compliance, 12 inches is recommended.
4. No experience
5. No experience
6. a. 24 b. 9
7. a. 9 b. 12
8. No answer
9. Not in use
10. a. 12 - with a terminal velocity of 8 ft./sec/ b. Not familiar with transfer-at-sea.
11. No answer
12. a. 9 b. 9

27. A container will tip over or roll over under the criterion

$$C = \frac{a x^2}{x^2 + y^2}$$

where c = height to which side is raised

x = distance along base to C.G.Proj.

y = height of C.G. Above base

a = ratio of width to x

If we assume that any container would have one side raised 12'' by a careless fork truck operator, we then might have a logical point at which narrow high containers should be tested for tip over, i.e., when width less than 12'' or when

$$y = \frac{X}{12}\sqrt{a^2x^2 - 144}$$

Would you like to see the test and design criteria so stated for:

a. Rectangular container?

b. Vertical cylindrical container?

c. Horizontal "Cylindrical Container" with skids?

d. If you like the idea but don't like the height, please nominate an alternate.

ANSWER:

1. Too many alternate "C"s.

2. Never had this assignment and never thought about it so my opinion doesn't have much to back it up.

3. No

4. No experience

5. No experience

6. Design criteria stated for: a

7. Yes

8. No answer

9. Design criteria stated for: a,b.

10. Yes, provided a minimum height to width ratio exists which crates a hazardous condition - again design considerations should prevent a "high-narrow" situation from happening, whenever possible.

11. No opinion

12. a.

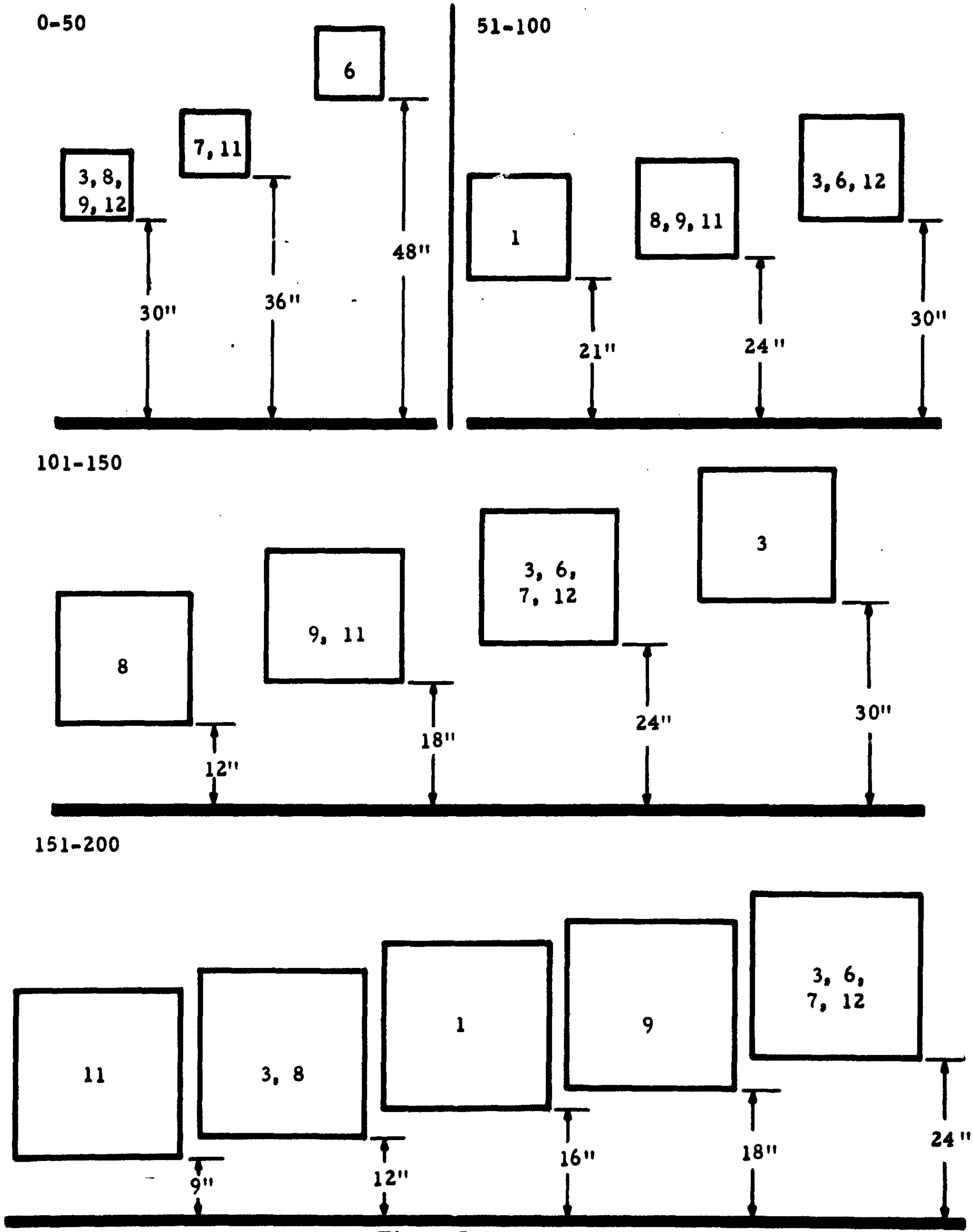


Figure I-1
FLAT DROP HEIGHTS RECOMMENDED
FOR CONTAINERS 0-200 POUNDS GROSS WEIGHT

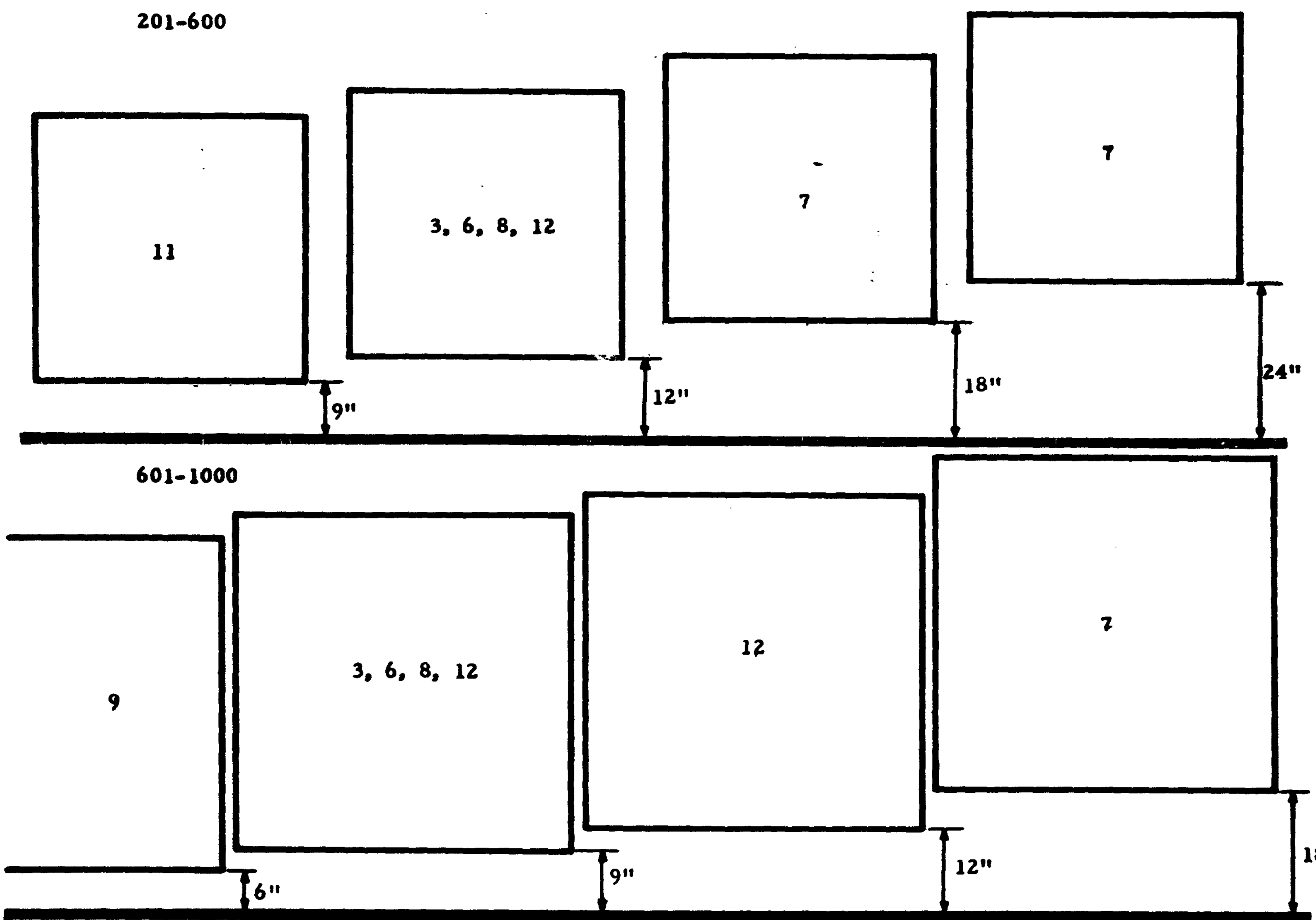


Figure I-2 FLAT DROP HEIGHTS RECOMMENDED FOR CONTAINERS
(201-1000 POUNDS GROSS WEIGHT)

1001-3000

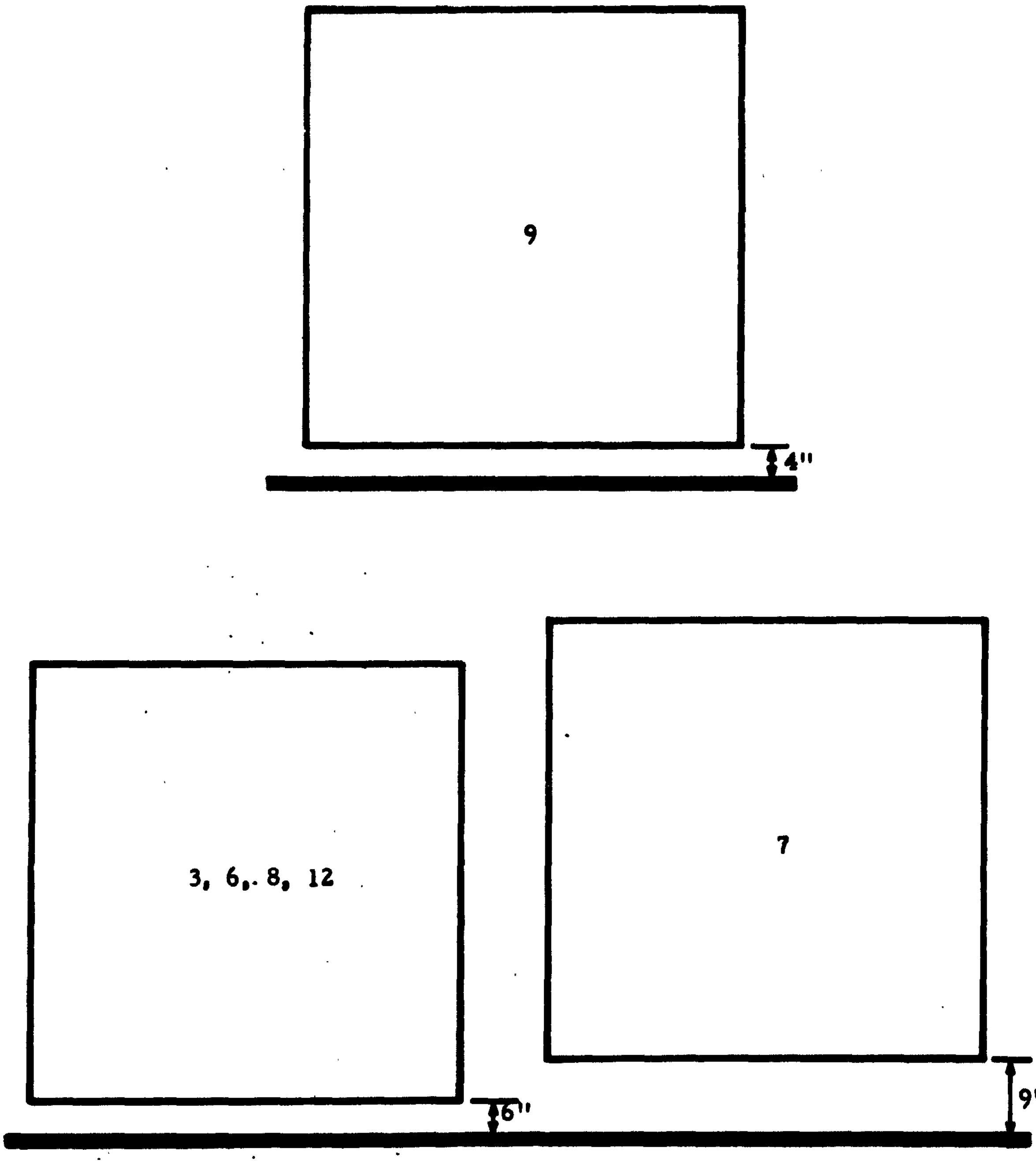


Figure I-3
FLAT DROP HEIGHTS RECOMMENDED
FOR CONTAINERS (1000-3000 POUNDS GROSS WEIGHT)

3001 and UP

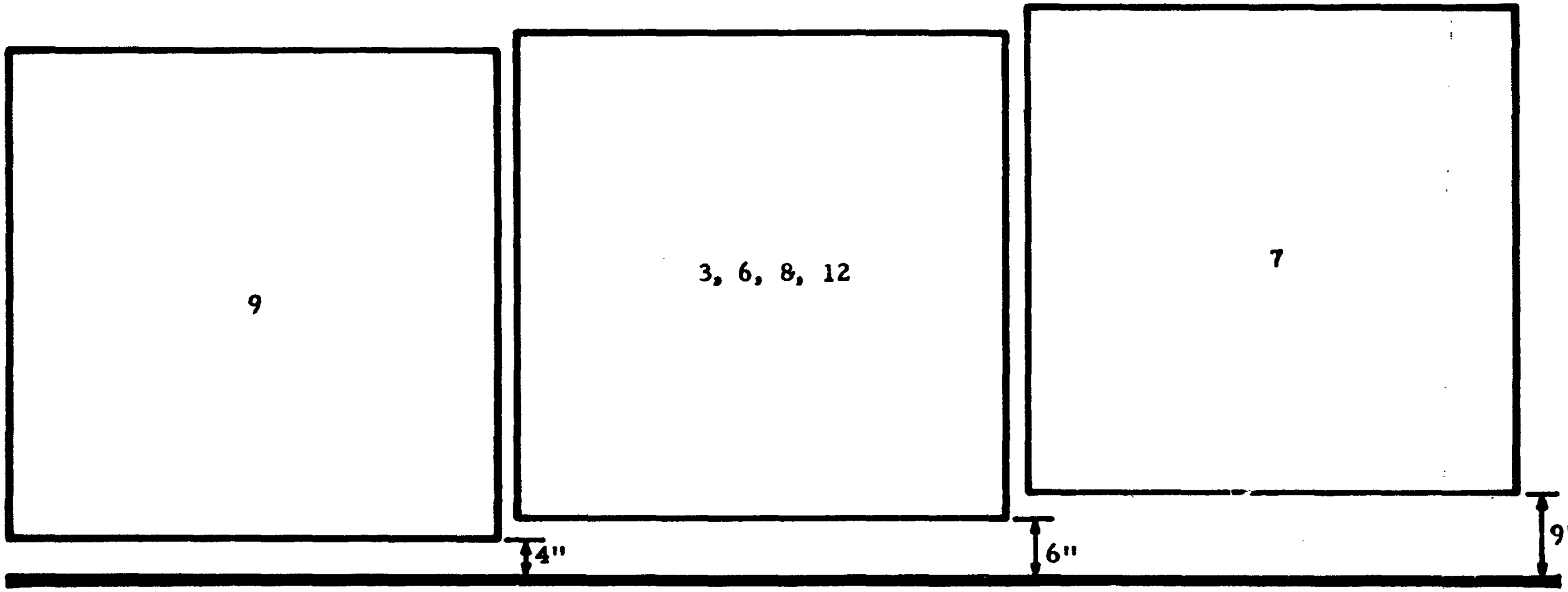


Figure I-4
FLAT DROP HEIGHTS RECOMMENDED
FOR CONTAINERS GROSS WEIGHT OVER 3000 POUNDS

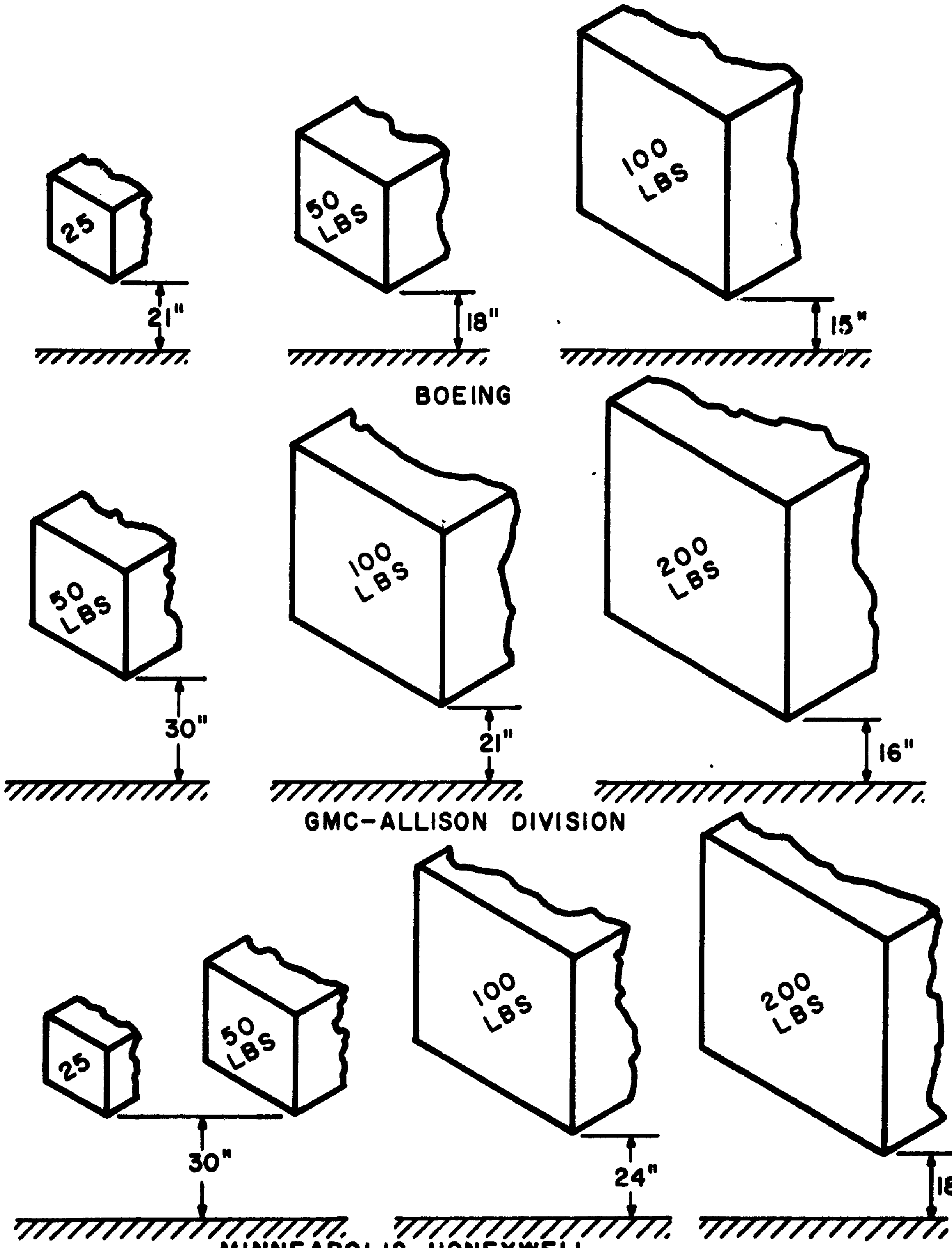
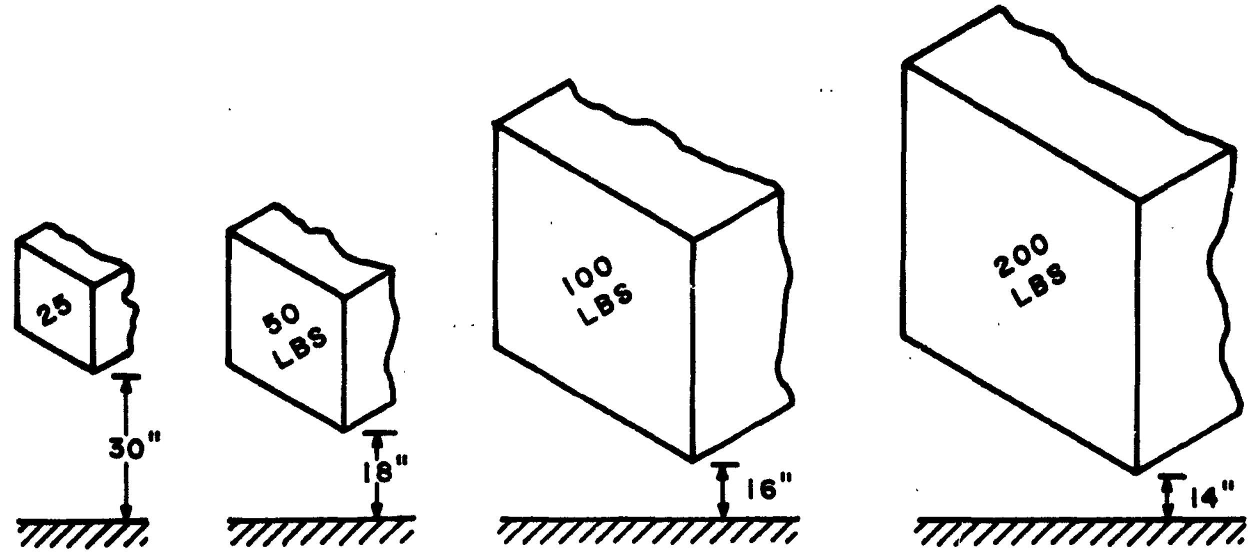
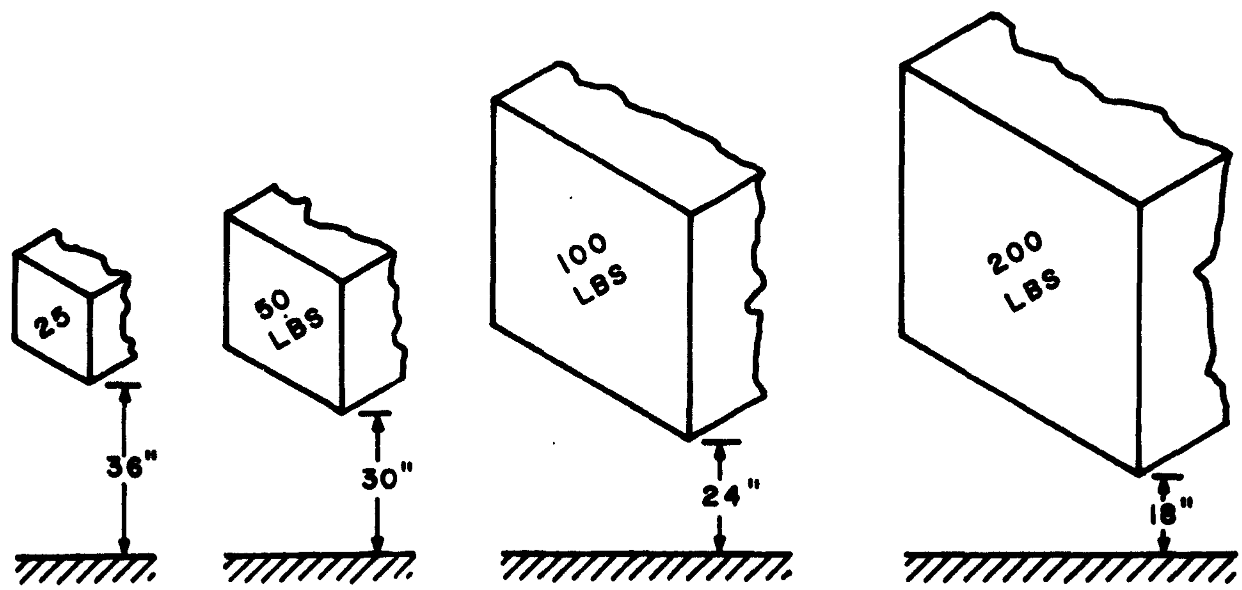


Figure I-5
TRANSIT CASE FREE FALL DROP TEST
AEROSPACE INDUSTRIES ASSOCIATION
COMMITTEE PP-5



NORTHROP CORPORATION



NORTH AMERICAN - L.A.

Figure I-5 (cont.)
TRANSIT CASE FREE FALL DROP TEST
AEROSPACE INDUSTRIES ASSOCIATION
COMMITTEE PP-5